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THE USE OF AUDITORY RHYTHM AND RHYTHMIC SPEECH
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THE USE OF AUDITORY RHYTHM AND RHYTHMIC SPEECH TO AID TEMPORAL AND QUANTITATIVE MUSCULAR CONTROL IN CHILDREN WITH GROSS MOTOR DYSFUNCTION

By

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This study examined the effectiveness of auditory rhythm and rhythmic speech to aid temporal and quantitative muscular control in children with gross motor dysfunction. The importance of timing in skilled motor performance has been widely accepted in the research literature. In this study, rhythmic aids were used to facilitate motor control in a remedial context over three treatment sessions. The effectiveness of rhythmic cues for temporal muscular control was proposed in a model of rhythmic auditory-motor integration based on a neuropsychological approach.

Subjects included 24 male children, ages 6.0 to 8.11 years, with gross motor dysfunction as identified by the Bruininks-Oseretsky Test of Motor Proficiency. All subjects participated in the screening test and three experimental sessions over a period of three weeks. The children were taught to perform a gross motor sequence consisting of alternating carried out: (1) measures of motor rhythm accuracy with auditory rhythmic and rhythmic speech present; (2) measures of motor rhythm accuracy after auditory rhythm has been faded out; (3) measures of synchronization and time interval conformity between motor rhythm and external rhythm,

measures of tempo maintenance under two different treatment conditions; (4) measures of quantitative muscular control with auditory rhythm and rhythmic speech present; and (5) measures of quantitative muscular control after auditory rhythm has been faded out. Data were gathered through the graphic recording of voltage coded sensor signals. The sensors responding to surface contact, were attached to the children's hands and feet.

Results

The data were analyzed through a multivariate repeated measures analysis of covariance. The results showed that subjects aided by auditory rhythm and rhythmic speech performed with significantly better motor rhythm accuracy, at the .05 level of confidence, than the control group using visual modeling for proprioceptive control only. Once the auditory rhythm was faded out, no performance difference between treatment and control conditions was found. However, the motor rhythm deviations between both treatment conditions decreased significantly as a function of time. Gains in synchronization, that is, the coincident motor response to the external beat, correlated significantly with gains in motor rhythm accuracy.

Quantitative muscular control measures remained uninfluenced by rhythmic aids. However, a significant age trend emerged, displaying better inhibition of erroneous or redundant movements with increasing age. Modified applications of the recording system to measure aspects of motor performance, as well as clinical applications of the findings in this study were discussed.

To the Memory of my Father

Dr. Rudolf Ernst Thaut (†1982)

His Wisdom and Courage

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INTRODUCTION

Purpose

The purpose of this study was to examine the use of auditory rhythm and rhythmic speech as an aid for the temporal organization and quantitative muscular control of a gross motor movement sequence. The effectiveness of these rhythmic aids was evaluated over three consecutive treatment sessions using children (ages 6-8 years) with a diagnosed gross-motor impairment based on test scores from the Bruininks-Oseretsky Test of motor proficiency.

The study compared the effectiveness of auditory rhythm with concomitant rhythmic speech to proprioceptive and visual control mechanisms upon learning to perform a complex movement sequence, with an even motor rhythmic timing of its subcomponents. Secondly, the study investigated if rhythmic speech, as an internal movement control, had an effect on the ability (1) to sustain an even motor rhythm, and (2) to maintain the same performance tempo once the external rhythm had been faded out. Thirdly, the study examined the effect of rhythmic rehearsal strategies over time on the ability (1) to synchronize body movement with an external auditory beat, and (2) to adjust the time duration of successive movement acts to the time intervals between auditory beats within a rhythmic grouping, regardless of coincident motor response. Fourthly, the effectiveness of auditory rhythm and rhythmic speech on quantitative muscular control, that is, inhibition of erroneous or redundant movements, was investigated.

Only a few studies, most of which were nonquantified, report the use of rhythmic materials to aid in certain aspects of motor control. Most studies in the relation of motor rhythm and external rhythm use limited movement responses in a noncomparative, one-shot response testing situation. This study tried to investigate the effectiveness of rhythmic materials on the actual performance of a gross motor task sequence in a remedial context, over a period of three week's sessions.

Background

Finding effective and efficient remedial teaching methods for gross motor impaired children is an ongoing concern to physical educators, therapists and parents, and is crucial to the future of the children themselves. Motor impairment hampers the development of physical abilities and acquisition of specific motor skills which the children need to perform appropriately in their environment. Affected areas range from sports or leisure activities to types of motions needed for actual vocational skills. Furthermore, considering physical abilities as one component of the child's developing personality, motor impairment also interferes severely with normal social and emotional development.

Bloom (1956), Krathwohl (1964), and Harrow (1972) have developed a widely accepted scheme of commonly recognized human behaviors which allow one to gain a more detailed picture of the interrelationship between motor development and other areas of human development. Their taxonomy of educational objectives classifies three domains of behavior: cognitive (intellectual skills), affective (feelings, opinions, attitudes, values), and psychomotor (physical abilities, general neuromuscular functioning). It is of great importance to understand, however, that these separated behavior domains occur in reality only in an integrated framework of cognitive-affective-psychomotor interrelationships. Gallahue (1976) has developed a theoretical model which delineates how the development of movement abilities and physical fitness influences affective and cognitive development.

Some conclusive research has been generated in the last thirty years investigating the relationship between movement skills and aspects of affective development such as self-concept, peer relationships and social status. A child's self-concept, the feeling of own worth, seems to be closely related to the degree of ease and efficiency with which the child can engage in physical activity (Gallahue, 1982). Although research in the area of movement and self-concept is hampered by methodological problems, such as how to construct valid measures of self-concept, Wallace and Stuff (1983), Johnson (1968), Clifford and Clifford (1967), and Collingswood and Willett (1971) have shown that specially designed motor training programs can positively influence measures of self-concept. It may be concluded from these that movement experiences can influence body image, experiences of success, and social experiences, and thus exert a desirable impact on self-image and experience of self-worth. Studies by Tuddenham (1951), Cratty (1967), and Martinek and Zaichowsky (1977) indicate also that levels of movement skills have an influence on social status and acceptance of children among their peers. Less conclusive is the relationship between psychomotor functioning and cognitive development. The euphoria of advocators of perceptual-motor programs (Delacatao, 1959; Getman, 1952; Kephart, 1971) to remediate or enhance academic abilities has not been substantiated scientifically through research in the past fifteen years (Gallahue, 1982). It can be safely stated, however, by referring to the nature of cognitive-affective-psychomotor interrelationships, that the influence of a poor self-concept on the learning process can be significant (Brookover, 1967). Thus, the research literature indicates that teaching and learning strategies which improve and facilitate movement abilities have an impact on the child's developing personality beyond the immediate focus on deficient motor performance.

On this conceptual background for remedial motor activity, several methodological problems arise in the search for effective treatment strategies. Sherrill (1976) points out that such a search goes through a sequence of steps integrating several areas of knowledge at each level. The adapted physical educator or therapist needs to focus on (1) analyzing motor performance, (2) identifying the problems of motor performance, (3) determining the factors contributing to the problem, and finally (4) designing an intervention program that uses efficient cues and teaching strategies to ameliorate the problem.

This study investigated the effectiveness of rhythmic aids on improving temporal and quantitative muscular control in a gross motor sequence with children (age 6, 7, 8 years), who performed below age-expected levels on a gross motor test. Four areas of knowledge converged in this study: (1) the nature of a movement act and movement patterns as a series of movements organized in a particular time-space sequence, that is, an organized series of time-space related movements; (2) the relation of auditory rhythmic stimuli to motor responses; (3) the diagnosis and remediation of gross motor impairment; and (4) the use of rhythmic materials as remedial tools. Each of these areas will be discussed separately in relationship to documented research efforts in order to develop a theoretical model on which the research hypotheses of this study can be based.

The Problem: Its Theoretical Background and Practical Implications

This study investigated whether auditory rhythm and rhythmic speech can aid children with gross motor impairment in the temporal organization and quantitative muscular control of a gross motor sequence. This problem was broken down into the following research questions:

1. Can auditory rhythm and rhythmic speech facilitate an even gross motor rhythm, that is, an evenly timed performance of gross motor acts, within a serially organized movement pattern?

2. Can auditory rhythm and rhythmic speech decrease erroneous, redundant or extraneous motions during the performance of a gross motor sequence?

3. Does age influence the level of temporal and quantitative muscular control?

In an additional step, the study examined the effectiveness of rhythmic speech as an internal control mechanism to maintain the timing and quantitative control of the movement sequence once the external rhythmic signal had been faded out. This research aspect was considered to be of major importance for an evaluation of this study's results regarding educational and therapeutic practice. The transfer of the effect of external timing cues into a system of internal timing control would, indeed, be most beneficial for the development of the children's movement control independent of the presence of external conditioning. This problem was broken down into the following research questions:

1. Can rhythmic speech facilitate the maintenance of an even gross motor rhythm once the auditory rhythm has been faded out?

2. Can rhythmic speech facilitate the maintenance of performance tempo, that is, the average performance time of one movement component, once the auditory rhythm has been faded out?

3. Is there a relationship between maintenance of performance tempo and maintenance of gross motor rhythm once the auditory rhythm has been faded out?

Furthermore, the study examined possible factors underlying the relationship between external auditory and internal motor rhythm. The relationship of motor rhythmic responses to an external rhythm condition can be measured in two ways. First, the synchronization between movement and external rhythmic signal can be measured. This measure yields whether the completion of a movement act actually coincides with the onset of the rhythmic signal. Second, the average time one movement act takes to be completed can be compared with the time that elapses between the onset of two subsequent rhythmic signals regardless of coincident motor response. This time lapse between two rhythmic signals, if consistently even for an extended pattern of auditory beats, actually determines the tempo of that pattern. A movement response thus could have the same average performance time or tempo as the auditory rhythm but still be consistently out of synchronization. In this specific case, the moving child would not be able to follow the actual beat with his individual motions, but would adapt the overall performance time of this movement sequence to the tempo superimposed by the external rhythm. This adaptation process could be expressed through the conformity between rhythmic signal speed and overall performance time.

Both measures, synchronization and conformity, can be understood as presenting different factors in the relationship between motor rhythm and external rhythm. Chyatte and Birdsong (1971), in a study investigating motor rehabilitation in brain injured patients, discussed overall performance time as an index for functional rehabilitation in motor performance whereas the timing of individual motions, in a complex movement sequence, would indicate the degree of actual neuromuscular control and recovery.

Glencross (1970) differentiated between positional and serial timing in a movement task. Positional timing, similar to the previously used term "synchronization," refers to the coincident motor response to an external signal. Serial timing refers to the time relationship of successive muscular motions in a movement pattern which can be expressed in an average overall performance time. Serial timing thus refers to the factor of movement within the previously discussed conformity relationship between signal speed and performance tempo. Serial timing within a movement sequence can conform with the rhythmic signal speed and, at the same time, the movement's positional timing can yield a considerable amount of variability. Two factors are suggested at this point to account for that discrepancy: (1) the subject's motor response comes consistently too late due to inadequate perceptual-motor integration, or (2) the child cannot perform successive body motions with an even timing due to insufficient neuromuscular control but is able to compensate, for example, for slower motions with subsequent accelerated motions to retain an externally paced performance tempo. In the latter case, it would seem that the child responds to the perception of an overall time structure rather than to actual time signal events. Many studies (Ashton, 1953; Groves, 1969; Beisman, 1967; Couper, 1981; Nelson, 1963) have investigated the influence of nonspecific rhythmic/musical background stimuli on the rhythmicity of a movement task. This study, by measuring both synchronization and time interval conformity of muscular activity to external timing signals in relation to gross motor rhythm, investigated the differential effect of both factors on temporal organization of successive movement patterns. Applied to teaching or therapy practice, this investigation should provide further insight into the effectiveness of rhythmic acoustic stimuli, superimposed as a nonspecific time structure, or as a cue for conscious and deliberate perceptual motor matches, expressed as coincident motor responses, when trying to facilitate evenly timed movement performance.* Thus, the problem was broken down into the following research questions:

1. Can movement synchronization to an auditory rhythm and time interval conformity between performance time and external rhythm be improved through rhythmic rehearsal strategies, repeated over a period of time?

2. Is there a relationship between gross motor rhythm and measures of synchronization and time conformity, respectively?

Research Hypotheses

The research questions presented in the previous section were examined in this study through an analysis of each child's

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*Four examples of a child's performance measures may illustrate the practical use of such examination:

(1) Synchronization and gross motor rhythm do not improve, but time interval conformity does improve: this would suggest that the child cannot perform coincident motor responses with an even motor rhythm, but learns to adapt his performance tempo to the external time structure (functional compensation of deficient motor control).

(2) Synchronization does not improve but motor rhythm and conformity do improve: this would suggest that the child cannot perform coincident motor responses but the perception of an external time structure has been extended to perceiving regularly recurring, evenly spaced, time events. In this case the synchronization or positional timing of the child's movements would show a fairly consistent time delay.

(3) Motor rhythm and synchronization improve, whereas time interval conformity does not improve. This would suggest that the child's deliberate attempt to perform coincident motor responses contributes to the improving motor rhythm regardless of performance time.

(4) Synchronization and time interval conformity do not improve, whereas motor rhythm improves: this would suggest that the child disregards external timing cues in favor of developing his idiosyncratic movement tempo. The facilitating influence of exposure to rhythmic stimuli on movement rhythm could be verified only against control group data without treatment.

movement recordings displaying temporal and quantitative muscular control in relationship to auditory rhythm and rhythmic speech. Analysis I examined the effects of age, treatment and time factors on the accuracy of motor rhythm performance. Analysis II examined the effect of age, treatment under faded conditions and time factor on maintenance of motor rhythm, maintenance of performance tempo, and their mutual relationship. Analysis III examined the effect of age and time factor within one treatment modality on synchronization, time conformity and their relationship to motor rhythm performance. Analysis IV examined the effect of age, treatment and time factor on quantitative muscular control. Analysis V examined the same variables as Analysis IV, but for treatment under faded conditions. The following research hypotheses were formulated accordingly:

Analysis I: Motor Rhythm Accuracy

1. The treatment group (T) will perform with greater motor rhythm accuracy than the control group (C).

2. Age differences will occur in motor rhythm accuracy for both T and C.

3. Both T and C will improve their motor rhythm accuracy over time.

Analysis II: Motor Rhythm Under Faded Treatment Conditions

1. The treatment group under faded conditions (TF) will perform with greater motor rhythm accuracy than C

2. Age differences will occur in motor rhythm accuracy for both T and C.

3. Both T and C will improve their motor rhythm accuracy over time.

4. The time differences in motor rhythm accuracy of T and TF will decrease over time.

Analysis III: Background Measures

1. Motor Rhythm Synchronization

    a. Synchronization measures of T will improve over time.

    b. Age differences will occur in synchronization measures.

    c. Synchronization measures will show a positive relationship to improvement of motor rhythm accuracy in T.

2. Time Interval Conformity (TIC)

    a. TIC measures of T will improve over time.

    b. Age differences will occur in TIC measures.

    c. TIC measures will show a positive relationship to improvement of motor rhythm accuracy in T.

3. Maintenance of Performance Tempo (MPT)

    a. MPT measures of TF will improve over time.

    b. Age differences ill occur in MPT measures.

    c. MPT measures will show a positive relationship to improvement of motor rhythm accuracy in TF.

Analysis IV: Quantitative Muscular Control

1. T will perform with better quantitative muscular control than C.

2. Age differences will occur in quantitative muscular control for both T and C.

3. Both T and C will improve their quantitative muscular control over time.

Analysis V: Quantitative Muscular Control Under Faded Treatment Conditions

1. TF will perform with better quantitative muscular control than C.

2. Age differences will occur in quantitative muscular control for both TF and C.

3. Both TF and C will improve their gross motor rhythm accuracy over time.

4. The error difference in quantitative muscular control of T and TF will decrease over time.

Importance of the Study

The field of music therapy, that is, using music and music-related activities to attain specific therapeutic goals, is a relatively young discipline in which continued and clinically oriented research efforts are needed greatly. Music therapists are becoming increasingly aware of the need to thoroughly document effectiveness of implemented music therapy methodology.

Although therapeutic work with physical or orthopedic handicaps had always been a field of music therapy practice, it never stood in the main focus like practice with psychiatric conditions or with the mentally retarded. In a recent monograph series on music therapy for handicapped children (Lathom and Eagle, 1982), however, one separate volume is dedicated to orthopedic handicaps, thus documenting a renewed therapeutic effort of music therapy in this field. These new efforts have partially evolved in response to new legislation during the last ten years regarding educational and therapeutic services for handicapped children.

When the client is primarily handicapped in physical functioning abilities, music therapists work in such a manner as to assist in bringing about increased mobility, greater muscle strength, smoothness of movement and other physical and emotional improvements. Research efforts in these areas of functioning are vital to clinical success and professional credibility. Currently, there is still much methodological reliance on work with mentally retarded clients using music in three main directions: (1) as background accompaniment during psychomotor tasks (e.g., Sternlight, 1967; Goodnow, 1968; Cotter, 1971; (2) as contingent reinforcement for certain motor behaviors (e.g., Hanser, 1974; Holloway, 1980); and (3) as a motivating tool to elicit nonspecific movement responses (e.g., Clark, 1968).

Very little available research exists on the objective oriented use of music to aid in the remediation of specific motor problems. To understand better the contribution musical materials can make to facilitate or regulate movement abilities, the psychological and physical properties of musically organized acoustic stimuli and related activities need to be viewed within the framework of functional and neural mechanisms for motor behavior. An analysis of those mechanisms following a neuropsychological model, as, for example, proposed by Sage (1977), would evaluate the specific impact of musical stimuli on the neurological processes underlying motor behavior. Reception of stimulus properties, selective attention and arousal, perception of stimulus cues, their translation into a motor program, and their command and feedback function in controlling the motor program would be foci of investigation in this evaluation process. In this respect, two aspects have been subject to much research outside of music therapy, although they have invaluable importance for an assessment of musical materials in clinical practice: (1) the effect of acoustic stimuli on motor neural activity, that is, the physiological basis for all motor behaviors; and (2) the effect of the temporal structure of acoustic events on, and the importance of the auditory modality for, the temporal discrimination process in the central nervous system.

Music as a complex temporal organization of acoustic events, perceived mainly through the auditory modality, possesses inherent qualities which may be used to aid in very specific aspects of motor behavior. Gallahue (1982) discusses these temporal qualities regarding motor development in children.

> Temporal awareness is intricately related to the coordinated interaction of various muscular systems and sensory modalities . . . . Rhythm is the basic and most important aspect of developing a stable temporal world . . . . Rhythmic movement involves the synchronous sequencing of events in time. Rhythm is crucial in the performance of any act in a coordinated manner. . . . We must recognize the rhythmic element in all efficient movement, and in doing so be sure that we duplicate the rhythmic component of all movement. . . . Activities that require performing movement tasks to auditory rhythmic patterns should begin with young children and be part of their daily lives (pp. 307-398).

This discussion may serve to influence the research direction of music therapists, i.e., a multidisciplinary approach. Several physical therapists, music therapists, and adapted physical educators contacted during the study stated frequently that they use music/rhythm-related methods; but when asked which aspect of movement abilities, and to what extent these methods actually aid, they were uncertain. Rather than assuming a method to be effective, music therapists need to scrutinize to the greatest degree possible the methods and materials for actual effectiveness, not only to justify current clinical practice, but to open new and more beneficial therapeutic avenues in a comprehensive music therapy methodology. This study, in investigating a clinical technique and gathering related research evidence to develop a theoretical model, tried to acknowledge the importance that work with motor dysfunctions has attained for clinical practice in music therapy.

Assumptions

For the purpose of this study, the following assumptions were made:

1. The Bruininks-Oseretsky test of motor proficiency, gross motor composite, is a valid and reliable screening instrument to identify male children, age 6-8, with subnormal gross motor development.

2. None of the children participating in the study had a gross motor impairment associated with a specifically diagnosed clinical orthopedic handicap, mental or emotional impairment.

3. The gross motor impaired children selected were a representative sample of the 6.0 to 8.11 year old male population for the greater Lansing, Michigan, area with comparable reported characteristics.

4. The movement task used in this study constitutes a developmentally appropriate gross motor task using large muscle activity in time and space.

5. The wide range of motor behavioral characteristics associated with the broad term gross motor dysfunction is accounted for through randomized assignment of subjects to treatment and control groups.

Limitations

1. Results of this study cannot be generalized beyond the following group characteristics: male, ages 6.0 to 8.11, gross motor proficiency scores 40th percentile and lower (as measured by the gross motor battery from the Bruininks-Oseretsky test of motor proficiency) and residents of the greater Lansing, Michigan, area.

2. This study does not intend to examine causal factors, specific diagnostic categories, or etiological groupings found in children with gross motor dysfunction.

3. While attention and motivation are important factors in gross motor performance, these factors are not examined directly in this study.

4. The results of the study are limited to the specific performance task, a movement sequence consisting of successively alternating sidesteps and arm movements, the parameters of the rehearsal method, and the specific characteristics of the treatment materials (rhythmic stimuli). Generalizations beyond these limitations will be indicated as such in the text.

CHAPTER II

RELATED LITERATURE

Aspects of Motor Behavior

The term motor behavior has become increasingly popular as evidenced by its usage in the research literature in connection with describing behavior expressed by bodily movement, as opposed to cognitive or affective behavior domains (Singer, 1980). The term "motor" by itself refers to muscular movement which may range from merely reflexive movement to performances involving highly cognitive and perceptual processes, such as cue detection, evaluation, and decision making. The emphasis, however, lies always on bodily movement and movement control as a physical response in a complex receptor-effector feedback process (Marteniuk, 1976).

Motor activities can be categorized into abilities, thought to be traits of a more general nature and affected by both learning and heredity, and skills which are specific to given tasks (Fleishman, 1972). Gallahue (1982) differentiates between physical fitness abilities, such as cardiovascular and muscular endurance, muscular strength, and flexibility, and motor fitness, such as coordination, balance, speed, agility, and power. Researchers in physical education have related general abilities, e.g., balance, to motor skills, e.g., dribbling a soccerball, as basic constituents underlying each a variety of specific motor skills, but in a manner specific to the situation in which the skill is practiced.

Motor skills and motor patterns can be differentiated, as well. A motor pattern, such as locomotion, consists of an extensive group or series of single motor acts. Motor activity consists of movements based on muscular activity in time and space, elements common to all motor types. Coordinated or skillful movement encompasses (1) the selection and stimulation of appropriate muscles, thereby changing the position of the body from one place in space to another (spatial control); (2) the activation of muscles at the right time sequentially or simultaneously (temporal control); and (3) gradual muscle inhibition (quantitative control) (Singer, 1980).

The development of spatial, temporal, and qualitative muscular control in motor performance seems to be most dependent on the coupled and interdependent development of movement forces, such as speed, agility, and power and movement control mechanisms, such as balance and coordination. While both balance and coordination require a strong amount of spatial and kinesthetic control abilities, coordination contains additional elements of temporal control mechanisms. Gallahue (1982) explains:

> Coordination is the ability to integrate separate motor systems with varying sensory modalities into efficient patterns of movement. The more complicated the movement tasks, the greater the level of coordination necessary for efficient performance. . . . Coordinated behavior requires the child to perform specific movements in a series quickly and accurately. Movement must be synchronous, rhythmical, and properly sequenced in order to be coordinated (p. 278).

The structure of time relationships in movement patterns described by Gallahue as synchronization, rhythm and sequential ordering, is an important description of motor coordination. Temporal control is intricately related to the coordinated interaction of various muscular systems and sensory modalities. Gallahue (1982) continues: "The individual with a well-developed time dimension is the one that we refer to as coordinated. One who has not fully established this is often called clumsy or awkward" (p. 307).

Many workers have emphasized the importance of temporal organization in movement as a fundamental motor ability required for skillful performance. Bartlett (1958) points to the importance of accurate timing between receptor and effector functions within their serial organization as crucial in skilled performance. Provins (1956) points out that timing of muscular contractions is displayed in any movement where several muscles act serially or alternately. Differences in timing between unskilled and skilled performance have been demonstrated by comparing performance of preferred and nonpreferred hands (Provins, 1956; Provins and Glencross, 1968). Smith, McDermid and Shideman (1960) have used the term "neural timing" for the complex temporal organization of human gait.

Glencross (1970) differentiates two aspects of timing in movement, positional timing which governs the coincidental response when a signal appears, and serial timing which refers to the timing of successive movement patterns. Glencross writes:

> Serial timing refers to the consistency with which a regular event occurs in an ongoing cycle of movements. Specifically serial timing relates to the consistency of the cycle length between successive force peaks. The skilled subject apparently is able to construct a consistent temporal pattern, whereby the time interval between principle events remains very constant (p. 234).

If a movement pattern consists of a succession or pattern of regularly recurring, serially organized gross motor events in time and space, the term motor rhythm has been used to describe this quality (Huff, 1972; MacDougal, 1902; Seashore, 1926; Thomas and Moon, 1976; Schwanda, 1969). Good motor rhythm is dependent on the ability to be in a specific point in space at a specific point in time and also dependent on the ability to maintain this temporal structure in a periodic succession of muscular events in space. Both aspects, the immediate rhythmic accuracy and the maintenance of accuracy in an ongoing cycle of movements, are contingent upon the development of spatial and temporal accuracy of motor rhythmic performance.

In summary, based on the presented literature and theoretical implications, it may be concluded that:

1. temporal control is one of the three main characteristics of a movement act;

2. skilled movement possesses good temporal control;

3. a series or grouping of motor acts requires a specific type of temporal control which may be called serial timing, referring to the temporal control of serial muscle contractions;

4. a series or grouping of motor acts constitutes a regularly recurring pattern, such as in an ongoing cycle of movements, with its components of immediate and maintained rhythmic accuracy, the term 'motor rhythm,' has been used to describe this quality.

Gross Motor Impairment, Diagnosis and Remediation

Diagnostic and remedial techniques for children with gross motor dysfunctions focus on the spatial, temporal and quantitative characteristics of gross motor activities. A number of diagnostic tools, such as motor proficiency tests, have been developed to identify and assess impaired motor development. Remedial strategies, however, are far from absolute since the term "motor dysfunction" seems to describe a disability with a wide and diverse background of possible causes. A variety of diagnostic labels reflect the assumption of some kind of underlying neurological problem, including labels like organic brain dysfunction, minimal or diffuse brain damage, organic drivenness, cerebral dysfunction, and cerebral dissynchronization syndrome (Cratty, 1975). Other diagnostic labels limit themselves to reflect the behavioral consequences of observed dysfunctions, e.g., clumsy child syndrome, hyperkinetic syndrome, etc.

Etiological insights remain scanty and preliminary in the research literature. Developmental delays due to diseases, minimal trauma to the nervous system, inherited disadvantageous physical problems such as cardiovascular or endocrine conditions, lack of practice, emotional problems, diffuse brain damage, obesity, could all be found or suspected to cause an identified motor impairment. Goellnitz (1976) suggests a diagnostic model of organic brain symptoms which differentiates three groups of severity: (1) unspecific vegetative symptoms, such as affective and vegetative lability, weak cerebral control, hyperkinetic restlessness, and attentional problems; (2) specific organic brain symptoms, such as psychomotor retardation, visuomotor dysintegration, and performance inconsistency; and (3) localized organic brain symptoms, such as apraxias, or agnosias.

A frequent incidence of attentional problems, lack of concentration, hyperactivity or learning disorders can be found in children with motor dysfunction (Cratty, 1975). This overlap of dysfunctions, although not given in every child with motor ineptitude, may complicate remedial strategies considerably. It is a useful distinction, however, to differentiate between motor problems based on known causes and defined clinical pathologies, such as different types of cerebral palsy, orthopedic handicaps, muscular dystrophy or neuro-physiological problems, e.g., infantile autism, and motor problems not readily associated with a clinical pathology. Haubenstricker and Seefeldt (1974) have given diagnostic characteristics of the movement performance of the latter group:

1. inconsistency when performing a specific gross motor task; the children vacillate in proficiency from stage to stage with repeated trials;

2. perseveration; the children continue their motions after the performance should be completed;

3. mirroring during visual modeling; the children exhibit an inability to separate their directional movements from those of the leader;

4. asymmetry in the performance of motor activities which require bilateral use of limbs;

5. loss of dynamic balance; the children exhibit an inability to maintain postural control of the body in relation to gravity when moving in space;

6. falling after completion of a specified motor task;

7. extraneous motions during the execution of gross motor activities which disrupt efficient spatial-temporal organization of the movement; the children

might pursue a limb motion beyond its range of efficiency or add redundant motions to the movement sequence;

8. inability to maintain a pattern or rhythm imposed internally or externally;

9. inability to control force; the children apply inappropriate force (too much or too little) when executing a motor task; this characteristic actually might disrupt attempts to establish a pattern in a motor activity, thus being closely related as a possible causative factor to the previous characteristic;

10. inappropriate motor planning, as exhibited through misapplication of force, the delay or prematurity of a motor response, or the inability to adequately integrate sensory input and plan motor responses in a complex stimulus-response sequence.

Some of these features may be linked causally to a delay in the developmental process and in skill attainment. Other characteristics may be more likely associated with an underlying neurological dysfunction. The overall performance impression of these children is that of being clumsy, awkward or uncoordinated. However, the motor skill development of children with gross motor dysfunction follows essentially the same sequence exhibited by their "normal" peers. Therefore, a more precise description of their movement deficiencies is possible. Haubenstricker and Seefeldt (1974) elaborate:

> It is inadequate to identify children with gross motor dysfunction as clumsy or awkward, since the movement characteristics which precipitate such labels are specific and identifiable. The first step in remedial motor education is to identify the level of skill development and the particular movement characteristics displayed by the child. Only then can adequate prescriptive activities be planned to meet the needs of each child (p. 5).

Specifically, then, the temporal and quantitative control of movement might have a particular importance for those motor impaired children, since the spatial control is not pathologically affected as in a spastic or muscular dystrophy child. A child with gross motor problems usually has the physical ability to reach every available point in space but might not do it at the right time, use appropriate force or consistently use the correct limb.

Remedial motor therapy, thus, is really concerned with developing and applying teaching strategies to improve a person's motor functioning. Current remedial motor therapy works twofold, improving basic physical abilities, e.g., muscular strength, endurance, coordination, balance, and agility, and improving fundamental motor skills, e.g., catching, throwing, and running, within the perspective of a developmental continuum. Other, more specialized applications, may be needed. For example, activities for daily living skills for more severely involved clientele or techniques for relaxation and reduction of hyperactivity are among those applications. It is well accepted that there exists no type of prescriptive movement exercise which improves range of motion, strength or coordination of serial muscular activity by affecting only peripheral mechanisms, such as the functional state of joints and muscles themselves. For all exercises, devised mainly for the purpose mentioned, some reeducation of the central nervous system mechanisms is involved to various extents (Fisher, 1958). Cratty (1975) summarizes the goals and clinical avenues in the field of remedial motor activities:

> (1) real modifications within the central or peripheral nervous system, (2) a change of strategies from the inappropriate to the more appropriate when attempting to execute some difficult motor task, (3) adoption of constant and efficient work methods, rather than continual experimentation

> with those methods of executing a motor task which are often inefficient, (4) improvement in what might be termed motor planning, the more efficient analysis of newly confronted physical tasks, and the discovery of sequentially analyzed steps in their solution, (5) improvement of physical strength which permits the child to tolerate better the stresses and strains of problems such as those represented in balance tasks, (6) a compensatory circumvention of difficult-to-remediate motor problems, standing with the legs farther apart when throwing, affording greater stability, for example, to "get around" a balance problem (p. 8).

A clinical technique, designed for use with the particular population described in this chapter, thus has to work on one of the problem areas associated with gross motor impairment. Insufficient temporal and quantitative control are among the factors underlying the motor problems of this population. A proposed clinical technique, furthermore, has to address itself to components of fundamental motor pattern or basic physical abilities which are in the treatment focus of remedial motor education. Lastly, such a clinical technique has to facilitate the execution of peripheral movement mechanisms as well as central nervous system learning processes through the selection of teaching cues, balance of modeling and practice time, and the amount of repetition needed to secure newly learned patterns. The treatment design of this study tries to incorporate all three of these principles.

Rhythm and Motor Response

Considering the importance of timing and temporal discrimination processes in movement, it is not surprising to find a huge array of research on the relationship of external rhythm, body rhythm and movement performance. The assumption that rhythm is a factor in learning and performing motor skills has often been taken for granted among educators and researchers concerned with various aspects of physical performance. However, no general agreement has emerged in the research literature about the exact nature of this rhythmic factor, the extent of its influence on motor ability, or the ways it is related to motor educability. An additional, complicating factor is the generally accepted notion that rhythm can be perceived in various ways, since all of the senses are capable of experiencing a rhythmic organization of sensations (Bond, 1959). Timing ability in movement performance has often been hypothetically related to rhythmic sense. Schwands (1969) summarizes research efforts in this direction:

> That a relationship exists between the sense of rhythm and movement performance has been suspected for some time. Many efforts have been made to discover the value of this supposition, but a substantial relationship has not yet been discovered (p. 567).

This state of uncertainty may be due to a lack of agreement in the literature on the nature or perceptual modality of the sense of rhythm. The term rhythm has been used to include a variety of events, both individual and universal in nature. Experimental psychology has looked at rhythm in terms of several distinct aspects: (1) the nature of objective rhythmic stimulation and its impact on the human organism; (2) the nature of subjective rhythmic perception; and (3) the nature of rhythmic motor experience. Barsch (1967) differentiates between fundamental types of rhythm: (1) cosmic rhythm as a cyclic nature of the universe; (2) biological rhythm as the physiological pattern regulated by the autonomic nervous system; (3) perceived-reproduced rhythm, consisting of perception of a rhythmic stimulus and subsequent reproduction of the stimulus pattern;

and (4) performance rhythm consisting of a consistent replication of a movement pattern with both spatial and temporal accuracy. The two last types of rhythm have been considered an important factor in the development, performance, and learning of motor skills.

Research in motor development has dealt with the role of perception in motor learning thereby focusing mainly on perceptual processes through vision, kinesthesis, and equilibrium. Auditory perceptual processes, e.g., through language or music, have been given lesser attention. These are reported as tools for motivation or unspecific accompaniment of movement experiences. However, a study by Smith (1970) indicates that temporal discrimination processes develop earlier through the auditory modality than the visual and that there is transfer from the auditory to the visual but not the reverse. The potential effect of auditorily perceived rhythmic stimuli on temporal accuracy in movement can be put forth quite logically, at least in theory, if the superior temporal discrimination process in the auditory mode can be translated into temporal muscular control. This translation process, which shall be called auditory-motor coordination or integration at this point, has been investigated from very different viewpoints and with very different methodological approaches in the neurophysiological and behavioral research literature. General models which relate these different research foci to each other and describe the utilization of auditory-motor integrative processes in motor learning or remedial motor education have not been found in the literature. Therefore it seemed necessary to provide a systematized discussion of neurophysiological and psychological research providing evidence that, and in which way, auditory rhythmic materials can aid motor performance.

Motor Rhythm and External Rhythm

Motor rhythm usually refers to the temporal organization of serial muscle response, observable as the consistent and regularly recurring grouping of single motor acts. Numerous studies have tried to investigate a possible relationship between external rhythm and motor rhythmic responses mediated through various perceptual processes, depending on the nature of the rhythmic stimulus. Rhythm, in this connection, shall be defined as the periodic succession or regular recurrence of events in time which constitute the organization of temporal relationships. Auditory rhythm refers to the perception of a series of acoustic stimuli as a rhythmic pattern. The nature of the perceived grouping is influenced by objective characteristics of the stimulus series, e.g., intensities of its components, duration, temporal spacing (Woodrow, 1951).

Two main approaches seem to have emerged to measure rhythmic perception. One approach measures the ability to maintain a steady tempo (Drake, 1957) or to discriminate differences in rhythmic patterns (Kwalwasser & Dykema, 1930; Seashore, 1919) via verbal responses to auditory stimuli. The other approach measures various small muscle motor responses such as finger tapping (Buck, 1936; Seashore, 1926), or foot tapping (McCristal, 1933) to auditory or visual stimuli and locomotor patterns (Ashton, 1953; Haight, 1944; Lemon & Sherbon, 1934; Simpson, 1959). Studies that have tried to correlate verbal and motor responses have overwhelmingly shown that the ability to perceive and discriminate rhythmic stimuli on verbal tests has no substantial relationship to the degree of motor rhythmic abilities (Bond, 1959; Lemon & Sherbon, 1934; Huff, 1972; Smith, 1957; Schwanda, 1969). The study by Huff (1972) showed instead that skilled athletes and dancers, although not superior on perceptual and rhythm discrimination tests, performed a gross motor sequence synchronized to an auditory rhythm more accurately than normal college students. These results indicate that the ability to synchronize motor rhythm patterns to an external rhythm forms a separate skill entity which seems to be dependent on training and exposure to rhythmic stimuli and movement. These results clearly contradict earlier notions that perception of rhythm is directly related to rhythmic motor responses because a kinesthetic or motor factor is already present in the perceptual process itself (MacDougal, 1902).

The presented literature leaves no other conclusion than that the kinesthetic or motor factor in the perceptual process still needs to be shaped or translated into a temporal muscular control scheme coordinated with external rhythmic stimuli before motor rhythmic performance can appear. However, the effectiveness of motor rhythmic training over time on temporal movement control and the ability to synchronize motions with external rhythms has not widely been investigated through quantifiable data. Groves (1969) reported that rhythmic training consisting of a nondirective technique with emphasis on rhythmic stimuli incorporated in a tonal setting had no measurable influence on scores on a motor rhythm synchronization test. Since the treatment is not further specified, an evaluation of the presented data remains inconclusive. Mikol and Denny (1955) reported that a synchronous metronome stimulus improved the performance accuracy in a rotary pursuit task when compared to synchronous music, no music, asynchronous music, or asynchronous metronome conditions.

Most other studies testing for accuracy of motor response in relation to rhythmic signals have used single testing situations without comparative data, measuring motor rhythmic and perceptual abilities based on limited movement types.

Two other questions are of concern in the relationship between external and motor rhythm. The first question, subject to much research, deals with the effect different sensory modalities in which the stimulus is presented have on the quality of the motor rhythmic response. Numerous studies have consistently shown that the auditory modality produces motor rhythmic responses less variable than the visual, tactile or combined auditory/visual presentation mode (Gault & Goodfellow, 1938; Haight, 1944; Huff, 1972; Lhamon & Goldstone, 1974; Rosenbusch & Gardner, 1968; Thomas & Moon, 1976).

The results of the study by Thomas and Moon (1976) measuring motor rhythmic abilities in children led the authors to conclude that, although the underlying mechanism is not clearly understood, the young child initially attempting performance tasks of a time-space rhythmic nature with a movement pattern accuracy component should be encouraged to rely on audio cues. These results might be better understood in the light of work by Smith (1970), which indicates that temporal discrimination processes develop through the auditory modality before the visual system and that there is transfer from the auditory to the visual but not the reverse.

Cooper (1982) tape recorded the sounds of movement patterns of selected sport skills in outstanding performers. The sounds made by these performers were transcribed into rhythmic notation illustrating that a recordable rhythmic element was present. In most instances the foot sounds were the most audible and were the ones used in recording the action. These rhythmic patterns were beaten out on a drum in several teaching situations with beginners. The observed results led to the conclusion that beginners can benefit from adapting an efficient performance rhythm, making the correct foot movements at the proper rate and with the proper emphasis, etc. The rhythm of even a very skilled performer was found to be not smooth or uneven in tempo but always consistent in pattern. It seems that the most beneficial presentation mode for rhythmic stimuli is in the auditory modality since it is most intimately related to the timing sense in man.

The second question is concerned with the development of rhythmic ability regarding perception of and motor response to auditory rhythmic stimuli. Studies by Van Alstyne & Osborne (1937), Rosenbusch & Gardner (1968) and Smoll (1974) have indicated an increase with age in the temporal accuracy of children's motor responses to auditory rhythmic stimuli. Smoll (1974) investigated development of spatial and temporal elements of motor responses to auditory rhythmic stimuli for children 5 to 11 years of age. The findings indicate a reduction of error in spatial and temporal accuracy with increasing age. The biggest improvement appeared between the

8 and 9 year old children. Rosenbusch & Gardner (1968), investigating the same rhythmic tasks with children 5 to 13 years of age, found a linear improvement of temporal error scores in the auditory modality which also proved to be superior to the visual rhythmic presentation.

In summary, it appears that motor rhythmic synchronization to an external rhythm is a skill entity which (1) is affected by training and teaching, (2) produces best responses in the auditory modality, and (3) is influenced in its growth by developmental mechanisms.

Neurophysiological Aspects

Sound stimuli, and in particular rhythmic stimuli, exert an influence on the motor system in man which can be detected through electrophysiological measurement devices. The most noticeable interaction between the auditory and motor system in man is the startle response (Landis & Hunt, 1939). The more frequent response types are usually more subtle than the startle response.

Paltsev and El'ner (1967) have reported that nerve pulses induced by sound signals travel not only along the pathways ascending to the cerebral cortex, but simultaneously spread to the spinal cord. For a strong sound signal, these impulses raise the excitability of the motor nuclei of the spinal cord. By the time of the appearance of supraspinal influences at the segmental level, the excitability of the corresponding spinal structures has become already sufficiently high so that they are ready to be brought into action under these influences. This process results in a shortening of the latent period of voluntary muscle reaction to strong sound signals.

Rossignol (1971) reported a two-fold increase of excitability induced by musical sound patterns in the spinal motor neuron pool. This report suggests that musical stimuli, at the spinal level, might influence the timing of motor responses. The results indicate also that there is a tendency for the increased motor neural activity to be timed to repetitive auditory stimulation in a synchronized manner. This synchronization (or timing) makes best use of the audio-spinal effect, electromyographic facilitation, for muscular response patterns.

Rossignol and Jones (1976) have conducted a series of experiments showing that sharp transient sounds, not intense enough to induce startle responses, facilitate an increase in excitability of spinal motor neurons. The increase of excitability was accompanied by a low habituation rate and a delay of the peak facilitation by the audio-spinal latency and conduction time. The peak facilitation of the motor neural pulse potentiation was also found to depend on the intensity of the sound stimulus. Tones of 30 to 110 db were found to double the measured motor neural activity. The duration of the facilitation also indicates that there is a minimal time interval between two successive sounds for which motor neural potentiation can still be observed. Unlike with sounds inducing the startle response, no inhibition was found following the period of facilitation. This lead the authors to the conclusion that the potentiation is the predominant feature when using nonstartling sounds and this might in turn potentiate whatever movement is synchronized to the incoming sounds.

Furthermore, to investigate the latter assumption, the time course of this audiospinal facilitation was superposed over the electromyogram events during hopping to a simplified musical stimulus. The presumed electromyographic facilitation period induced by the "on" and "off" beats of the stimulus apparently synchronized with the peak upwards acceleration of the electromyographic activity. Rossignol and Jones (1976) elaborate:

> The mode of synchronization was not indeed arbitrary but followed a fixed pattern. One can obviously hop at the same frequency without auditory cues and other factors such as vestibular, neuromuscular, or even energetic could certainly contribute in fixing the preferred frequency. However, when hopping at the preferred frequency with music, the mode of synchronization of the motor events and auditory events is very suggestive of a purposeful use of audio-spinal facilitation. . . . It is not known yet which changes occur in the transmission of pathways mediating the present audio-spinal influences during hopping but one can imagine that man could have learned to use his endowed subcortical startle mechanisms as a pathway through which to generate subtle sensory-motor interactions such as needed when dancing to music (p. 90).

With this mode of synchronization, the timing of the beat pattern of the musical stimulus would be suitable to potentiate the electromyographic events related respectively to the peak upwards acceleration determining the take off and to the landing. Thus, it could be inferred that during a synchronized fixed movement pattern to rhythmic auditory stimuli, the motor events are timed in phase with the audio-spinal facilitation period.

In summary, auditory signals exert various neurophysiological effects on the motor system. Of specific concern for motor performance are the effects of motor neural potentiation through audio-spinal processes and the effect of repetitive stimulation. Measurements of both effects strongly suggest that when one is synchronizing repetitive movement patterns to rhythmic auditory stimulation, such as in music, the motor events would benefit from this facilitation regarding the timing of the motor response if the proper sensory-motor interactions can be generated.

Automatization of Movement Patterns

Highly skilled movement performance seems to be associated with a preconceived, well-developed movement plan, established in the brain areas which are responsible for execution and control of motor activities (Singer, 1980). For example, a beginner needs to go through the steps in performing a task very consciously, attending to the various components of the movements and to all external guiding cues present. Conversely, an experienced performer seems to be able to complete the same sequence "unconsciously" without heavy reliance on external cues. A well-developed movement plan seems to provide built-in mechanisms for control and continuance of required activities. The skilled performer does not need to repeat the trial-and-error process once a movement plan is established. The performer rather calls on a plan well-constructed beforehand. It is then assumed that the specific skill which is based on a movement plan or program becomes automatic and reflex-like (Isaacson, Douglas, Lubar & Schmaltz, 1971).

In the development of the brain areas responsible for the control of motor behavior, the cerebral cortex plays an important role in any type of voluntary movement, and obviously in learning complex movements, e.g., athletic skills; whereas the cerebellum offers an automatic control function, being responsible for smooth, coordinated movement and for the execution of reflex-like movement patterns. Well-learned motor patterns, presumably not requiring conscious control anymore, might indeed have become almost like reflex acts then. This development would be connected to a shift in cortical areas from the cortex to the cerebellum as being responsible for execution and control.

Isaacson et al. (1971) suggest that a given area might be necessary for the trial-and-error process of mastering a given motor skill but will not be involved any longer once the skill has become automatic or reflex-like. This change would also account for the finding that very complex motor behavior often remains intact after extensive damage to prime motor areas in the cortex. Despite a suggested change in involved brain areas, it has to be emphasized, however, that the cerebellum and cerebrum work closely together, though to various extents, on all forms of coordinated motor acts.

Different approaches have been taken to investigate the development and manifestation of automatization in motor patterns. A more recent approach, of considerable pertinence to this study, has required the subject to process dual streams of information. The proficiency of a secondary task has been used as an index of automatization of the primary task. The majority of studies support the notion that the degree of anticipation displayed by the subjects performing the task is an important factor in the process of movement response automatization. Anticipation, however, seemed to be a variable depending on the predictability of external response cues.

Schmidt (1968) reported that predictable tasks cued by external stimuli seemed to be learned better when a concurrent secondary task was required to be performed. Schmidt suggests that a task which can be anticipated, in terms of serial ordering and reaction time, will require decreasing conscious control and attention over time, thus becoming automatized.

Adams and Chambers' (1962) findings represent the results of a number of studies employing two concurrent tasks, each time-cued by simultaneous visual or auditory stimuli. Task performances cued by the predictable stimulus were superior to those in the unpredictable condition. The auditory stimulus always proved to elicit better responses than the visual.

These findings support the data that show the superiority of the temporal discrimination process in the auditory modality over the visual. Auditory cues, or sound events, if rhythmically organized, are predictable timing cues since they fall into consistent patterns even if the time intervals between the onsets of each sound event are not all of the same length. It is logical to assume, then, that auditory rhythmic stimuli can serve as predictable timing cues which facilitate the anticipation of a motor response, and thus, that this response pattern gradually becomes automatized.

A similar view, but on a neurophysiological basis, has been developed by Jones, Watt & Rossignol (1973) and Jones & Watt (1971). Anticipatory patterns of electromyographic activity during stepping and hopping movements seem to indicate that the entire motor act, as a sequence of muscle contractions and inhibitions programmed and dispatched from higher cortical centers, becomes automatized. When exposed to an auditory rhythmic signal, the audio-spinal, vestibulo-spinal and muscle afferent responses seem to contribute to the automatic maintenance of the ongoing cycle of movement events.

Temporal Predictability and Response Anticipation

Another quality of temporally predictable stimulus groups, besides their effect on the automatization of a response pattern, can be found in their impact on reaction time and quality of the particular response. A shortening of the latency for volitional motor responses has already been suggested in the section on neurophysiological aspects.

Conrad (1956) has found that individuals, when given a choice, tended to organize response cues, presented at random time, in a consistent temporal structure. The influence of temporal consistency of the signal on the quality of response was statistically positive. Schmidt (1968), in surveying the literature on anticipation and timing in human motor performance, points out that anticipation and timing can be learned and that temporal and spatial predictability of the response cues seems to be the most potent determiner for anticipation. Furthermore, temporally predictable stimuli produced better response quality (Cross, 1966; Trumbo, Noble & Swink, 1967) and shorter response times (Adams & Boulter, 1964).

Wilson (1959) reported that the reaction time for rhythmic signal presentation was significantly faster than for non-rhythmic presentation. Movement time, the travel time of the particular limb from initial muscle response to target contact, was not influenced by the presentation mode. Thus the study indicates that the response improvement occurred during the time after stimulus presentation and between stimulus perception and response initiation, while the quickness of the muscular motions remained unaffected.

Wilson attributes the faster speed of reaction under the rhythmic compared with non-rhythmic conditions mainly to differences in the foreperiod in which a state of mental and physical readiness needs to be established. Thus, if the foreperiod is too short, the subject may have no time to attain the optimal state of readiness. If the foreperiod is too long, the subject's readiness may fade away. The physical state of readiness, according to Wilson, is characterized by a tensing of muscles which execute movement during the foreperiod. The reaction can occur quicker as the tension is higher at the end of the foreperiod. The tension is apt to be greatest when the foreperiod is regular and of optimal length. In a rhythmic series, the length of all single foreperiods can be optimal, unlike in a non-rhythmic series where many of the individual foreperiods would necessarily be different from optimal. The aspect of rhythmicity, however, influences the state of mental readiness as well. Wilson put forth that the mental readiness can be raised optimally at the respective reaction points if it is known just when a possible stimulus can occur. This premeditation of reaction is not possible in a non-rhythmic series of stimuli. Wilson's findings and model of explanation seem to reinforce, indeed, the view on movement response patterns to rhythmic stimuli as discussed in the section on neurophysiological research. The observed rhythmicity of motor neural potentiation to auditory rhythms seems to support the notion that an optimal movement response time can be achieved best in a rhythmic presentation of auditory stimuli.

In summary, it is apparent that the auditory presentation mode produces consistently faster reaction times and better response qualities than the visual, tactile, or combined auditory/visual presentations.

Muscular Fatigue and Recovery Time

Many studies have investigated the influence of the presence of musical stimuli on endurance in physical performance. There seems to be general agreement suggesting that physical endurance may be enhanced if movement is rhythmically coordinated with a musical stimulus. Bushey (1966) and Widdop (1968) have both reported that musical accompaniment enhances the muscular endurance in dance performance. Movement synchronized to the pace of musical stimuli has been shown to benefit in terms of speed (Harding, 1933) and cardiovascular endurance (Anshel & Marishi, 1978). Nelson (1963), using musical background stimuli without response synchronization, failed to disclose better strength or endurance in motor performance. Stull & Kearney (1974) found a shortened recovery time of muscular strength after a 3-minute rhythmic isometric grip-flexion exercise compared to

the same exercise when sustained for 1 minute, without rhythmic organization. Explanations for the advantageous effect of musical accompaniment on physical activity have been set forth by Marteniuk (1976) who suggests that, due to the process of selective attention, the subject's perception of a pleasant auditory stimulus predominates over the attention to the less pleasant stimuli of physical exertion, and by Hernandez-Peon (1961) who offers a neurophysiological model for apparently the same process. He contended that pleasurable sensory stimuli can facilitate electrical activity in one sensory pathway while blocking the transmission of other afferent pathways. Thus music may prolong physical endurance in the organism because it inhibits psychological feedback associated with physical exertion and fatigue. However, the importance of rhythmic organization of physical exercise to muscular endurance as emphasized by Anshel and Marishi (1978) and Stull and Kearney (1974) and possible underlying causal factors might deserve a more in-depth look in future research.

Auditory Feedback and Proprioceptive Control

External auditory cues have been used successfully in a number of studies as an auxiliary feedback system for, or contingent reinforcement of, muscular control. Non-rhythmically organized acoustic stimuli, however, do not pertain directly to the temporal ordering process necessary for a motor rhythmic performance. They have been used instead to facilitate various other aspects of motor learning, mainly in terms of quantitative muscular control or as response feedback for short term motor retention. Adams, Marshall and Goetz (1972) reported the use of combined auditory, proprioceptive and visual feedback for learning and recalling a movement. The biggest retention loss was found for the condition with the least feedback present. Thus the authors conclude that the various sources of feedback contribute to the strength of the perceptual trace which secures retention of a movement task.

Carlsoo and Edfeldt (1963) have used auditory stimulation to aid proprioceptive control in achieving stable activity from a single motor unit as displayed on an oscillograph screen. They found that proprioception can be assisted by external stimuli in achieving motor precision, whereby auditory feedback produced better results than visual. Even a slight auditory stimulus showed greater effect on performance than a very pronounced visual stimulus.

Sachs and Mayhall (1972) reported that auditory feedback as contingent reinforcement improved the pursuit motor performance of a cerebral palsied adult. Auditory feedback has been successfully used to reduce foot dragging in a cerebral palsied patient (Spearing & Poppen, 1974). Contingent auditory feedback has been used to control jaw movement and thumb switching (Hefferline & Kennan, 1963; Hefferline & Perrera, 1963), to modify poor posture (O'Brien & Azrin, 1970), and to acquire proper head posturing control in cerebral palsied children (Wolfe, 1980).

Auditory and visual feedback facilitated improvement and retention of dorsiflexion twice as much when compared to conventional therapy (Basmajian, Kukulka, Narayan, & Takebi, 1975), helped in controlling various other muscular functions in spastic conditions

(Basmajian, 1979), and facilitated the attainment of upper and lower limb function in a hemiplegic patient (Nafpliotis, 1976). The perceptual motor system obviously is sensitive to auditory stimulation, and the effectiveness of auditory feedback for the achievement of muscular control especially in populations with various motor handicaps is well documented.

Rhythmic Speech as Internal Movement Control

A crucial aspect in motor therapy is the maintenance of therapeutic success in addition to an immediate effect of a clinical technique. The question of concern is, whether the individual can maintain the motor rhythm accuracy once the cue is removed, after having learned to adjust the respective motor performance to an auditory timing aid. In this regard Luria's (1961) investigations about the role of speech in regulation of behavior patterns is of great importance. Luria carried out a number of experiments where he investigated the development of the regulatory role of speech in the formation of a child's behavior. In the first stage the child understands and uses the speech of others to direct its own behavior. Later the role of these external signals is assumed by the child's own overt speech but its regulatory influence proceeds not from the connection of semantic content of speech to behavior pattern, but rather from the direct, impellant or initiating action of speech itself. It is only at a third stage where the impellant action of speech is replaced by a regulatory influence based on semantic connections produced by speech. At a last stage, internal speech, closely bound to the formation of the mental processes of abstract thinking, becomes the dominant instance to direct thought and volitional action.

Meichenbaum (1977) has used verbal-instructional training, based on Luria's theories, to modify behavior in hyperactive children. His training program progresses through five stages:

1. An adult model performed a task while talking to him/herself out loud (cognitive modeling);
2. The child performed the same task under the direction of the model's instructions (overt, external guidance);
3. The child performed the task while instructing him/herself aloud (overt self-guidance);
4. The child whispered the instructions to himself as he/she went through the task (faded, overt self-guidance);
5. The child performed the task while guiding his/her performance via private speech (covert self-instruction).

Cotton (1965, 1974) reported on the technique of "rhythm intention" which uses chants to direct and control volitional movement patterns in cerebral palsied children. These children talk through their motions to enhance cortical control over their volitional movement attempts. Each chant is structured in a rhythmic pattern to emphasize the temporal frame of each motion, that is, a starting point, a point of completion and a regularly recurring grouping and ordering of the motions involved, even if the performed rhythm might be far from even. Rhythmic speech, e.g., in chant-form, really seems to serve two purposes in regard to movement control: (1) it regulates the desired motor behavior through either the initiating action of speech itself or through semantic connections between movement and verbal accompaniment, depending on the developmental level of the individual;

and (2) it regulates the timing of the movement, that is, the correct serial ordering and time relationship of the motor acts involved, through its rhythmic structure which can be anticipated as regularly recurring information.

A Model of Rhythmic Auditory-Motor Integration

A model is now introduced to summarize the findings of the previous discussions (Figure 1). This model depicts several research factors as possible constituents of a relationship between auditory rhythmic stimuli and motor rhythm performance underlying auditory-motor coordination processes. Auditory rhythm and rhythmic speech, the two treatment stimuli in this study, are suggested to aid temporal and quantitative muscular control of successive gross motor patterns through various psychological and neurophysiological processes. These processes constitute an auditory-motor integrative relationship as displayed in the model. The hypothesized relationship can be summarized as follows.

Auditory rhythmic signals as external stimuli can facilitate temporal and quantitative muscular control of movement patterns by:

1. influencing timing and potentiation of motor neural discharge ;
2. decreasing muscular fatigue sensation;
3. facilitating automatized movement performance through the temporal predictability of its timing cues;
4. improving reaction time and response quality through facilitated response anticipation; and
5. providing auditory feedback for proprioceptive control mechanisms.

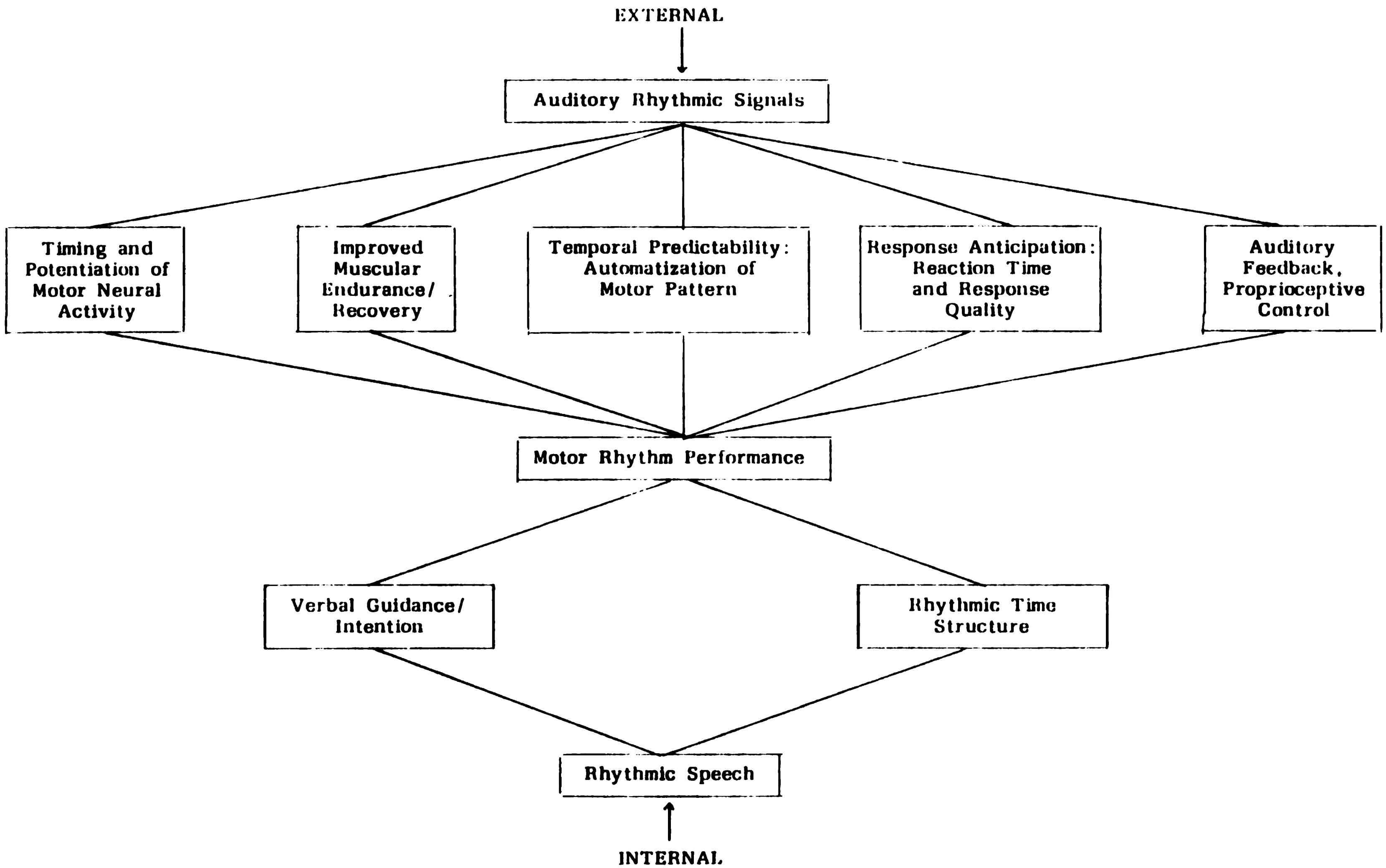


Figure 1.--A Model of Rhythmic Auditory-Motor Integration

Rhythmic speech as an internal stimulus can facilitate temporal and quantitative muscular control of movement patterns by:

1. verbally guiding the conscious initiation or intention of the movement as well as the actual movement performance ; and

2. providing a regularly recurring (rhythmic) time structure for the verbal cues, thus regulating the timing relationship between conscious (cortical) control mechanisms and muscular activity within each movement pattern.

Rhythmic Materials as Remedial Tools

Only a few experimental and clinical studies report the application of rhythmic aids as remedial tools in motor activities. More typical are comments on the general usefulness of music as accompaniment for movement because it possesses, as an enjoyable activity, certain motivating and compensatory values (Levitt, 1976). Reports on the specific therapeutic values of rhythmic materials are rare. Liemohn (1947), in a factor analysis of components of gross motor skills, identified rhythmic quality as one factor, thus suggesting that rhythmic organization of a movement might help to remediate aspects of motor functioning. Therefore, she concludes that rhythmic training in developmentally disabled children could facilitate remediation of certain motor dysfunction areas by its effect on kinesthetic and other peripheral motor abilities.

Beisman (1967) reported that rhythmic accompaniment, although not specifically synchronized to movement, influenced positively the acquisition of fundamental motor skills, such as throwing, catching, jumping, striking, and balancing. The rhythmic accompaniment was mainly provided through records, although piano, singing and clapping activities were also used. The author found that music and rhythm produced an enjoyable and relaxed atmosphere conducive to better motor learning.

Couper (1981), using dance therapy with learning disabled children, reported gains on performance of fundamental motor skills. Dance and movement were always performed to a rhythm of some kind. Music, drum beat, verbal chant, singing, or body percussion have all been used at different times. Activities comprised isolations and coordinations of single body parts, improvisations on different themes and locomotor patterns, emphasizing always the creative aspect of movement. Gains were measured for standing balance, hopping, jumping, and walking on a straight line.

Painter (1966) found that a rhythmic and sensory motor activity program improved the perceptual motor spatial abilities of kindergarten children. The children gained developmentally on draw-a-human-figure tests, body part identification, visual motor integration, spatial performance skills, and psycholinguistic abilities.

Staum (1983) used rhythmic stimuli successfully to decrease foot travel time deviations in gait rehabilitation caused by a variety of neuromuscular and skeletal disorders. Hecox, Levine & Scott (1976) report the successful use of dance techniques with a wide variety of neurological and orthopedic handicaps, but fail to present quantified data. Questionable or unclear control parameters in some of the presented studies make an interpretation of the data inconclusive. Studies on the effectiveness of remedial techniques where each subject serves as his/her own control over time and no other control parameters are included, e.g., to isolate practice effects, do not provide convincing evidence in favor of their treatment implementation.

Gallahue (1982) stresses rhythm as a basic component of all coordinated movement. He believes that rhythmic activities should be used to (1) enhance children's fundamental locomotor and nonlocomotor abilities, (2) enhance the child's ability to respond to variations in tempo, accent, intensity, underlying beat, and rhythmic pattern, (3) enhance children's ability to imitate and interpret through creative rhythmic movement, and (4) develop and refine children's auditory rhythmic abilities through participation in finger plays, nursery rhymes, poems, and singing rhymes. Those objectives, though not specifically formulated for remedial purposes, can obviously be transferred to motorically disabled children since their motor learning processes follow the same dvelopmental sequence as in normal children (Haubenstricker & Seefeldt, 1974). Musical, especially rhythmic, materials have been used to improve the physical and psychological functioning of children with cerebral palsy and a variety of psychiatric and developmental disturbances. Goellnitz (1975, 1976) claims that, apart from a general enjoyment of musical-rhythmic activities, motor, speech, cognitive, and socio-emotional performance deficiencies can be positively influenced through adaptive rhythmic psychomotor music therapy. This therapy focuses on the following main points:

1. to develop awareness of rhythmic forms and expression,
2. to promote musical enjoyment, differentiation between notes, memorization of tone sequences and rhythms, informal and relaxed involvement,
3. to arouse active participation in the musical arrangement and to arouse the phantasy,

4. to bring the patients into harmony; tension, affection, aggression and inhibitions are removed,

5. to train the concentration, particularly of patients who are easily distracted and tired (encephalopaths) by giving them tasks, rhythms, tempi, of adapted difficulty and by using several instruments,

6. to improve posture and motor coordination,

7. to improve integration and life within the group,

8. to train and coordinate respiration, speech, and song,

9. to help the patients learn to play musical and movement parts selected according to their personality,

10. to train limbs which are hindered paretically or poorly coordinated (p. 133).

Rhythmical intention is a clinical technique that uses the speech of the child to guide his/her movement, unaided by the therapist, within a rhythmical count. The rhythmic count provides a temporal structure for the chant-like "talking through the movement" which expresses the intention of the exercise. The method stresses, unlike therapeutic methods built on analysis of muscle work, cortical control of motor processes through establishing a link between speech and movement. The movements are guided by the child's own speech, or attempts to speak, without being physically handled by the therapist. The cortex controls the movements.

The use of rhythmical intention in working with cerebral palsied children has been reported by Cotton (1965), and Cotton & Parnwell (1968). The reports describe the use of this method at the Institute for Movement Therapy in Budapest, Hungary. Cotton (1974) also has reported on clinical adaptations of this method in Great Britain. The following example will illustrate the method:

> The children are lying supine on their plinths. The conductor (therapist) says slowly and loudly, "I lift my arms above my head"; the children repeat slowly and loudly: "I lift my arms above my head." The conductor and the children start to count slowly and loudly from one to five, and while doing so they raise their arms above their heads. The conductor counts with them to keep the rhythm steady and slow. In this example counting is the rhythm and "above the head" the intention (p. 438).

The link between speech and movement has been proposed in neurophysiological theories developed by Luria (1961). Luria describes how a small child is unable to squeeze a rubber ball twice in regular sequence on a given signal. But when the child is asked to say "go-go" and to reinforce the action with speech, he can do it without difficulty, thus developing a new movement pattern, like a conditioned reflex, through an internal control system.

In summary, it can be said that, although the research base is rather small, most of the authors seem to agree on some positive value of rhythmic materials or remedial tools. Most of the documented experimental research implements different types of training on rhythmic ability and subsequently, measures a variety of treatment outcomes which are not always directly related to the skills focused on during the period of rhythmic training. Thus, the question of transfer, e.g., how much effect does clapping hands on beat or moving freely to background music have on skipping with a smooth motor rhythm, seem to gain crucial importance and might be responsible for less conclusive results.

The only clinical technique which is based on widely accepted neurophysiological theories is rhythmical intention. Although no quantified data have been available regarding rhythmical intention, the amount of documented clinical experience makes this method, and likewise the ones reported by Goellnitz, particularly meaningful for researchers dealing with rhythmic materials as remedial tools.

CHAPTER III

METHODOLOGY

Subject Selection and Characteristics

Twenty-four subjects were drawn for this study from referral lists of two remedial motor programs in the Department of Health and Physical Education at Michigan State University. All subjects were male, since a frequency check of the sex ratio in the respective remedial motor programs indicated an overwhelming majority of male children (80 percent). Eight subjects were drawn from each of three age brackets: 6.0 to 6.11, 7.0 to 7.11, and 8.0 to 8.11, and randomly assigned to control and treatment conditions in an even number for each age level.

Selecting subjects in this age range seemed most appropriate for the gross motor task and the treatment studied, since skilled motor performance is an essential part of the requirements in daily life for early school-age children. Coordinated movement is not only important for requirements in physical education, but also for many classroom or leisure time activities. Longitudinal studies have shown that it is also during this age span when a normally developing child learns to master fundamental motor skill activities (Way, Haubenstricker & Seefeldt, 1979).

In addition, this motor-developmentally crucial age span comprises two stages of cognitive development as hypothesized by the

Swiss psychologist Jean Piaget (1955), the stages of preoperational intelligence (2-7 years) and concrete operational intelligence (7-11 years). Both stages characterize different degrees of complexity for mental operations based on perception, thought and emergence of language. For the purpose of gaining insight into developmental mechanisms it seemed, therefore, quite appropriate in this study to investigate the relationship between cognitive and motor development by choosing an age span where developmental changes are likely to occur.

Much attention has been given to the study of developmental sequences in normal and handicapped children. The research literature seems to be in general agreement that the sequence of development, at least in areas of psychomotor, cognitive and affective functioning where developmental stages have been postulated, is essentially the same for handicapped and normal children. The conceptual background of the importance of developmental processes can, therefore, be safely extended to this study where a handicapped population is exclusively represented. A last argument in favor of the age selection has been discussed earlier in this study--namely, that motor rhythmic synchronization to an external rhythm, as required by the testing item in this study, underlies developmental mechanisms in its growth. In order for a subject to be eligible for the study he had to be referred by an outside source, such as a teacher, therapist or physician, to one of the remedial motor programs at Michigan State University. The gross motor composite of the Bruininks-Oseretsky Test of Motor Proficiency was used as a second screening source to identify children with subnormal gross motor performance who would be eligible to participate in this study.

This test, published in 1978, was developed to provide educators, clinicians and researchers with information to assess motor skill development, serious motor dysfunctions or developmental handicaps in children aged 4.6 to 14.5 years. The gross motor composite of the test includes twenty items organized into four subtests: (1) running speed and agility, (2) balance, (3) bilateral coordination, and (4) strength. The composite score is considered to be an index of ability to use the large muscles effectively. A factor analysis of the gross motor composite subtest items, as reported by the publishers, resulted in the identification of three factors representing distinct aspects of gross motor ability: (1) static and dynamic balance; (2) strength--the ability to perform tasks requiring arm and leg muscles; and (3) bilateral coordination--the ability to coordinate hands and feet in simultaneous or sequential movement patterns. All three factors pertain quite directly to the characteristics of the movement tasks required in this study. The subtest "running speed and agility" which did not result in a separate factor loading for gross motor ability during the factor analysis, and does not seem to pertain to the movement task of this study, has been kept in the testing procedure because, as recommended by the publisher, only a total composite score can be reliably interpreted as an index for gross motor proficiency.

The publishers report a test-retest reliability for the gross motor composite, for boys in grade 2, of .90 with a Standard Error of Measurement of 5.0. In regard to construct validity, correlations ranging from .5 to .86 with a median of .78 are reported between total test scores and successive age levels. The test manual contains research in which the Bruininks-Oseretsky Test differentiated in a statistically significant manner between normal subjects and mildly retarded, moderately-to-severely retarded, and learning disabled subjects. Haubenstricker, Seefeldt, Fountain & Sapp (1981) have also shown the efficiency of the test to discriminate between normal children and those with gross motor dysfunction.

The test provides normative data, including standard scores for each age group, percentile ranks, and stanines. Percentile ranks, which describe a subject's performance in relation to the standardization sample scores, were used as screening criteria. A below-average performance score would be indicated by a percentile rank of 49 or lower. However, considering the irregularity of the units in the percentile rank scale, a concentration of scores near the middle of the scale can be expected. A percentage frequency of 20 between the 40th and 59th percentile rank makes a reliable discrimination process rather difficult in this area due to two facts: (1) the difference in performance expressed through the percentile ranks of 49 and 50 is extremely marginal compared to other points on the percentil rank scale; and (2) the standard error of measurement may imply a confidence interval for the "true" performance score that actually includes an above-average performance if the percentile rank cut-off point is so close to the mean. Therefore, a more robust indicator for subnormal gross motor performance was utilized. A subject's motor performance standard score needed to be equivalent to a percentile rank of 40 or lower to participate in the study. No other diagnosed mental, emotional, or orthopedic handicap was present in the subjects.

In order to provide consistency, all screening with the Bruininks-Oseretsky Test was performed by the experimenter. The subject characteristics, according to age groups, and percentile ranks, are presented in Table 1. Table 2 gives the mean percentile ranks of the gross motor composite differentiated by treatment and control group. A double classification analysis of variance was carried out to check for differences on the gross motor test scores between treatment and control groups and different age levels. The results are reported in Table 3.

TABLE 1.--Subject Characteristics According to Age Group, and Percentile Rank.

Age Group	Number of Subjects	Mean Percentile Rank
6.0 - 6.11	8	22
7.0 - 7.11	8	20
8.0 - 8.11	8	15

The results indicated that all groups were identical in their level of gross motor proficiency. An F of 3.55 or bigger would have been needed to exceed the critical value of the $p < .05$ level. The results support the notion that treatment effects cannot be linked to initial differences between groups on the gross motor

TABLE 2.--Mean Percentile Rank for Gross Motor Composite by Age, Treatment and Control Condition (n = 4 per cell).

Age Group	Treatment	Control
6.0 - 6.11	23	20
7.0 - 7.11	20	19
8.0 - 8.11	16	12

TABLE 3.--Double Classification Analysis of Variance of Gross Motor Test Standard Scores for Different Age Levels, and Treatment and Control Conditions.

Source of Variation	Sum of Squares	df	Mean Squares	F
Age level	224	1	224	1.60
Treatment Condition	39	2	19.5	0.14
Interaction	6	2	3	0.02
Within	2488	18	138	
TOTAL	1757	23		

proficiency level as measured by the gross motor composite of the Bruininks-Oseretsky Test of Motor Proficiency.

Performance Item

A gross motor pattern consisting of two consecutive side steps, a hand clap above the head and a hand slap on both thighs was used as the performance item. The movement pattern was sequenced as follows: (1) lead foot step sideways (the child may start with his preferred foot); (2) support foot closes in; (3) both arms swing upward with extended elbows, followed by a simultaneous hand clap above the head; and (4) both arms swing downward with extended elbows, followed by a simultaneous hand slap on both thighs. Thus the pattern could be described as a serially organized movement task, consisting of discrete motor events which were to be performed in a continuous manner. The item incorporated types of movements which are considered basic components of various gross motor skills: simultaneous bilateral arm movements, sequential unilateral leg movement (a side step gait variation), static and dynamic balance, inward and outward shoulder and arm rotation, three space direction, and sequential limb coordination in time and space. During a pilot study the item discriminated between low and high achievers in gross motor performance among five remedial motor clinic clients in terms of temporal acuity, speed of learning, and amount of erroneous movement. The side step, as a gait variation, is also considered to be of diagnostic value for asymmetrical motor function (Cratty, 1975).

Rhythmic Materials

The external auditory rhythmic stimulus consisted of a four-beat percussion pattern, played by a professional percussionist, on a percussion set comprised of a standing tom, a pair of timpanettis and a set of five temple blocks. The stimulus was recorded for two minutes on cassette tape, using a Sony TC-FX 6 stereo cassette deck and two

Unidyme Shure microphones. The pattern, rhythmically notated as ♩ ♩ ♩ ♩ , was played at a metronome speed of 58 per quarter note. An electric metronome with auditory and visual signal was used as a pulse orientation during the recording. The first beat was played on the standing tom, the second beat on the higher pitched timpanetti. Beats three and four were played on a high and low pitched temple block, respectively. The average time interval between the onset of each beat was 98 hsecs with a maximum deviation of 2 hsecs in either direction. The rhythmic speech pattern synchronized with each acoustically expressed beat, used this percussion pattern as timing for the words "step, close, up, down."

Setting and Apparatus

All experimental sessions were held in the Center for the Study of Human Performance at Michigan State University. The movement pattern was performed along a six-yards-long line of masking tape, laid out on the carpeted floor. Measurements were done with a measurement system consisting of two hand and two foot sensors, connectors, an encoding module, and a two-channel graphic level recorder MFE 1200. Two foot and two hand sensors were connected to the connector unit by small wires. The connector unit was taped to the back of the child. The sensors were covered by thin layers of foam on both sides and self-adhesive stickers on one side which helped to keep the sensors attached to the respective contact points. The hand sensors were placed in the palms of both hands. The foot sensors were attached to the center part of the soles of both shoes.

A 20-foot main cable connected the connector unit and the encoding module which was mounted on a table unit next to the graphic level recorders. The time duration of each movement was graphically recorded on the lower channel of the graphic level recorder. Each sensor, responsing to surface contact, was voltage-coded, which resulted in a distinct graphic shape for each movement. The baseline for the foot was displaced upwards as long as the child's respective foot traveled through the air. Upon surface contact, that is, upon completion of the respective foot movement, the line dropped vertically to its original position. Contact events of the hand sensors were displayed by elevated single peaks. Sample measures are displayed in Appendix C of this study.

During the pilot study and in tests prior to the main study a transmission of the sensory signals by telemetry instead of by cable was tried. Transmission of the sensor signals by telemetry offers freedom from cables between subject and recorder. This could be especially important in cases involving complex body motions such as rotation. Two types of telemetry transmitters were used.

A commercially available telemetry transmitter, typically used with bio-signals such as ECG, EMG, etc., did not produce satisfactory data recordings. The signals were obscured by carrier frequency instability, resulting from sensitivity to changes in position of conductive surfaces (e.g., parts of the body). This produced severe baseline shifts which obliterated the sensor signals.

An in-house telemetry transmitter circumvented the baseline-shift problem by modulating the carrier with a subcarrier (4000 Hz), which in turn was modulated by the sensor signals. Improved stability resulted from the inherently stable nature of the 4000 Hz oscillator, relative to the much higher frequency main carrier oscillator (FM band). The data recordings proved to be quite satisfactory. The disadvantage to this approach was a greater complexity of both transmitter and receiver since the receiver output consists of the modulated 4000 Hz subcarrier which must go to a second stage of demodulation to recover the sensor signals.*

It was concluded that commercial transmitters using the subcarrier approach should work well in the application described in this study. Those without subcarriers are probably unsuitable. However, for the main study the cable transmission was chosen over the telemetry approach due to these reasons: (1) cable transmission did not interfere with the nature of the movement since the performance required only a straight path in space and no body rotations; (2) cable transmission is less complex than telemetry transmission with subcarriers and, thus, less susceptable to breakdowns over a projected testing time of several months; and (3) the telemetry unit would not have been available at each desired testing time over the course of seven months.

The sound system consisted of a cassette tape with the recorded rhythmic stimulus, a cassette deck Kenwood Stereo KX 650, a stereo amplified-receiver Superscope S-330 with monitor device, and a loudspeaker. The amplifier was connected to the graphic level recorder. The transmitted sound signal was recorded on the upper

*Personal communication with R. Wells, engineer at the Center for the Study of Human Performance, Michigan State University.

channel of the graphic level recorder. The onset of each beat was displayed by a vertical displacement of the baseline. When the monitor button was switched on, the sound signal could also be heard in the session room via the loudspeaker system. A diagram of the whole apparatus is displayed in Appendix B of this study. The graphic level recorder was calibrated so that a single frame on the printout paper equaled a hundredth of a second. The motor driving the graphic level recorder is designed to maintain its calibrated speed independently of voltage fluctuations in the electrical source. Since the frames of the chart display had to be counted and converted into hundredths of seconds of movement time a test-retest check for intrarater reliability was performed. Ten measurements were drawn at random from a total of 96 measurements of motor rhythm accuracy and recounted. A pearson product moment correlation coefficient was computed from the original measure and the retest measure. A correlation coefficient of $r = .976$ yielded a satisfactory reliability account.

This recording system allowed measurement of the temporal parameters of movement without restraining the child's spatial range of movement by directly connecting the child's movement response to some kind of external stationary recording device, e.g., contact plates or levers. The voltage-coded sensors permitted identification of each limb motion separately, thus providing measurement of the quantitative parameters of the movement as well. This recording system, which was designed and built especially for this study by the laboratory engineer, allows one to record reliabily and precisely the temporal and quantitative parameters of a complex gross motor pattern in relation to a simultaneously recorded external stimulus without hampering the subjects' motions through stationary recording devices.

Treatment Procedures

Each subject in the experimental and control group was seen individually for approximately 30 minutes during three treatment sessions. The sessions were scheduled a week apart to minimize environmental influences and to equalize the treatment intervals for each subject. All sessions, held in the Center for the Study of Human Performance at Michigan State University, were conducted by the experimenter. An assistant engineer was present to operate the technical equipment and assist in attaching the measurement devices to the child's body. Each session consisted of teaching, practice, and recording time segments.

The first session comprised an initial assessment time for each subject where a baseline performance was recorded. The movement was demonstrated by the experimenter and the child was subsequently asked to imitate the model. If the sequence of the motions was accurate the sensors were attached to the child's body and the child was asked to perform five repetitions of the movement sequence. Cycles 2-5 served as measurement of the baseline performance, without treatment or rehearsal time. After the baseline measure the sensors were taken off and the session proceeded with teaching, practice and recording time segments.

Teaching time was defined as active demonstration of, or participation in, the movement by the experimenter. Practice time was defined as movement by the child alone. Recording time was defined as movement time with the sensors attached. On each step level in each time segment, displayed in Table 4, the movement pattern was performed for 10 cycles. Thus, each group had the same amount of exposure in each of the three different types of time involvements. The treatment group had an additional stationary time involvement where clapping on the beat and the rhythmic speech pattern were taught and practiced.

At the beginning of the sessions, each subject was asked to stand at one end of the taped line and face the experimenter, who stood about five feet away. The child was then asked to observe the experimenter and to follow his model when told to do so. Eventually the child was asked to perform alone, until a verbal signal to stop was given.

During the recording time, the subjects in the control group received the verbal command "and move" to start their movement performance. The subjects in the treatment group listened to the auditory rhythm for four beats, then spoke their pattern for another four beats, and finally started moving. The experimenter guided each change by a verbal command on the last beat of the preceding pattern. Before the recording devices were attached, the experimenter demonstrated the use of the sensors and the response of the needles on the chart paper. Before the actual recording, each child was allowed to move a few steps and clap his hands freely to get used to wearing the sensors and to check if any wiring was restraining the child's range of motions. Praise and encouragement were given after each step completion. Verbal feedback was kept to a

TABLE 4.--Time Involvement for Treatment and Control Group During Experimental Sessions.

	Treatment		Control	
	Child	Experimenter	Child	Experimenter
TEACHING	Watch	Visual model	Watch	Visual model
TEACHING	Movement Rhythmic speech	Movement Rhythmic speech	Movement	Movement
PRACTICE	Movement Rhythmic speech	Watch	Movement	Watch
	TURN ON MUSIC			
TEACHING	Clap beat	Clap beat Watch		
TEACHING	Clap beat Rhythmic speech	Clap beat Rhythmic speech Watch		
TEACHING	Movement Rhythmic speech	Movement Rhythmic speech	Movement	Movement
PRACTICE	Movement Rhythmic speech	Watch	Movement	Watch
	MANIPULATIONS			
	Turn off music Attach sensors Turn on music Turn on Graphic Level Recorder		 Attach sensors Turn on Graphic Level Recorder	
RECORDING	Movement Rhythmic speech	Watch Eatch	Movement	Watch
	FADE OUT MUSIC - MOVEMENT CONTINUES		MOVEMENT CONTINUES	
RECORDING	Movement Rhythmic Speech	Watch	Movement	Watch

minimum. Some children needed to be encouraged to make real surface contact when clapping their hands or slapping their thighs in order to get a recording of that particular motion.

Pilot Study

For the pilot study three former and two currently enrolled male clients of the Remedial Motor Program in the Department of Health and Physical Education at Michigan State University were tested. Two subjects were 6 years old, the others 7, 8, and 12 years old, respectively. All sessions were held in the same research laboratory used for the main study. The pilot study was intended to give information about the following areas of concern for the main study: (1) appropriateness of the particular movement task as a testing item; (2) appropriateness of the rhythmic aids; (3) efficiency of teaching and rehearsal strategies; (4) feasibility of the recording equipment; (5) technical reliability of the recording equipment; (6) production of meaningful and interpretable data; and (7) amount of repetition needed to record data within an acceptable interval of confidence. Each of these concerns now will be discussed.

1. The movement task proved to be appropriate for the performance abilities of the subjects. All subjects were able to perform the movements, however, with difficulties in timing, rhythmic synchronization and sequencing. The task also discriminated between age and low and high achievement in the Remedial Motor Program. The six year old subjects struggled most obviously with rhythmic synchronization to the external beat, while the twelve year old child seemed to

have no observable difficulties with the three problem areas mentioned. However, due to technical failure, only one 7 and one 8 year old subject's motor rhythm and synchronization measures could be recorded.

2. The auditory pattern consisted of the same four beats played on the same instruments as described earlier. However, beat one and beat two had an additional auditory signal on the weak part of the beat, notated as: ♫ ♫ ♩ ♩. These additional beats were intended to provide better anticipation cues for the subject. However, it was felt that they obscured the feeling for coincident motor response more than they helped. It was then decided to present acoustically only those beats requiring coincident motor response. The auditory rhythm pattern for the main study therefore contained four beats, equally spaced, for four distinct coincident motor responses. A change had to be made in the rhythmic speech pattern. The pattern used in the pilot study--"step, together, up, down"--showed some rhythmic problem with the word "together," since the external beat accentuates the syllable "-ge-" rather than the initial part of the word. Thus, it was decided to use the monosyllabic word "close" to avoid confusion between external beat and synchronization of speech patterns.

3. During the pilot study, for three of the children, the sensors were attached at the beginning of the session. All teaching and practice was done, then, wearing the transmitter module and the sensors. The subjects, although not resenting the idea of wearing the equipment, seemed somewhat distracted during the modeling and practice procedures from concentrating on watching the experimenter or his own movements. Two children learned and practiced the

movement without equipment first, and started wearing the devices only prior to the recording. After the devices were attached, they had some time, however, to move around freely and to experience that their movements were not restrained by the equipment. This procedure helped the initial concentration of the subjects on learning the movement without unfamiliar items present. Once the child was secure in his movements, the reattachment of the sensors did not interfere with his performance anymore. This procedure was thus adopted for the main study.

4. The recording system proved to be adequate and feasible for the projected study. The devices attached to the child were extremely light of weight, did not interfere with any natural body movement, and did not tie the child's motions to any stationary response-measuring device. No child expressed any discomfort with the equipment during the pilot study.

5. The transmission and recording of data worked flawlessly during the pilot study. The weak link of the recording system proved to be the stability of the sensors. A foot sensor broke during the pilot study, thus producing no displacement of the baseline on that particular limb motion. Therefore, several substitute sensors were built to replace a broken one whenever needed.

6. The motor of the graphic level recorder was calibrated so that fluctuation in the electrical supply source could not influence the calibrated speed. Displacements of the baseline as well as the different recorded shapes for each limb motion were clearly identifiable, thus providing a reliable account of timing and motions used during the movement task.

7. Motor rhythm deviations form the component mean performance time of 6 cycles were calculated for two children. The data indicated that after the fourth cycle, the deviations stabilize and thus a reliable recording of the average motor rhythm deviation could be obtained at this point (see Table 5).

TABLE 5.--Development of Motor Rhythm Deviations in Hundredths of a Second Through 6 Cycles.

Subject	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6
1	20	21	18	19	18	19
2	4	6	7	6	6	5

Recording Procedures

Four repetitions, or cycles, of each movement sequence were recorded under treatment and control conditions. Each cycle consisted of four sequential movement components: (1) lead foot steps sideways, (2) support foot closes in, (3) arms swing upward while feet are stationary, and (4) arms swing downward while feet are stationary.

A component performance time lasted from the end of the preceding component to the completion (at contact point) of the component itself. Thus, the component performance time included reaction time and actual travel time of the respective limb.

The four component performance times were added to obtain the total cycle performance time. Four cycles added up to the total performance measure of one recording session. The first cycle each child performed was used as an adjustment or warm-up cycle and was not recorded. Cycles 2-5 were recorded. In the treatment group the rhythmic stimulus was faded out during Cycle 6 and Cycles 7-10 were again recorded for treatment under faded conditions. The control group also performed 10 cycles to offset practice time effects, but only Cycles 2-5 were measured.

Measurement of Dependent Variables

Motor Rhythm Accuracy

For Analysis I and Analysis II (Motor Rhythm and Motor Rhythm under Faded Conditions) a calculation of motor rhythm performance time was completed. For each subject, a total performance time of four cycles was summed and divided by 16, the number of separate components. The figure was the component mean performance time (CMPT). For each component the time deviations from this CMPT were summed and divided by four, the number of times each component occurred. This figure stood for the average time deviation of each component from the CMPT, that is, the deviation of each component from the averaged motor rhythm. A summation of all four components' average time deviations and a division of this number by four resulted in the general motor rhythm consistency deviation for one recording session. Thus, the deviations from the averaged motor rhythm displayed in one general average deviation and four separate average deviations for each movement component. A decrease of these numbers toward zero would indicate an improving motor rhythm, that is, an even timing of each component within the total movement sequence.

Motor Rhythm Synchronization

For Analysis III (Motor Rhythm and External Rhythm) the synchronization between completion of each movement and the external beat was carried out. The time deviations between the onset of the auditory beat and the completion of each movement at contact point were summed for each movement component for four cycles and then divided by four, the number of cycles, to yield a mean deviation for each component. These four mean deviations were again averaged to yield a mean deviation for motor rhythm synchronization for one recording session.

Quantitative Muscular Control

For Analysis IV (Quantitative Muscular Control) and Analysis V (Quantitative Muscular Control under Faded Conditions), a count of erroneous movements was carried out for each subject's total movement performance. Two types of movement errors were counted: (1) extraneous foot and hand motions interspersed between the correct movement sequence which produced a reading on the chart paper, and (2) actual mistakes in the movement sequence.

Dependent Measures

For Analysis III, Maintenance of Performance Tempo between "Treatment Present" and "Treatment Faded" conditions, was calculated by subtracting both conditions' component mean performance times from each other. The resulting number indicated the difference between both conditions' performance tempo.

For Analysis III, Time Interval Conformity measures were calculated by subtracting the component mean performance time of each subject from the time interval number of the external beat which was 98 hsec. The resulting difference indicated the degree of conformity between the time duration of each movement component and the time interval between each beat, regardless of coincident motor response.

TABLE 6.--Measurements of Dependent Variables.

MOTOR RHYTHM ACCURACY (Analyses I and II)	
	Deviations from mean performance time of 16 movement components.
QUANTITATIVE MUSCULAR CONTROL (Analyses IV and V)	
	Count of extraneous or erroneous hand and foot motions during 16 movement components.
MOVEMENT RHYTHM SYNCHRONIZATION (Analysis III)	
	Deviations of movement completion from external beat.
MAINTENANCE OF PERFORMANCE TEMPO (Analysis III)	
	Difference between mean performance times of "Treatment Faded" and "Treatment Present" conditions.
TIME INTERVAL CONFORMITY (Analysis III)	
	Difference between mean performance time and external beat interval (98 hsec).

Statistical Analysis

In this study, analysis of variance procedures with repeated measures, by means of multivariate analysis, were chosen as the main statistical technique for analysis of the data. Repeated measures on the outcome variables were obtained from each subject during three treatment sessions. Considering the nature of a learning experiment, it is likely that performance measures in later sessions are related to the performance in earlier sessions. This relationship, however, may not be constant from session to session. Consequently, multivariate procedures were used for testing the various hypotheses (Winer, 1971).

Although the multivariate procedures allowed for heterogeneous correlations among the repeated measures, the validity of the procedure still relied on the assumption of compound symmetry. That means that the repeated measures were distributed with identical variance-covariance matrices for all groups in the study. The decompositions of sums of squares for the between subject sources of variation, however, would be similar to the univariate treatment of analysis of variance with repeated measures (Winer, 1971).

Because of the small number of cases involved in this study, the analyses were performed for each outcome variable separately. To improve precision and to adjust for possible performance differences at the outset of the experiment, the baseline measure was included as a covariate. In summary, in addition to the experimental variable treatment and the blocking variable age, baseline measures were used also as an independent variable. The design of the experiment was a 2x3 design with three repeated measures and one covariate. For analysis purposes, multivariate procedures were used for each outcome variable.

In order to provide information about trends among measures, orthogonal polynomials contrasts were used to express trend profiles, since the treatments formed a series of equal steps along an underlying ordered continuum, equally spaced time points.

Differences in performance profiles were tested for in terms of level, parallelism, and trend, that is, the interaction of the respective main effect of an experimental factor with time. In this study six contrast vectors were formed which provided for testing level differences and parallelism, and in interaction with repeated measurements, directional differences between the shapes of the performance profiles. Thus, a total of twelve contrasts was calculated in each analysis. The contrast vectors were: grand mean, linear trend for age, quadratic trend for age, treatment vs. control, linear trend for age by treatment interaction, quadratic trend for age by treatment interaction.

The Multivariate VI computer program for univariate and multivariate analyses of variance, covariance, regression, and repeated measures by Finn (1980) was used to computer analyze the data. The analyses were performed on a CDC Cyber/750 computer at Michigan State University.

In summary, by applying multivariate statistics in conjunction with repeated measures, a complete trend analysis on each outcome measure's performance profile was derived in terms of equal level, equal shape, and equal direction.

CHAPTER IV

FINDINGS

Analysis I: Motor Rhythm

Analysis I consisted of a 2 x 3 factorial design with repeated measures on one factor. The following independent variables were used: treatment (auditory rhythm and rhythmic speech versus visual modeling only), and three age groups (6, 7, and 8 year olds). The repeated measures were performed on the treatment factor. A baseline measure was taken for each subject prior to the experiment. Three treatment sessions followed using the respective treatment mode for each group. The dependent variable, deviations from the mean performance time for each movement component in hundredths of seconds, acted as a measure of even timing of gross motor performance which will be called motor rhythm accuracy (MRA). Measures on MRA were taken during each of the three sessions.

The results were analyzed using a multivariate repeated measures analysis of covariance. The baseline measure served as the covariate. The three repeated measures of MRA served as time factor measures. The criterion for statistical significance was set at $p < .05$. The research hypotheses for Analysis I were presented in Chapter I. Based on these research hypotheses the following null hypotheses for main effects were derived:

Hypothesis I: Treatment Effects

H_o: No difference will be found in motor rhythm accuracy between treatment and control groups.

Hypothesis II: Age Effects

H_o: No difference will be found in motor rhythm accuracy among subjects in different age groups.

Hypothesis III: Time Effects

H_o: No difference will be found in motor rhythm accuracy among subjects across time between baseline measures and three treatment sessions.

No separate research hypotheses about interaction effects have been proposed in this experiment since the study focused on the implementation of the main factors: treatment, age, and time. However, a consideration of interaction effects, as has been discussed earlier, has to precede the interpretation of main effects since the source of any interaction must be accounted for before main effects can be separately and independently examined. Therefore, the following null hypothesis for interaction effects was postulated:

Hypothesis IV: Interaction Effects

H_o: No difference will be found in motor rhythm accuracy due to the interaction effects of

a. treatment, age level, and time
b. treatment and age level
c. age level and time
d. treatment and time session

The results of analysis I are reported in Table 7.

Report of Results: Interaction Effects

First, consider the three-way interaction of age, treatment, and time. The p values for both the linear and the quadratic approximation to the data profile (.6387, .8451) by exceeding the .05 level of confidence, provide support for the notion that there is no significant difference in motor rhythm accuracy due to interaction effects between treatment, age, and time. In addition, the constant contrasts or contrasts of sums for the linear and quadratic trend function for age by treatment interaction do not yield significant p values (.6358, .4331). This finding gives reason to believe that, even when disregarding influence of separate time points, there is still no significant difference in motor rhythm accuracy due to an interaction of age level and treatment mode.

Next, consider the interaction of age by time. The p values for the linear and quadratic approximation to the data profile (.7874, .2012) exceed the .05 level of confidence which suggests no significant interaction effect between age and time. Different age groups did not perform differently as a function of time.

Similar results determine the interaction between treatment mode and time. The p value of .2985 exceeds the .05 level of confidence. This finding gives reason to believe that the motor rhythm accuracy of treatment and control group did not differ significantly as a function of time.

In summary, all probability values suggest that the null hypothesis for interaction effects should be accepted. Based on the results it seems reasonable to believe that, when comparing the motor rhythm accuracy of treatment and control group, no significant interaction effects could be found due to the factors of treatment mode, age level, and time.

Report of Results: Main Effect Treatment

The performance differences between treatment and control group are significant at the .05 level of confidence (.0038). This result supports very clearly a rejection of the null hypothesis I. The examination of interaction effects showed that the shapes of the performance profiles of both groups did not differ significantly as a function of time. The highly significant p value for the main effect (contrast of sums), however, indicates a very pronounced level difference between both performance profiles. By working with auditory rhythm and rhythmic speech, the treatment group performed the gross motor pattern with significantly better motor rhythm accuracy than subjects guided by visual modeling only.

Report of Results: Main Effect Age

The p values for the linear and quadratic trend approximation to the performance profile both exceed the .05 level of confidence (.5237, .7664). Therefore, the acceptance of null hypothesis II is supported. The results suggest that the age level did not influence significantly motor rhythm accuracy in all subjects, regardless of treatment mode.

Report of Results: Main Effect Time

In order to analyze the total gain in motor rhythm accuracy across time between initial assessment and all three treatment sessions the baseline measures were included as fourth time point rather than as pretest covariate in multivariate repeated measures analysis of variance. Both groups improved their combined performance profiles

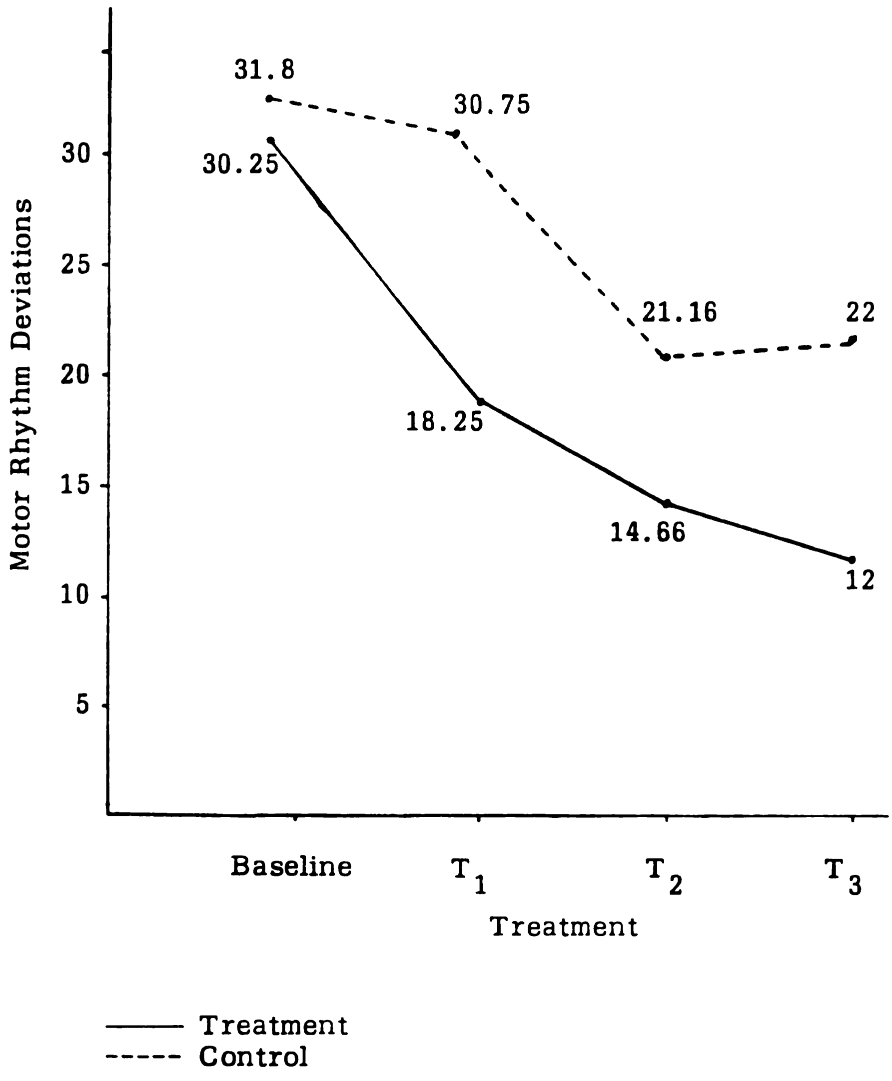


Figure 2.--Motor Rhythm Performance Profiles of Treatment and Control Group (in hundredths of seconds)

TABLE 7.--Multivariate Analysis of Covariance--Analysis I: Motor Rhythm.

Source	Degrees of Freedom	F	p
Grand Mean	1, 17	2.6617	.1212
Age			
Linear Trend	1, 17	.4329	.5237
Quadratic Trend	1, 17	.0912	.7665
Treatment Mode	1, 17	11.2579	.0038
Age by Treatment			
Linear Trend	1, 17	.2326	.6358
Quadratic Trend	1, 17	.6447	.4331
Time	2, 16	1.4586	.2619
Age by Time			
Linear Trend	2, 16	.2427	.7874
Quadratic Trend	2, 16	1.7759	.2012
Treatment Mode by Time	2, 16	1.3053	.2985
Age by Time by Treatment			
Linear Trend	2, 16	.6387	.6387
Quadratic Trend	2, 16	.1701	.8451

across time beyond the .05 confidence level ($p = .0002$). Thus the null hypothesis III must be rejected in favor of the notion that, when defining the baseline measure as first time point, all subjects improved their performance measures significantly from the initial assessment. The best fitting polynomial approximation for the combined performance profile would be expressed by a quadratic function which appears graphically as a line with one bend.

TABLE 8.--Multivariate Analysis of Variance--Effect of Time for Four Time Points.

Source	Degrees of Freedom	F	p
Time	3, 16	12.8737	.0002
Trends		Univariate F	
Linear	1, 16	18.4952	.0005
Quadratic	1, 16	7.6473	.0128
Cubic	1, 16	.8612	.3657

A second analysis was carried out to investigate the effect of time across the three treatment sessions only, disregarding the baseline measures, and thus assessing the effect of repetition on performance once the treatment had been established. The p value of .0879 exceeds the .05 confidence level. This finding gives reason to believe that neither group improved significantly at the first treatment session and, therefore, the point of substantial improvement must lie after the first treatment implementation. At this point the performance profile takes the shape of a quadratic function.

An inspection of the performance profiles, as plotted in Figure 2 reveals that the treatment group made a rather substantial gain after the first treatment implementation. This gain is obviously

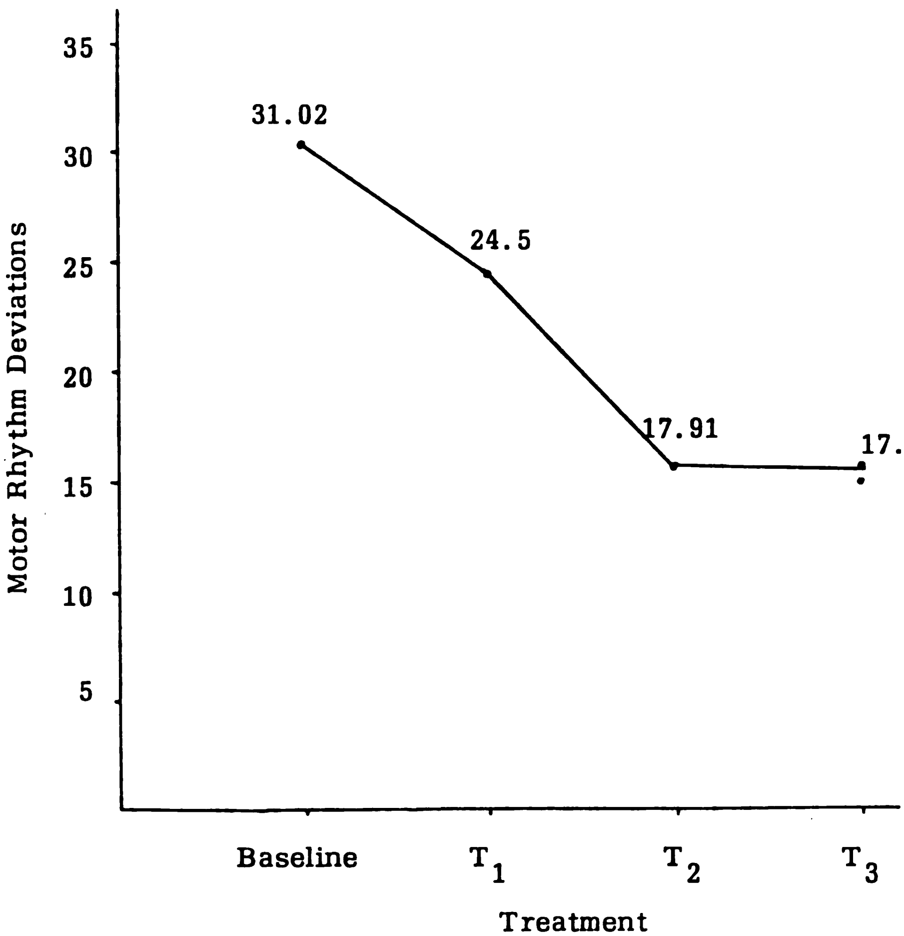


Figure 3.--Motor Rhythm Effect of Time on Treatment and Control Group Combined (in hundredths of seconds)

TABLE 9.--Multivariate Analysis of Variance--Effect of Time for Three Time Points.

Source	Degrees of Freedom	F	p
Time	2, 17	2.8164	.0879

the main contributor to the significant time effect when including the baseline as time point since the biggest gain for the control group occurs at the second treatment implementation. This gain, however, is not strong enough to yield a significant time trend when analyzing the performance profile across the three treatment sessions only. The treatment group continues to make consistent but moderate gains whereas the control group, after a delayed gain, even loses some ground after the last treatment session.

Analysis II: Motor Rhythm under Faded Conditions

The measures of motor rhythm accuracy under faded treatment conditions were compared in two separate subanalyses with (a) the control group data, and with (b) the performance measures of the same group under treatment conditions present. The statistical analysis for the first subanalysis consisted of a 2 x 3 factorial design with repeated measures on one factor in strict analogy to Analysis I. The results were analyzed through a multivariate repeated measures analysis of covariance. The research hypotheses for Analysis II were presented in Chapter I. Based on these research hypotheses the following null hypotheses for main effects were derived:

First Subanalysis

Hypothesis I: Treatment Effects

H_o: No differences will be found in motor rhythm accuracy between the treatment group under faded conditions and the control group.

Hypothesis II: Age Effects

H_o: No differences will be found in motor rhythm accuracy for all subjects due to age group levels.

Hypothesis III: Time Effects

H_o: No differences will be found in motor rhythm accuracy for all subjects across time between baseline measures and three treatment sessions.

In analogy to Analysis I, no separate research hypothesis about interaction effects have been presented. However, in order to check for possible interactions between the factors of the research design, which might influence the interpretation of main effects, the following null hypothesis for interaction effects was stated:

Hypothesis IV: Interaction Effects

H_o: No differences will be found in motor rhythm accuracy due to interaction effects of

a. treatment mode by age level by time
b. treatment mode by age level
c. age level by time
d. treatment mode by time

The second subanalysis compared the performance of the subjects under faded treatment conditions with their own performance under treatment conditions present. The research design again consisted of a 2 x 3 factorial design with repeated measures on one factor, in strict analogy to Analysis I. However, a different method was used to derive the dependent variable. Rather than using the baseline measure as pretest covariate and the motor rhythm deviations as dependent variables for each subject, the difference value in hundredths of seconds between the baseline and each treatment session's performance was used as the dependent variable for each subject. Two reasons account for that. First, the cell design cannot be completely crossed. The repeated measures factor produced only seven measurements per subject because there is only one measure at the first time point. Second, using the same covariate for each subject under two different treatment conditions was believed to result in a highly correlational relationship between the two dependent measurements on each subject which would confound actual performance differences. Thus, a multivariate analysis of variance with repeated treatment measures on three time points was used to compare the rate of decrease of difference values in motor rhythm accuracy. The following null hypothesis, based on Chapter I's research hypothesis, was postulated:

Second Subanalysis

Hypothesis V: Effect of Time on Rate of Decrease

H_o: No decrease in difference of motor rhythm accuracy will be found between the treatment group's performances under treatment conditions present and faded.

The results of Analysis II are reported in Table 10.

First Subanalysis

Report of Results: Interaction Effects

An inspection of the p values for the three-way interaction of age by treatment by time (.5670, .8586) shows that both the linear and quadratic approximations of performance profiles do not contain significant performance differences due to the effect of interactional relationships. A similar result was obtained for the two-way interaction of age by treatment. The linear trend contrast yielded a p value of .5536, and the quadratic trend contrast showed an even lower p value of .8214. This finding clearly suggests that no significant differences between treatment group under faded conditions and control group can be found due to an interaction of age by treatment.

The p values for the interaction effect of age and time indicate that no significant differences due to interaction between both factors can be accounted for. This finding holds true for the linear and the quadratic trend approximation, with pa values of .7660 and .5950, respectively.

A check for the interaction between treatment mode and time reveals a p value of .3580 which exceeds quite clearly the .05 level of confidence. This finding gives reason to believe that the effect of time produces no significant differences in motor rhythm accuracy of treatment and control group.

In summary, all p values for interactional relationships lead to a global acceptance of null hypothesis IV. No significant interactions between the factors of treatment mode, time, and age level could be found when comparing the motor rhythm accuracy of the treatment group under faded conditions and the control group.

TABLE 10.--Multivariate Analysis of Covariance--Analysis II: Motor Rhythm under Faded Conditions.

Source	Degrees of Freedom	F	p
Grand Mean	1, 17	1.9034	.1856
Age			
Linear Trend	1, 17	.2459	.6264
Quadratic Trend	1, 17	.4369	.5175
Treatment Mode	1, 17	.7222	.4073
Age by Treatment			
Linear Trend	1, 17	.3653	.5536
Quadratic Trend	1, 17	.0526	.8214
Time	2, 16	2.8740	.0859
Age by Time			
Linear Trend	2, 16	.2712	.7660
Quadratic Trend	2. 16	.5365	.5950
Treatment Mode by Time	2, 16	1.0964	.3580
Age by Time by Treatment			
Linear Trend	2, 16	.5881	.5670
Quadratic Trend	2, 16	.1540	.8586

Report of Results: Main Effect Treatment

The p value of .4073, which is higher than the set .05 level of confidence, supports the acceptance of the null hypothesis I. This finding suggests that the treatment group, once the auditory rhythm had been faded out, did not perform significantly better anymore than the control group.

Report of Results: Main Effect Age

The p values of .6264 for the linear age trend, and .5175 for the quadratic age trend, both exceed the .05 confidence level and thus provide support for accepting the null hypothesis II. It is reasonable to believe that there is no significant difference in motor rhythm accuracy between both treatment modes due to age.

Report of Results: Main Effect Time

In analogy to Analysis I, a multivariate analysis of variance was carried out to check for the effect of time, including the baseline measures as another time point. The p value of .0001 is significant beyond the set .05 level of confidence and, therefore, gives reason to believe that both groups improve their motor rhythm accuracy when combining their respective mean vectors across four time points.

TABLE 11.--Multivariate Analysis of Variance--Effect of Time for Four Time Points.

Source	Degrees of Freedom	F	p
Time	3, 16	22.0405	.0001
Trends		Univariate F	
Linear	1, 16	16.0858	.0004
Quadratic	1, 16	.0218	.8843
Cubic	1, 16	8.3152	.0099

The best fitting polynomial approximation for the combined performance profile would be expressed by a cubic function which appears graphically as a line with two bends.

To check the development of motor rhythm accuracy across the three treatment sessions by disregarding the initial baseline performance, a second multivariate analysis of variance was carried out using the three treatment sessions as time points. The p value of .0113, which is smaller than the set .05 level of confidence, provides support for the notion that the combined performance profiles of the treatment group under faded conditions and the control group still improve significantly over the period of the three treatment sessions.

TABLE 12.--Multivariate Analysis of Variance--Effect of Time for Three Time Points.

Source	Degrees of Freedom	F	p
Time	2, 17	5.9134	.0113
Trends		Univariate F	
Linear	1, 17	11.1233	.0037
Quadratic	1, 17	7.7194	.0124

The line, which optimally fits the combined mean vectors, is best expressed as a quadratic function or curve with one bend. An inspection of the performance profiles indicates indeed that both groups improve substantially between the first and second treatment session. The treatment group under faded conditions, at the third treatment session, maintains its direction of improvement although at a slightly slower rate, whereas the control group, as noted in Analysis I already, falls behind its accuracy level of treatment session two.

Second Subanalysis

Report of Results: Effect of Time on Rate of Decrease

Under effects of time for three time points, (a) the separate combination of the mean vectors of treatment group with treatment present and control group, and (b) treatment group with treatment faded and control group has yielded two different results in regard to the effect of time. Whereas the first combination did not show a significant performance difference across time, the second combination did. Knowing this, it can be logically inferred that the performance profile of the treatment group under faded conditions must have made the difference to produce significance in the latter case. However, it has been shown already that the treatment group with treatment present performed significantly better than the control group and the same group under treatment conditions faded did not perform significantly better anymore than the control group. How, then, can the performance profile under faded treatment conditions reinforce the mean vector of the control group such that a significant effect of time occurs. To answer this question it must be remembered that the significant performance difference between treatment and control group in Analysis I was not a difference as a function of time but a difference of levels. Thus, the mean vector for the faded treatment conditions, although at all probability at a similarly significant distance from the treatment with conditions present as the control group, can only produce the observed significant time effect if its improvement of motor rhythm accuracy is more a function of time than with treatment conditions present. This notion is actually formulated in null hypothesis V which, thus, would not only test the specifics of the research question hypothesized on, but would assure the validity of the previous analyses of performance profiles if rejected.

The p value of .0465 for the interaction of linear trend differences by time is smaller than the set .05 level of confidence. This interaction effect indicates a significant difference in the shape of the two performance profiles across time. More specifically, it can be said that the profile difference is a difference in direction, because the mean vectors of both groups shape a significant linear trend over time ($p < .0003$) and the contrast of sums of both groups across time shows a significant performance difference or, graphically expressed, level difference. An inspection of the resultant mean vectors of both groups shows that the difference values between the group's two measures become increasingly smaller over the three treatment sessions. Thus, the null hypothesis can be indeed rejected in favor of the notion that there is a significant decrease in difference of motor rhythm accuracy between both measures due to the interaction with the factor time. The rejection of the null hypothesis also lends validity to the previous analyses of performance profiles between

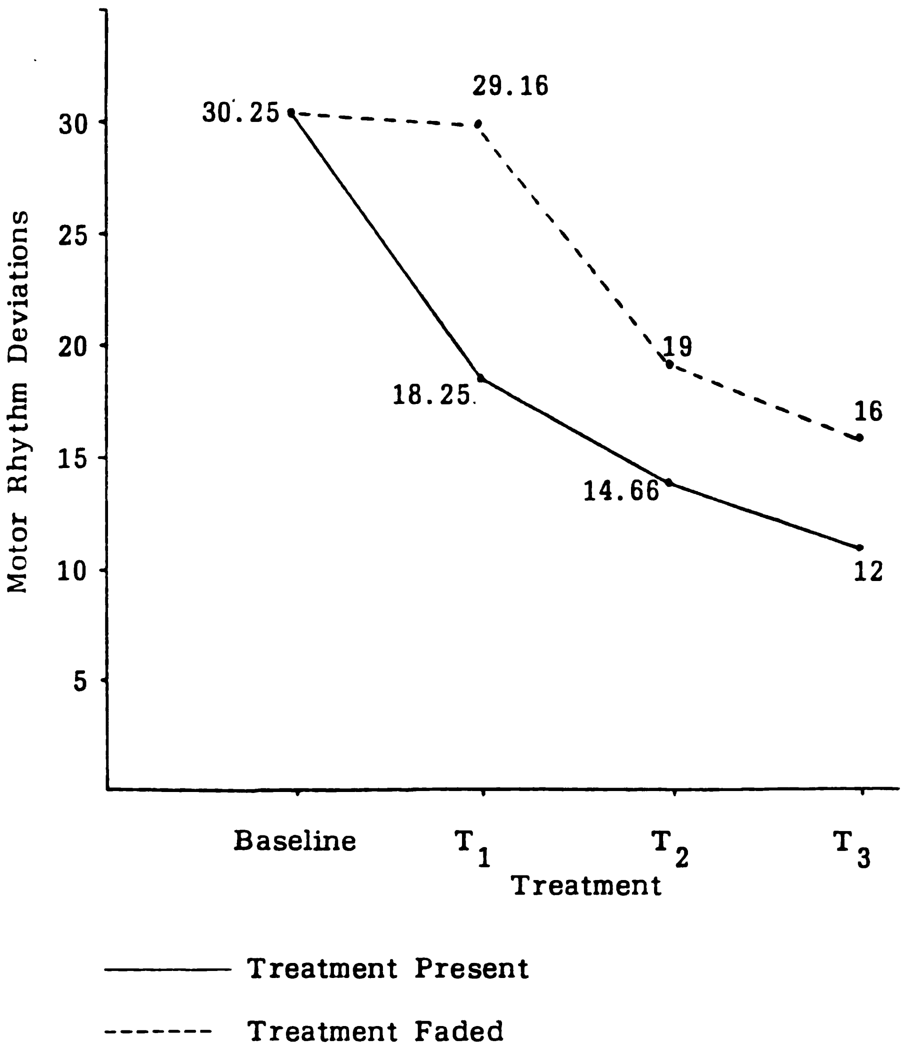


Figure 4.--Motor Rhythm Performance Profiles of Treatment Group with Treatment Present and Treatment Faded (in hundredths of seconds).

TABLE 13.--Multivariate Analysis of Variance--Treatment Present Versus Treatment Faded.

Source	Degrees of Freedom	F	p
Treatment Present (TP) vs. Treatment Faded (TF)	5, 5	16,7026	.0028
Linear Trend	5, 5	34,5451	.0003
Quadratic Trend	5, 5	1.9226	.1990
Linear Trend for TP vs. TF by Time	5, 5	5.3245	.0465
Quadratic Trend for TP vs. TF by Time	5, 5	1.2741	.2882

both measures due to the interaction with the factor time. The rejection of the null hypothesis also lends validity to the previous analyses of performance profiles between (a) treatment group with treatment present and control group, and (b) treatment group with treatment faded and control group.

In summary, there are significant performance differences between the treatment group's two conditions. The group performs significantly better with auditory rhythm and rhythmic speech both present than with rhythmic speech as the only timing cue after fading the external beat. The mean vectors for both conditions form a significant linear trend over time, but the significant interaction effect precludes to view both performance profiles as moving linear and parallel across time rather than as linear but moving toward each other. The rate of improvement of motor rhythm accuracy, as a function of time, is greater with the treatment group under faded conditions than with treatment present despite a significant level difference in favor of the treatment present condition. The rate of approach, as a function of time, is significant at the .05 level of confidence and can be interpreted as a significant decrease of difference values in hundredths of seconds between the motor rhythm accuracy of both treatment conditions across time.

Analysis III: Background Measures

All three subanalyses consisted of a multifactorial design with three age levels and three repeated measures on the treatment factor, using the treatment group only. The results regarding Hypotheses I and II were analyzed in a multivariate analysis of variance. For Hypothesis III a correlational relationship was computed using the Pearson product-moment correlation coefficient.

First Subanalysis

Synchronization

The dependent variable, deviations between the onset of the auditory beat and the completion of each movement component in hundredths of seconds, served as a measure of motor rhythm synchronization. The research hypotheses for this subanalysis were stated in Chapter I. The null hypotheses read as follows:

Hypothesis I: Time Effects

H_o: No differences will be found in synchronization measures among subjects across three time points.

Hypothesis II: Age Effects

H_o: No differences will be found in synchronization measures among all subjects on different age levels.

Hypothesis III: Synchronization and Motor Rhythm Accuracy

H_o: No relationship will be found between measures of synchronization and motor rhythm accuracy among subjects across time.

TABLE 14.-- Measures of Motor Rhythm Synchronization.

Source	Degrees of Freedom	F	p
Grand Mean	1, 9	40.8536	.0002
Age			
Linear	1, 9	2.0215	.1888
Quadratic	1, 9	.2426	.6342
Time	2, 8	3.7269	.0719
Age by Time			
Linear	2, 8	.0264	.9741
Quadratic	2, 8	.2483	.7860

All interaction effects are nonsignificant. Therefore, the main effects can be interpreted independently. The results of Analysis III are reported in Tables 14, 15, and 16.

Report of Results: Main Effect Time

The p value ($p < .0719$) is insignificant at the .05 level of confidence. Therefore, the null hypothesis should be accepted. It is reasonable to believe that measures of motor rhythm synchronization did not improve beyond the level of chance, although an inspection of the group means reveals a net gain of from 25 hsecs to 15 hsecs to 16 hsecs over three time points. The very high standard deviation of 14.9352 for the ungrouped data at time point three might explain the inconclusive results.

Report of Results: Main Effect Age

The p values for both trend approximations are insignificant at the set level of confidence ($p < .1888$ for linear, $p < .6342$ for quadratic). Therefore, the null hypothesis of no performance differences due to age should be accepted.

Report of Results: Synchronization and Motor Rhythm Accuracy

An average gain in hundredths of seconds for one time point was computed for both motor rhythms synchronization and motor rhythms accuracy by means of linear interpolation. The product moment correlation coefficient for both measures was $r = .586$ which is significant at the .05 level of confidence (initial value .516). Therefore, the null hypothesis should be rejected in favor of the notion that improvement in motor rhythm accuracy correlates significantly with improvements in motor rhythm synchronization, that is, the coincidental motor response to an external auditory beat.

<u>Second Subanalysis</u>

Time Interval Conformity (TIC)

The dependent variable, differences in length between auditory beat intervals and movement intervals in hundredths of seconds, served as a measure of time interval conformity between auditory rhythm and motor rhythm. Based on the research hypotheses stated in Chapter I, the following null hypotheses were put forth:

Hypothesis I: Time Effects

H_o: No difference will be found in TIC measures among subjects across three time points.

Hypothesis II: Age Effects

H_o: No difference will be found in TIC measures among subjects on different age levels.

Hypothesis III: TIC and Motor Rhythm Accuracy

H_o: No relationship will be found between measures of TIC and motor rhythm accuracy among subjects across time.

TABLE 15.--Measures of Time Interval Conformity.

Source	Degrees of Freedom	F	p
Grand Mean	1, 9	35.1585	.0003
Age			
Linear	1, 9	1.9756	.1935
Quadratic	1, 9	.2927	.6017
Time	2, 8	1.4299	.2945
Age by Time			
Linear	2, 8	.7410	.5068
Quadratic	2, 8	2.1138	.1833

All interaction effects are nonsignificant. Therefore, the main effects can be interpreted independently.

Report of Results: Main Effect Time

The p value of .2945 is nonsignificant at the set level of confidence. Therefore, the null hypothesis of no difference in performance across time will be accepted.

Report of Results: Main Effect Age

The p values for both trend approximations are nonsignificant at the .05 level of confidence (.1935 linear, .6017 quadratic). The null hypothesis should be accepted, negating performance differences due to age level.

Report of Results: TIC and Motor
Rhythm Accuracy

An average gain in hundredths of seconds for one time point was compued for both motor rhythms accuracy and TIC measures by means of linear interpolation. The product moment correlation coefficient for both measures was $r = .079$ which is insignificant at the set level of confidence. Therefore, the null hypothesis should be accepted. It is reasonable to believe that gains in motor rhythm accuracy are not accompanied by gains in time interval conformity.

Third Subanalysis

Tempo Maintenance (TM)

The dependent variable, differences in length between the component mean performance times of the treatment group under treatment present and treatment present conditions, served as a measure of the ability to maintain the same performance tempo across two treatment conditions. Based on the research hypothesis stated in Chapter I, the following null hypotheses were stated.

Hypothesis I: Time Effects

H_o: No differences will be found in TM measures for all subjects across time.

Hypothesis II: Age Effects

H_o: No differences will be found in TM measures for all subjects due to age levels.

Hypothesis III: TM and Motor Rhythm Accuracy

H_o: No relationship will be found between measures of TM and motor rhythm accuracy for all subjects across time.

TABLE 16.--Measures of Tempo Maintenance.

Source	Degrees of Freedom	F	p
Grand Mean	1, 9	39.0143	.0002
Age			
Linear	1, 9	1.6865	.2264
Quadratic	1, 9	4.0604	.0748
Time	2, 8	6.9164	.0181
Trends		Univariate F	
Linear	1, 8	5.8151	.0392
Quadratic	1, 8	.2925	.6018
Age by Time			
Linear	2, 8	1.8272	.2221
Quadratic	2, 8	1.3677	.3084

All interaction effects are nonsignificant. Therefore, the main effects can be interpreted independently.

Report of Results: Main Effect Time

The p value of .0181 is significant at the set level of confidence. Thus, the null hypothesis should be rejected in favor of the notion that tempo maintenance improved significantly over the three treatment sessions in a linear fashion. The average difference between the performance tempos of the two treatment conditions decreased from 17 hsec to 9.3 hsec to 5.6 hsec. The results indicate that the subjects learned over time to maintain the performance tempo they had established when listening to the auditory beat.

Report of Results: Main Effect Age

Both timed approximations resulted in insignificant p values at the set level of confidence (.2264 linear, .0748 quadratic). The null hypothesis of no difference due to age level will be accepted.

Report of Results: TM and
Motor Rhythm Accuracy

An average gain in hundredths of seconds for one time point was computed for both motor rhythm accuracy and TM measures by means of linear interpolation. The product moment correlation coefficient for both measures was $r = .346$ which is nonsignificant at the .05 level of confidence. The null hypothesis will be accepted. Therefore, it is reasonable to believe that improved maintenance of performance tempo did not correlate significantly with gains in motor rhythm accuracy.

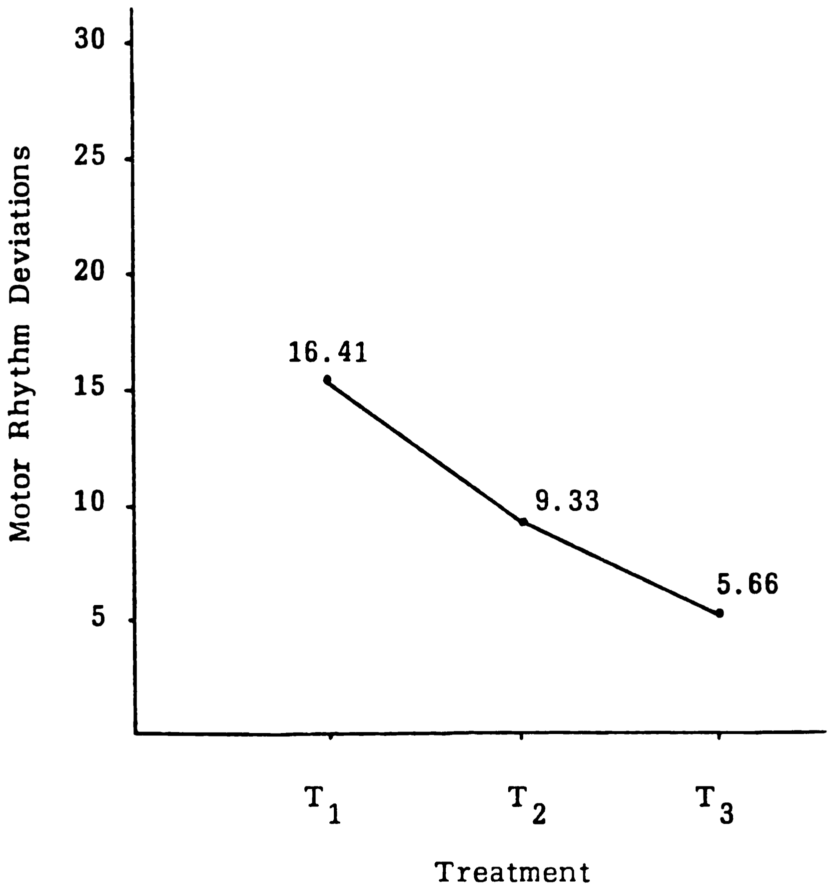


Figure 5.--Effect of Time on Tempo Maintenance (in hundredths of seconds).

Analysis IV: Quantitative Muscular Control

Analysis IV consisted of a 2 x 3 factorial design with repeated measures on the treatment factors. The independent variables (two treatment modes and three age group levels) and the number of measurements (baseline plus three treatment sessions) were the same as for the analysis of motor rhythm accuracy.

The dependent variable, number of extraneous motions in one complete movement sequence, served as measure of quantitative muscular control (QMC). The results were analyzed through a multivariate repeated measures analysis of covariance. The baseline measure served as covariate. The three repeated measures of QMC served as time factor. The criterion for statistical significance was set at $p < .05$. The research hypotheses for Analysis IV were presented in Chapter I. Based on these research hypotheses the following null hypotheses for main effects were derived:

Hypothesis I: Treatment Effects

H_o: No differences will be found in QMC between treatment and control group.

Hypothesis II: Age Effects

H_o: No differences will be found in QMC among subjects due on different age levels.

Hypothesis III: Time Effects

H_o: No differences will be found in QMC among subjects across time between baseline measures and three treatment sessions.

The null hypothesis for interaction effects read as follows:

Hypothesis IV: Interaction Effects

H_o: No difference will be found in QMC due to interaction effects of

a. treatment, age level and time
b. treatment and age level
c. age level and time
d. treatment and time

The results of Analysis IV are reported in Table 17.

Report of Results: Interaction Effects

An inspection of all possible interactional relationships yields insignificant probability values in all cases beyond the .05 level of confidence. The interaction of treatment mode by age level by time point shows a p value of .7578 for the linear and .3625 for the quadratic trend approximation. The interaction of treatment mode by age level, disregarding time, resulted in p values of .1902 for the linear and .8463 for the quadratic trend approximation. The factor age did not interact with the factor time in a significant manner. The p values were .1044 for the linear and .2923 for the quadratic trend approximation. The factor treatment was not considered a function of time either. The p value for the interaction effect was .6863 which is not significant at the set level of confidence. In summary, all probability values suggest that the null hypothesis for interaction effects should be accepted. It is reasonable to believe that, when comparing quantitative muscular control of treatment and control group, no significant interaction effects could be found due to the factors of treatment mode, age level, and time.

TABLE 17.--Multivariate Analysis of Covariance--Analysis IV: Quantitative Muscular Control.

Source	Degrees of Freedom	F	p
Grand Mean Behavior	1, 17	1.9212	.1837
Age			
Linear Trend	1, 17	10.0808	.0056
Quadratic Trend	1, 17	3.5968	.0751
Treatment Mode	1, 17	.9645	.3399
Age by Treatment			
Linear Trend	1, 17	1.8623	.1902
Quadratic Trend	1, 17	.0388	.8463
Time	2, 16	2.6122	.1043
Age by Time			
Linear Trend	2, 16	2.6120	.1044
Quadratic Trend	2, 16	1.3297	.2923
Treatment by Time	2, 16	.3855	.6863
Age by Time by Treatment			
Linear Trend	2, 16	.2823	.7578
Quadratic Trend	2, 16	1.0820	.3625

Report of Results: Main Effect Treatment

The p value of .3399 is insignificant at the .05 level of confidence. Thus, the null hypothesis of no difference should be accepted. The data suggest that treatment group and control group did not differ in the amount of extraneous movement during their respective motor performance, regardless of the presence of auditory rhythm and rhythmic speech as performance aids.

Report of Results: Main Effect Age

The p value of .0056 for the linear trend is significant beyond the .05 level of confidence. The p value for the quadratic trend approximation yields .0751 which exceeds the set level of confidence. Thus, it is reasonable to reject the null hypothesis in favor of the research hypothesis which postulates a performance difference based on age. The combined performance profile of treatment and control group takes on a linear shape which means the performance measures for the three age groups lie on a straight line. An inspection of the data as plotted in Figure 6 shows a linear decrease of extraneous movements with increasing age, using the age levels of 6, 7, and 8 years.

Report of Results: Main Effect Time

A multivariate repeated measures analysis of variance, including the baseline as first time point, was carried out to determine gains in quantitative muscular control across time from the baseline to the last of three treatment sessions. The highly significant p value of .0001 suggests that both groups improved their combined performance profile across time beyond the .05 level of confidence. It is suggested therefore, to reject the null hypothesis III in favor of the notion that both groups made significant gains over time after their baseline performances. The best trend approximation for the performance profile is given by a quadratic function.

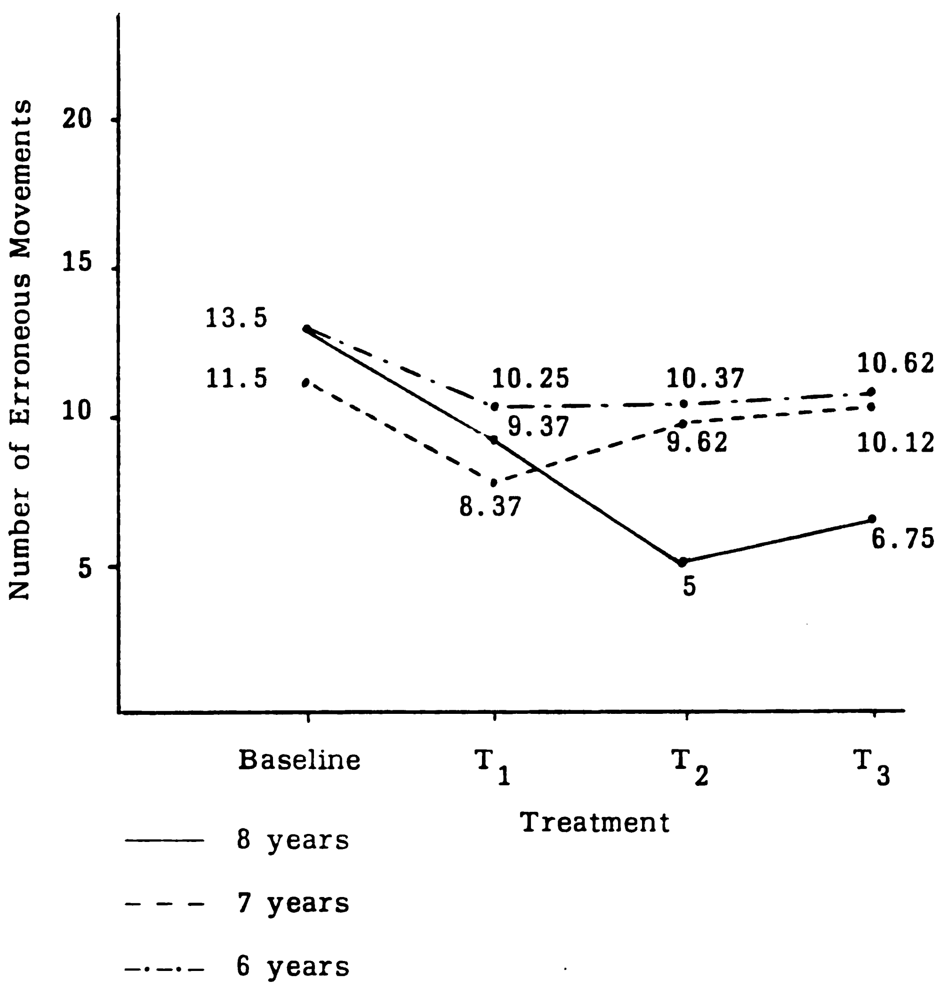


Figure 6.--Quantitative Muscular Control. Effect of Age on Treatment and Control Group Combined (in number of errors).

TABLE 18.--Multivariate Analysis of Variance--Effect of Time for Four Time Points.

Source	Degrees of Freedom	F	p
Time	3, 16	19.8567	.0001
Trends		Univariate F	
Linear	1, 16	19.6238	.0004
Quadratic	1, 16	11.5841	.0032
Cubic	1, 16	.0702	.7941

In a second analysis only the three treatment sessions were considered as time points. The p value of .6594 3xceeds the set confidence level and, therefore, lends strong support to accept no significant differences between the performance measures at the three respective time points. The results of both analyses lead to the conclusion that substantial gains in quantitative muscular control occurred only between the baseline and the first treatment session. An inspection of the plotted performance profile in Figure 7 shows an increase in extraneous movements at the third session offsetting the gains at the second session. This trend might be due to sampling error in a small size sample, as well as to the performance inconsistency of the experimental population, as discussed in Chapter II.

TABLE 19.-- Multivariate Analysis of Variance--Effect of Time for Three Time Points.

Source	Degrees of Freedom	F	p
Time	2, 17	.4268	.6594

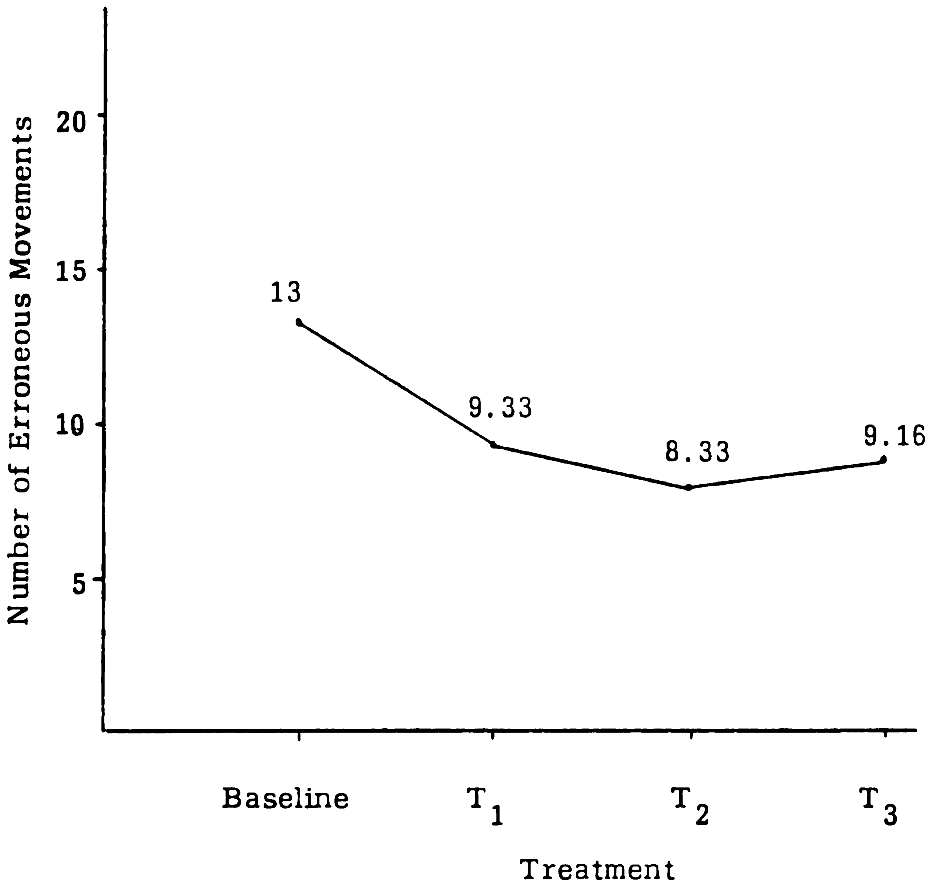


Figure 7.--Quantitative Muscular Control. Effect of Time on Treatment and Control Group Combined (in number of errors).

Analysis V: Quantitative Muscular Control Under Faded Conditions

The measures of the treatment group for quantitative muscular control under faded treatment conditions were compared in two separate subanalyses with (a) the control group data, and (b) their own performance measures under treatment conditions present. The statistical analysis for the first subanalysis consisted of the same 2 x 3 factorial design as in Analysis IV with repeated measures on the treatment factor. The results were analyzed through a multivariate repeated measures analysis of covariance. The research hypothese for Analysis II were presented in Chapter I. Based on these research hypotheses the following null hypotheses for main effects were stated:

First Subanalysis

Hypothesis I: Treatment Effects

H_o: No differences will be found in QMC between treatment group under faded conditions and control group.

Hypothesis II: Age Effects

H_o: No differences will be found in QMC among subjects in different age levels.

Hypothesis III: Time Effects

H_o: No differences will be found in QMC among subjects across time between baseline measures and three treatment sessions.

The following null hypothesis for interaction effects between the factors of the statistical design was stated:

Hypothesis IV: Interaction Effects

H_o: No differences will be found in QMC due to interaction effects of:

a. treatment, age level, and time
b. treatment and age level
c. age level and time
d. treatment and time

The second subanalysis compared the performance of the subjects under faded treatment conditions with their own performance under treatment conditions present. The research design was a 2 x 3 factorial design with repeated measures on the treatment factor. The difference value in number of extraneous movements between baseline and each treatment session's performance was used as dependent variable for each subject. Thus, the baseline measure was eliminated as a separate time point in the research design, leaving three measurements over time per subject in each of the two treatment conditions. By the same procedure, the baseline measure was eliminated as covariate because using the same covariate for each subject under two different treatment conditions was believed to mask actual performance differences between the two dependent measurements. A multivariate analysis of variance with repeated treatment measures over three time points was used to analyze the rate of decrease of difference values in quantitative muscular control. The following null hypothesis, based on Chapter I's research hypothesis, was stated:

Second Subanalysis

Hypothesis V: Effect of Time on Rate of Decrease

H_o: No decrease in difference of QMC will be found between the treatment group's performances under treatment conditions present and faded.

The results of Analysis V are reported in Table 20.

First Subanalysis

Report of Results: Interaction Effects

Only one of the four possible interaction effects yielded a significant p value at the .05 level of confidence. The three-way interaction between age, treatment, and time resulted in p values of .2410 for the linear trend and .5336 for the quadratic trend which are both insiginficant. The two-way interaction of age by treatment showed p values of .9995 for the linear trend and .6779 for the quadratic trend, both of which exceed the set level of confidence. Treatment did not interact with the factor time in a significant manner either. The p value of .9632 is highly insignificant. Age, however, interacted significantly with time using the linear trend approximation ($p < .0213$ for linear, but $p < .1301$ for quadratic). This result indicates that the performance profiles of the three age groups approximate linear trends over time which, however, have significant slope differences and, thus, point in quite different directions in a two-dimensional time by performance accuracy design. The plotted shapes of the performance profiles show that the 8 year old group improves their quantitative muscular control measures linearly over time, whereas for the 6 year olds, the performance measures stagnate and the 7 year olds show a slight increase of error across time. In summary, the null hypothesis for interaction effects has to be rejected.

TABLE 20.--Multivariate Analysis of Covariance--Analysis V: Quantitative Muscular Control Under Faded Treatment Conditions.

Source	Degrees of Freedom	F	p
Grand Mean	1, 17	1.8008	.1973
Age			
Linear Trend	1, 17	3.5371	.0773
Quadratic Trend	1, 17	2.0139	.1740
Treatment Mode	1, 17	.1252	.7279
Age by Treatment			
Linear Trend	1, 17	.0000	.9995
Quadratic Trend	1, 17	.1787	.6779
Time	2, 16	8.5660	.0030
Age by Time			
Linear Trend	2, 16	4.9464	.0213
Quadratic Trend	2, 16	2.3237	.1301
Treatment Mode by Time	2, 16	.0376	.0632
Age by Time by Treatment			
Linear Trend	2, 16	1.5578	.2410
Quadratic Trend	2, 16	.6536	.5336

in regard to a significant interaction of age and time. It is, therefore, reasonable to believe that, under faded treatment conditions, the ability to control extraneous movements differ over time between the tested age levels. The 8 year old children seem to benefit from repeated treatment sessions whereas the 6 and 7 year old children do not show a consistent improvement as a function of time.

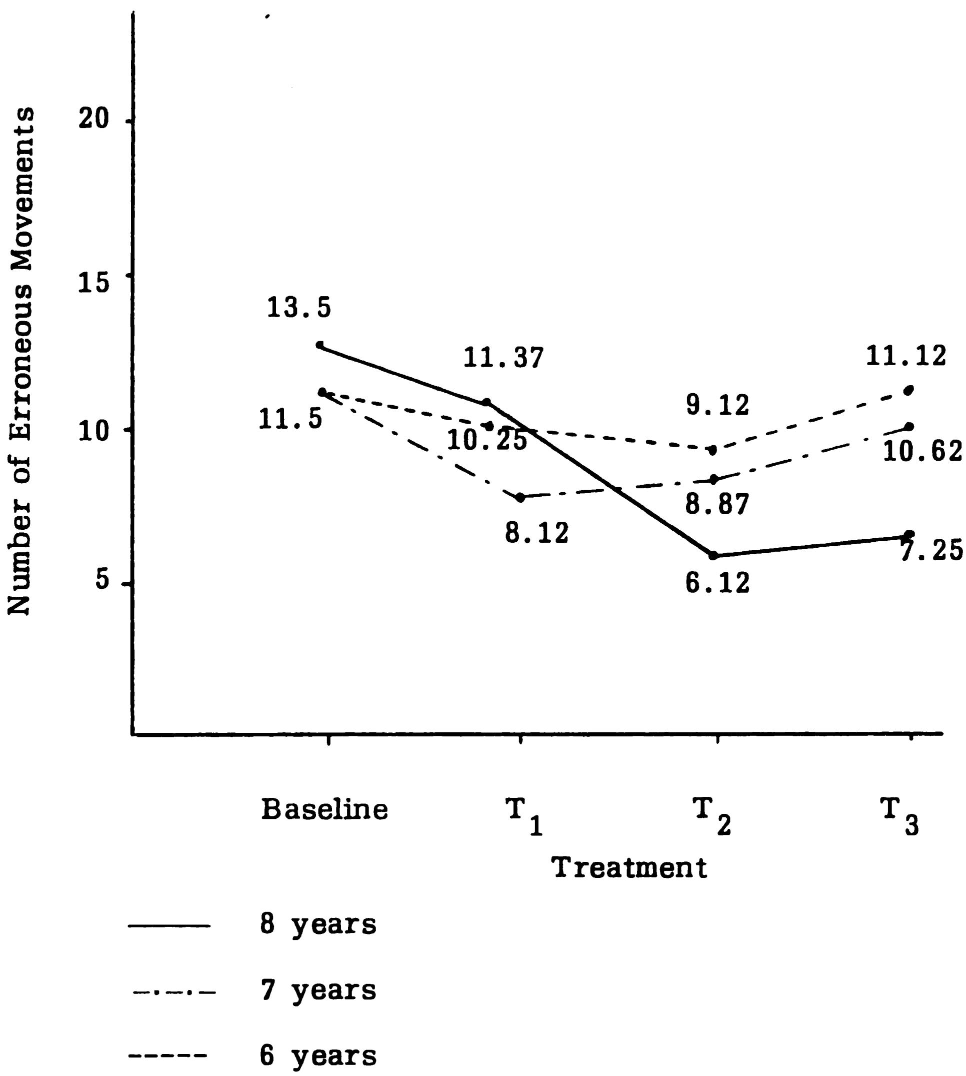


Figure 8.--Quantitative Muscular Control. Effect of Age and Time on Treatment Under Faded Conditions and Control Group (in number of errors).

Report of Results: Main Effect Treatment

The p value of .7279 for treatment effects is not significant at the set confidence level. Therefore, the null hypothesis should be accepted. It should be concluded that the treatment group under faded conditions does not perform better than the control group.

Report of Results: Main Effect Age and Main Effect Time

Due to the interaction of age and time a separate analysis of the main effects age and time is not meaningful. The respective null hypotheses II and III, therefore, are not interpretable.

Second Subanalysis

Report of Results: Effect of Time Points on Rate of Decrease

The results show that there are no significant performance differences between the treatment group's time conditions ($p < .4607$). No significant trend approximations across time are formed by the two performance profiles. Most importantly, however, is the finding that the number of treatment sessions does not affect the performance quality of either group. Therefore, the null hypothesis should be accepted postulating that the difference in number of extraneous movements between treatment faded and treatment present does not decrease over time.

TABLE 21.--Multivariate Analysis of Variance: Treatment Present versus Treatment Faded.

Source	Degrees of Freedom	F	p
Treatment Present (TP) vs. Treatment Faded (TF)	5, 5	.5941	.4607
Linear Trend	5, 5		.6374
Quadratic Trend	5, 5	1.2321	.2958
Linear Trend for TO vs. TF by Time Points	5, 5	.0000	.9999
Quadratic Trend for TP vs. TF by Time Points	5, 5	2.3667	.1584

CHAPTER V

CONCLUSIONS

Analysis I: Motor Rhythm

Analysis I examined the effect of auditory rhythm and rhythmic speech on the temporal control of a gross motor sequence in children with gross motor dysfunction. The gross motor sequence consisted of four repetitions of a movement pattern which itself was made up of four different components (two sidesteps and two arm motions). Deviations in hundredths of seconds from a computed average performance time for one component served as indicators of motor rhythm accuracy, that is, an even timing of each component within the whole movement sequence. The results show that the subject, who rehearsed and performed the movement with auditory rhythm and rhythmic speech, achieved consistently smaller deviation values than the subjects who relied on visual modeling and cueing only. Of special importance in this respect is that all subjects had very similar baseline measures which virtually eliminates the influence of pre-experiment performance differences. This finding is significant at the .05 level of confidence.

The model of rhythmic auditory-motor integration which has been discussed in Chapter II, thus has been substantiated by the findings of this study. The proprioceptive control of the temporal organization of complex gross motor acts seemed to be considerably aided by the use of an external auditory beat with concomitant rhythmic speech. Both treatment factors facilitated the accuracy of the motor response. However, it was also felt that the rhythmic chant, which made the children talk through their motions, added security in performing the motor task. Less attention needed to be given to the correct sequence of motions once the chant was learned.

In discussing the results of this study it needs to be emphasized, however, that the children were taught to respond to the auditory rhythm and to use the chant as part of a repeated rhythmic rehearsal strategy. The children were not shown the task visually and then immediately asked to synchronize their movement with a beat. The children had to listen to the beat first, then perform a coincident stationary gross muscle movement (handclaps), and finally synchronize their chant pattern with the beat. After these preliminary learning steps the child was asked to move in correct timing with the beat. The specificity of the rehearsal mode and the rhythmic aids in regard to the learning task makes the treatment of this study different from many of the previously discussed experiments. Therefore, the specific task-oriented implementation of rhythmic aids has to be emphasized when presenting the results of this study.

The biggest gain for the treatment group occurred after the first treatment implementation. After that, the gains continued in proportionally smaller fashion. These results may be interpreted in favor of the treatment procedure which resulted in immediate

TABLE 22.--Motor Rhythm Development of Mean Deviations (in hundredths of seconds)

	Treatment	Control
Baseline	30.25	31.80
T_1	18.25	30.75
T_2	14.66	21.16
T_3	12.00	22.00

improvements, unlike the control group, where gains seem to be more a function of time and repetition. The overall significant improvement of all participating subjects seems to support the appropriateness of the movement item and the unbiased effectiveness of the experimenter to teach the performance task. It also lends support, to a certain degree, to the efficiency of visual modeling and repetition when teaching movement. However, there is substantial evidence to assume that the addition of auditory rhythmic materials resulted in a consistenty better temporal organization of the gross motor task used at a faster pace.

The influence of age levels on temporal muscular control remained inconclusive in this part of the study. The age groups, regardless of treatment mode, performed on very similar levels. This finding might be attributed to the small cell size and large within-group variability of performance scores. However, all treatment group cells performed with lower motor rhythm deviations than the control group at all times.

The mean differences between treatment and control group across time (three sessions) were larger for the seven (32.75 hsec) and eight (36 hsec) year olds than the six year olds (19.25). This could be discussed as a tendency for the older age levels to be more receptive to the rhythmic treatment. These data, however, could not be clarified beyond the mere chance level in this study.

In summary, auditory rhythm and rhythmic speech, as constituents of a motor rhythmic training program, proved to be successful in aiding the aspect of temporal muscular control in a complex gross motor sequence. Thus, the initial research hypothesis regarding the effectiveness of auditory rhythmic tools to facilitate motor rhythm accuracy is confirmed by the presented data. A model of rhythmic auditory-motor integration processes, as presented in Chapter II, is suggested to guide further investigations of the observed relationship between gross motor performance and auditory stimuli.

Analysis II: Motor Rhythm Under Faded Treatment Conditions

Analysis II examined the effect of rhythmic speech on the ability to maintain an even gross motor timing after the auditory rhythm had been faded out. The results show that the treatment group could not maintain its temporal accuracy with rhythmic speech only. The motor rhythm deviations dropped back to levels of accuracy which were not significantly different from those of the control group.

These findings support the importance of auditory rhythm to develop and maintain an even gross motor timing within the

TABLE 23.--Motor Rhythm Under Faded Conditions--Development of Mean Deviations (in hundredths of seconds).

	Treatment Faded	Treatment Present	Control
Baseline	30.25		31.80
T_1	29.16	18.25	30.75
T_2	18.91	14.66	21.16
T_3	16.25	12.00	22.00

implemented training program. Maintenance of temporal control could not be achieved during the three treatment sessions with four measured performance cycles under treatment present (TP) conditions preceding the treatment faded (TF) condition. However, a significant decrease of motor rhythmic deviations between both treatment conditions as a function of time strongly suggests that, with a larger number of sessions, the level differences between both performance profiles would continue to diminish. More evidence in this direction, however, not clarified beyond the level of chance, is that the TF data continuously improved whereas the control group data stagnated from the second to third treatment sessions. Also, on all age group levels at all time points the TF group had better mean deviations than the control group. However, the differences were too small to fulfill criteria of significance. In summary, the subjects in the treatment group were not able to maintain their gains in temporal muscular control with the help of rhythmic speech only, after the auditory rhythm had been faded out. A significant decrease of performance differences between TP and TF conditions as a function of time indicates a significant approximation of performance profiles over time. Therefore, it is suggested that a motor rhythmic training program with an extended number of sessions would help the maintenance of motor rhythm accuracy.

Analysis III: Background Measures

Analysis III examined the effect of auditory rhythms and rhythmic speech on motor rhythm synchronization (S), time interval conformity (TIC), and maintenance of performance tempo (TM). It also investigated the relationship of all three measures with gains in motor rhythm accuracy.

TABLE 24.--Synchronization Time Interval Conformity Tempo Maintenance--Development of Mean Deviations (in hundredths of seconds).

	Motor Rhythm Synchronization	Time Interval Conformity	Maintenance of Performance Tempo
T_1	26.25	5.1	16.41
T_2	26.08	2.58	9.33
T_3	17.16	2.58	5.66

Although all three measures showed gains, only the improvement in TM proved to be significant. The subjects under faded treatment conditions learned to maintain the same average performance tempo they had established when exposed to the auditory beat. However, the gains over time did not correlate significantly with the maintenance of motor rhythm accuracy. Therefore, it can be concluded that the ability to maintain an externally imposed motor performance tempo has no relationship with the ability to maintain accuracy in gross motor timing. In other words, learning to maintain an external time structure had no carry-over effect on temporal muscular control once the external structure was removed. It is therefore suggested that the movement tempo which produces optimal results in timing, should be more depending on intra-subject abilities than on externally superimposed time structures. Measures on TIC did not show any substantial gain. They also did not correlate significantly with measures of motor rhythm accuracy. Recalling the discussion in Chapter I, measures of TIC were thought of as being indicative of functional compensation of deficient motor control. TIC measures show the conformity relationship between signal speed and performance tempo, regardless of coincident motor response. Gains in TIC would indicate that the child improved his/her perception of a nonspecific time structure and used this to regulate his/her movement timing. However, an inspection of the data shows that TIC measures yielded a rather constant, stagnating tendency without displaying a substantial relationship to the simultaneous improvement of motor rhythm timing.

Synchronization measures improved after the second treatment implementation by 10 hsecs. The gains were not quite sustained throughout the third session. The statistical analysis shows a p-value of .0719 which is nonsignificant at the set level of confidence. The synchronization measures correlated significantly with gains in motor rhythm accuracy, which means that low deviations in synchrono-zation measures accompanied low deviations in motor rhythm timing. Synchronization, measuring the actual coincident motor response as conscious and deliberate perceptual motor match with an external stimulus, was thought of as being indicative of neuromuscular control of movement responses. The significant correlation between synchronization and motor rhythm accuracy may, therefore, be interpreted as suggesting that the child's deliberate attempts to match his movements with the beat stand in a substantial relationship to improvement in motor rhythm. The results support the notion that gains in positional timing (coincident motor responses) are related to gains in serial timing (evenness of the movement rhythm). These findings have considerable impact on the use of auditory rhythmic means in therapy and educational practice. Auditory rhythmic stimuli need to be specifically designed to match the timing sequence of the particular gross motor task.

Based on the results of this study, it may be suggested that timing/rhythmic stimuli, not specifically related to a movement task, will not improve motor rhythm accuracy. The only substantial relationship in this study has been found between measures of synchronization and motor rhythm. Therefore, coincident motor responses should be taught, using rhythmically organized acoustic stimuli which match the temporal structure of the motor task when working on temporal muscular control.

Again, no age trends could be detected in this part of the study. The seven (27.6 hsecs) and eight (15.5 hsecs) year olds scored better on the synchronization mean deviations across time than the six year olds (20.3 hsecs). However, the differences were statistically insignificant due to large within-group variability. TIC and TM measures did not show any consistent age trends, regardless of significance testing techniques.

Analysis IV: Quantitative Muscular Control

Analysis IV examined the effect of auditory rhythm and rhythmic speech on quantitative muscular control (QMC), that is, the inhibition of extraneous or erroneous movements during a gross motor sequence. The results show that measures of QMC were virtually unchanged during the course of the experiment. No treatment effect could be detected. The very consistent recurring number of faulty or extraneous movements lends strong support to the reliability of the measurement as well as to the notion that auditory rhythmic stimuli did not contribute substantially to the mechanisms of muscular inhibition.

A frequency check of the type of movement errors showed that 95 percent of all errors were extraneous motions rather than errors in the movement sequence. Of these extraneous motions, 80 percent were committed by the feet. A typical pattern was to move the respective support foot after the other foot had completed its motion to readjust the stance and secure balance. Another frequent example of extraneous motions was moving the feet slightly back and

TABLE 25.--Quantitative Muscular Control--Mean Development in Number of Errors.

	Treatment	Control
Baseline	13.00	12.66
T_1	9.00	9.66
T_2	8.50	8.16
T_3	8.50	9.83

forth or sideways during the arm/hand patterns. The overhead clap seemed to cause static balance problems in some children. Also, some children overextended the upward force direction during the overhead clap which resulted in lifting the heels from the floor for a brief moment. Since the foot sensors were attached to the shoe at the middle of the sole this motion was recorded as foot movement on the graphic display. During the downward arm motion to slap the thighs many children anticipated prematurely the next sidestep by starting to shuffle their feet. All these observations have been discussed in Chapter II of this study as very typical features of the motor performance of children with gross motor dysfunction. Inability to control force, inappropriate motor planning, redundant motions or loss of balance have all been very pronounced in this experimental population. The implemented treatment has shown to improve the timing of a motor sequence but quite frequently short redundant or extraneous motions occurred between the completion of the correct movement components. Measures of QMC, although virtually uninfluenced by the implemented treatment, exhibited a significant linear age trend. The eight year olds performed better (7.04 than the seven year olds (9.31) and six year old children (10.4). Thus, in the test sample of this study the ability of quantitative muscular control followed a developmental pattern. With increasing age the children were more able to inhibit extraneous or erroneous motions during their gross motor performance.

Analysis V: Qualitative Muscular Control Under Faded Treatment Conditions

The measures in this analysis remained unchanged despite the implementation of rhythmic aids and repetition of the treatment over three treatment sessions. Measures of QMC under faded treatment conditions showed the same error rate as under treatment conditions present or without treatment at all. Thus, the results of Analysis V really reinforce the notion that the ability to inhibit faulty or redundant movements could not be improved through the implementation of temporally oriented stimuli. The only significant improvement occurred when comparing the number of errors during the baseline measures and during the treatment sessions. All subjects improved their performance, when compared to the baseline, but not any more during the three treatment sessions.

Age did influence the performance results significantly as an interaction with the time factor. The eight year old children benefited from repeated treatment sessions significantly unlike the six and seven year olds who did not show consistent improvement over the course of the three treatment sessions. The biggest gain in measures of QMC for the eight year olds appeared after the second treatment implemetation. Thus the trend of significant performance differences in QMC, based on age levels, has been replicated also under faded treatment conditions. However, the trend seems to develop more gradually as a function of time under faded treatment conditions compared to treatment conditions present where a pronounced performance difference is already present at the second session.

Summary

In summary, the following statements express the major findings in this study:

1. Subjects in the treatment group who learned a gross motor task by using auditory rhythm and rhythmic speech as timing cues performed with significantly better motor rhythm accuracy than control group subjects who had no rhythmic aids for their proprioceptive motor control.

2. After the auditory rhythm was faded the treatment group, aided by rhythmic speech only, no longer performed significantly better than the control group. However, the performance differences between both treatment conditions decreased significantly as a function of time. This finding points to the need for prolonged treatment to maintain the level of improvement after external timing aids are removed.

3. Measures of synchronization, that is the coincident motor response to an external stimulus, were the only background measures that correlated significantly with improvement in motor rhythm accuracy. It is, therefore, concluded that (a) efficient auditory rhythmic timing cues need to match the temporal structure of the motor task, and (b) the coincident motor response to the respective timing signal, as deliberate perceptual-motor match, should be specifically taught.

4. Auditory rhythm and rhythmic speech had no influence on the ability to inhibit extraneous or erroneous movements (measures of quantiative muscular control). Quantitative muscular control was dependent on age levels. Significant developmental trends were observed, displaying a continuous decrease in amount of faulty movements with increasing age. Under faded treatment conditions these trends developed significantly as a function of time (repeated treatment sessions).

Recommendations

Future Research

It is hoped that this study has produced basic data and preliminary insights into the efficient use of auditory rhythmic materials facilitate temporal muscular control in gross motor tasks within a remedial context. The following direction for future research in this area are suggested. as follows:

1. Use of larger sample size;
2. Extension of age levels below six and above eight years of age;
3. Inclusion of both sexes;

4. Increase number of treatment sessions;

5. Follow up studies to check maintenance of treatment success;

6. Research with populations with different handicaps, e.g., spastic, athetoid, ataxic conditions, muscular dystrophy, amputations, or visual impairments;

7. Use of less synthetic motor tasks, e.g., fundamental motor patterns such as walking, skipping, punting, or complex athletic skills such as discus throwing, hurdle running, gymnastic routines;

8. Use of more functional motor tasks for severely involved populations, e.g., reading, grasping, sequencing when manipulating items of daily living activities;

9. Differentiation of the impact auditory rhythm and rhythmic speech made on the improvement of motor rhythm accuracy.

Measurement Techniques

The measurement techniques used have been proven to be quite satisfactory. The system, as made available through the Center for the Study of Human Performance at Michigan State University, produced reliable, precise data and allowed for a maximum of natural movement range when measuring quantitative and temporal aspects of force motor performance. It is strongly recommended to use a telemetric measurement system with subcarrier approach in research investigating the timing of more complex movements which include change of spatial directions, full body rotations, and wide ranges of motions.

Although the rather tedious translation by hand of analogue data into numbers showed acceptable reliability coefficients in this study, a digital approach is recommended for future research. This would also allow for immediate feedback in a practice or training situation.

Clinical Applications

It is recommended to use auditory rhythm and rhythmic speech, on the conceptual background of a model of rhythmic auditory-motor integration, in remedial settings to improve the timing aspect of movement skills. Care should be taken that all elements of the treatment approach in this study are considered in clinical use:

1. Use of auditory rhythm and a concurrent rhythmic chant which makes the child talk through the motions.

2. Rehearsal strategies that emphasize coincident motor response to a specific timing signal, one at a time.

3. Clarification of motor pattern through chanting.

4. Synchronization of speech and stationary gross muscle response before proceeding to locomotion.

5. Use of an auditory rhythmic stimulus that matches the temporal structure of the motor task and has no other musical elements (melodic, harmonic, orchestration, etc.) that obscure the perception of the rhythmic structure of the stimulus.

6. Use of high and low indefinite pitches to match the respective space levels of the movement sequence, and use of pitch and accentuation to mark rhythmic groupings of auditory signals as related to a recurring sequence of motions.

APPENDICES

APPENDIX A

PARENTAL CONSENT FORMS

MICHIGAN STATE UNIVERSITY

DEPARTMENT OF MUSIC

EAST LANSING · MICHIGAN · 48824

Parental Consent Form

Dear Parent:

I am writing to ask your permission for your child to participate in my rhythm and movement testing project. This is a research study within my dissertation for the doctoral degree in music education/music therapy. The study is supervised by the Music Department and the Department of Health and Physical Education at Michigan State University. The objective of my study is whether rhythmic/musical materials can influence and facilitate movement performance in children seven to twelve years old.

To accomplish this your child will be asked to perform a short, dance-like movement along to different rhythms. Learning and performing the movement will take not longer than 20 minutes. In order to observe the effectiveness of this teaching method your child will be asked to come to four weekly sessions, each 20 minutes long. The sessions will be scheduled each a week apart from each other. The study will take place in the Center for the Study of Human Performance at Michigan State University, between November 17 and December 15. Maps and schedules will be provided.

This study has been already explained to your school principal and to your child's classroom teacher and has been approved by both. Your support would be greatly appreciated and most helpful for a deeper understanding of using rhythm and music to teach movement skills efficiently. Therefore I would be very thankful if you also could approve, and indicate this by signing and returning the consent form below.

Sincerely,

Michael Thaut
Doctoral Candidate
Music Education/Music Therapy

Dr. Dale Bartlett
Department of Music

Dr. Crystal Fountain Branta
Department of Health and
Physical Education

Rhythm and Movement Testing Project Consent Form

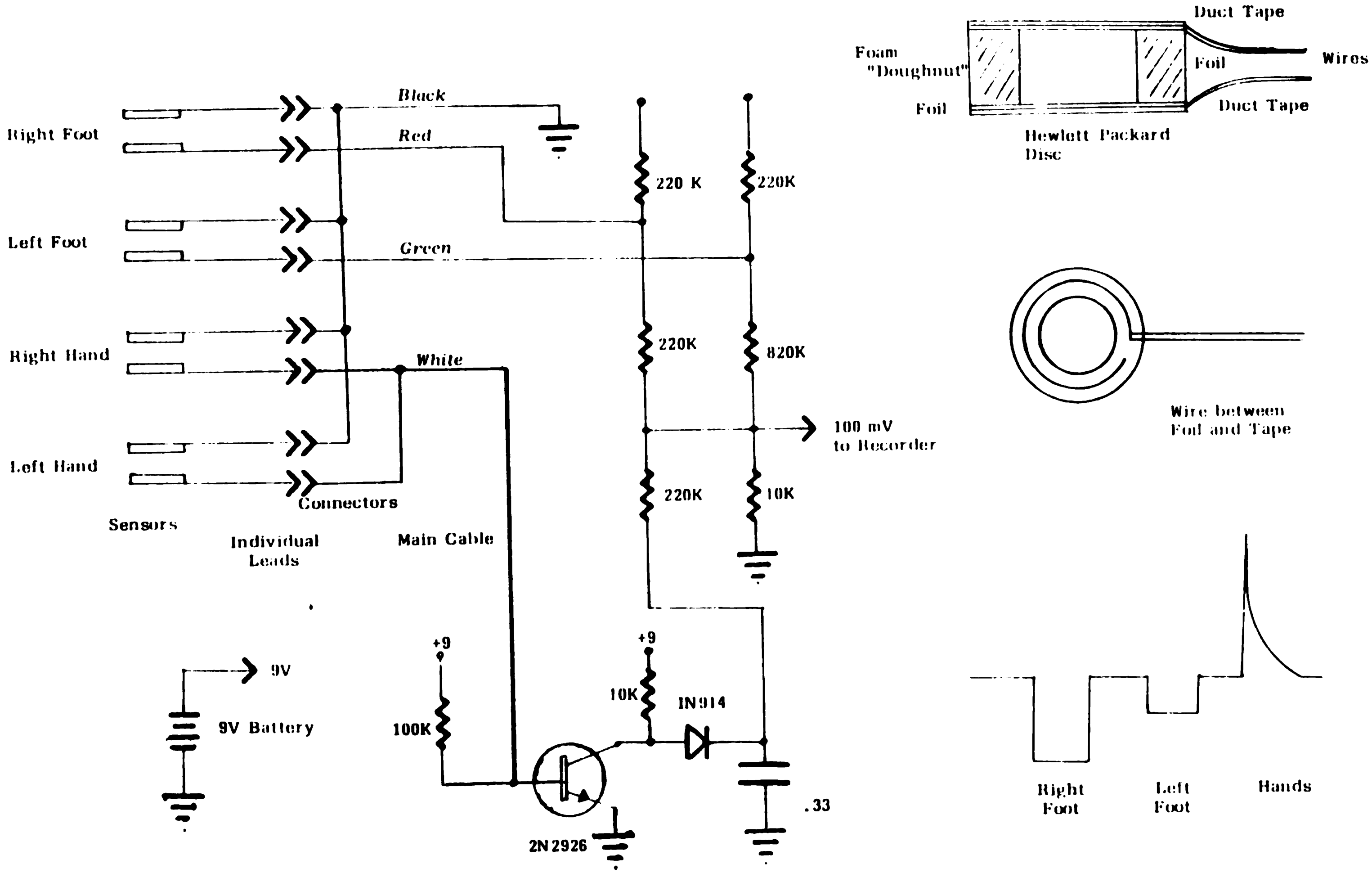
I have read the explanation above and hereby give consent for my child to participate in your study of rhythm and movement. I understand that my child is free to withdraw from the study at any time. I understand that my child will remain anonymous and his responses will remain confidential. I understand that no pictures or video taping will be made during the project. Within these restrictions, I understand that when the study is completed the overall results of it will be made available to me upon my written request.

Signed ______________________ Date ______________

Child's Name ______________________ Teacher's Name ______________

APPENDIX B

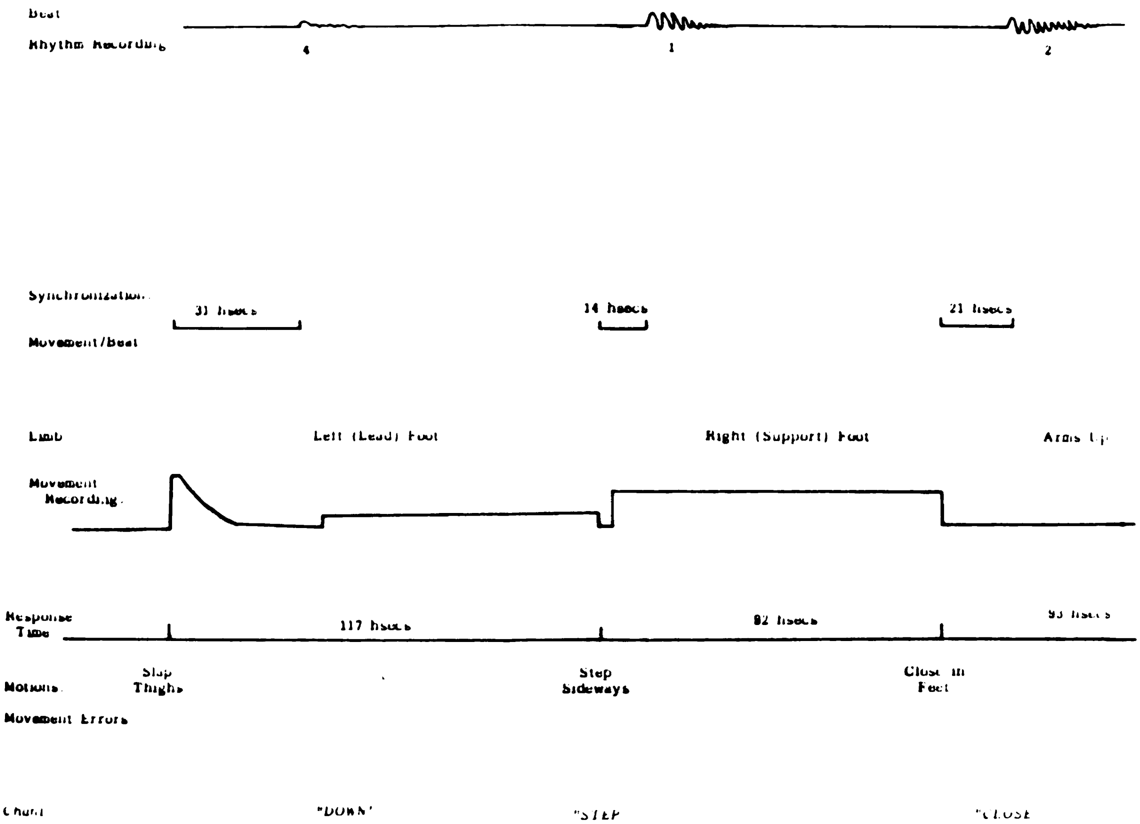
SENSORS AND ENCODING CIRCUITS

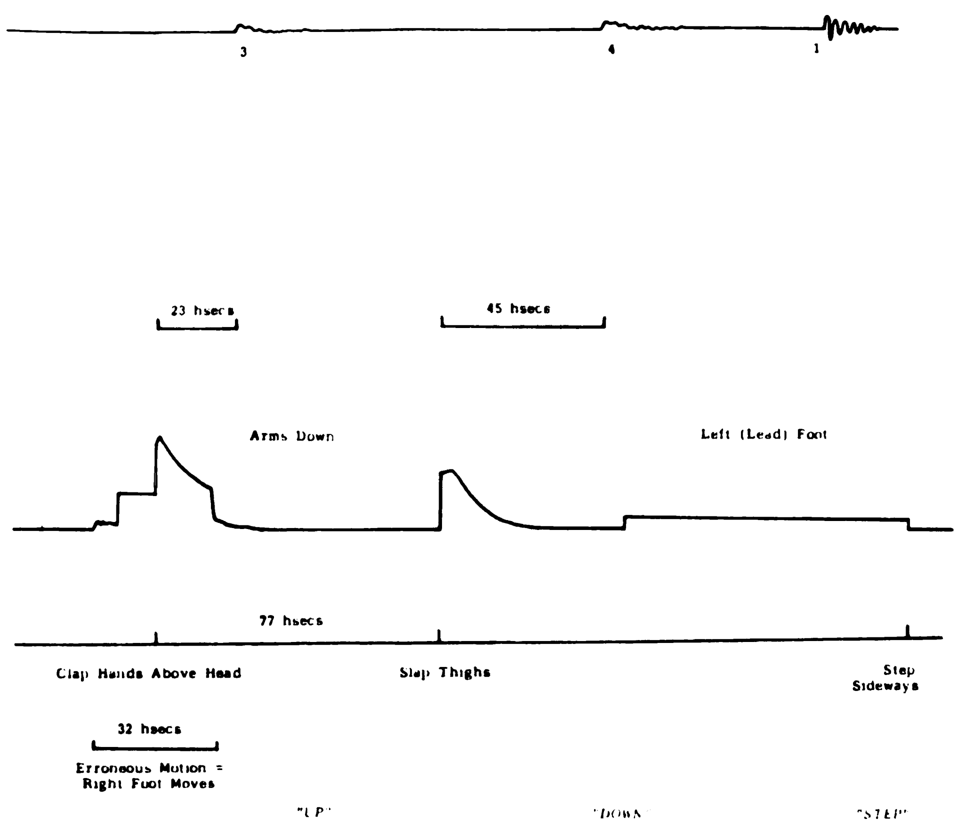


Encoding Circuits

APPENDIX C

SAMPLE PRINTOUT OF MOVEMENT RECORDING


Rhythm Recording
4
1
2
31 hsecs
14 hsecs
21 hsecs
Movement/Beat
Limb
Left (Lead) Foot
Right (Support) Foot
Movement
Recording
Response
Time
117 hsecs
82 hsecs
Slap
Thighs
Step
Sideways
Close in
Feet
Motions
Movement Errors
"DOWN"
"STEP
"CLOSE


3
4
1
23 hsecs
45 hsecs
Arms Down
Left (Lead) Foot
77 hsecs
Clap Hands Above Head
Slap Thighs
Step Sideways
32 hsecs
Erroneous Motion = Right Foot Moves
"UP"
"DOWN"
"STEP"

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