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BRAIN HEMISPHERE FUNCTIONS: NEW IMPLICATIONS FOR MUSICAL APTITUDE TESTING

by

Ada Joan Hall

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Approved:

Chairperson, Graduate Committee

Head, Major Department

Graduate Dean

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TABLE OF CONTENTS

		Page
LIST OF TABLES		v
Chapter		
I	Introduction and Statement of the Purpose	1
	Introduction	1
	Statement of the Purpose	2
	Definition of Terms	2
	Preview of the Remaining Chapters	3
II	Review of the Literature	5
	Two Independent Brain Hemispheres	5
	Hemisphere Dominance and Handedness	7
	Empirical Testing for Hemisphere Dominance	10
	Hemisphere Dominance and Handedness in Musical Aptitude and Ability	12
III	Implications, Discussion and Summary	25
	Implications and Discussion	29
	Summary	35
References		37
Appendix		42

LIST OF TABLES

Table		Page
1	Summary and Compairson of the Functions and Characteristics of the Brain's Left and Righ Hemispheres	26
2	Summary and Comparison of Brain Hemisphere Dominance and Handedness in Relation to Aural Perception.	27
3	Summary of Musical Test Items Employed by Seashore (1938), Wing (1939), Gordon (1965) and Vaughan (1971) Relative to Hemisphere Functions . . .	30

Abstract

The primary purpose of this paper is to survey selected research in brain hemispheric functions and link this research to musical aptitude testing.

Neurological research has found the human brain to be two complementary hemispheres with the left hemisphere functioning in a linear, logical, verbal mode and the right hemisphere functioning in an intuitive, holistic, nonverbal mode (Herron, 1976; Ornstein and Galin, 1975; Regelski, 1977; Samples, 1975; Sperry, 1975).

Neurological research has further established that right- and left-handedness is regulated by: (1) brain hemisphere dominance (Hicks and Kinsbroune, 1976); (2) sex and age (Witelson, 1976); and (3) environment (Barsch, 1968).

Testing for musical aptitude has relied primarily on the heredity based type of test such as that of Seashore (1939) and the environmentally based type of test such as that of Gordon (1965). The linkage between brain hemispheric functions and musical aptitude has been established through research in (1) musical intelligence and creativity (Vaughan, 1971) and (2) specialized functions in musical aptitude as regulated by brain hemisphere dominance (Deutsch, 1975).

The research reported in this paper suggests two significant factors. First, that a number of the instruments used to measure musical aptitude (viz., Seashore, 1938; Gordon, 1965) may not be as reliable and valid for left-handed subjects. Second, that variations in auditory perception may result as a difference between individuals at a basic neurological level.

From these research factors emerge two significant implications for the structuring of new test instruments. First, for musical aptitude testing, a thorough case history and pretest could be formulated to identify (1) brain hemisphere dominance, (2) sex, (3) age, (4) formal academic education, (5) formal musical training, (6) socioeconomic background, (7) psychomotor ability levels, and (8) acoustic hearing levels.

Second, predicated on these data, testors could assign the presentation of musical test items to the appropriate ear for a more accurate hemispheric processing and measurement of musical aptitude or ability.

CHAPTER I

INTRODUCTION AND STATEMENT OF THE PURPOSE

Introduction

The measurement of musical aptitude has been a subject of controversy among music educators and musicians since the early 1900's. Conceptual definitions of musical aptitude range from the ability to recognize, retain and reproduce music, through a highly structured list of characteristic elements of the musical mind. Other scientific and academic disciplines have contributed to this complexity by suggesting that will power, socioeconomic background, self-confidence and general intelligence may be involved.

More recently, research has suggested that various psychological and physiological functions are essential to musicality (e.g., absolute pitch, ability in the recognition of intervals, feelings for tonality, a sense of rhythm, and a quality of affective response to music).

Investigation in the functions of the human brain by researchers during the last half century has been concerned primarily with three areas: (1) modes of consciousness, (2) specific functions of the brain, and (3) processes of the brain. Research findings in these three areas are proving to be highly relevant for music educators by

suggesting a direct linkage to (1) the teaching of music, (2) the testing of musical aptitude, and (3) experimental research in music education.

Statement of the Purpose

The primary purpose of this paper is to survey research in the field of brain hemispheric functions and link this research to existing practices of musical aptitude testing.

More specifically, contemporary neurological research on the function of the human brain has found this part of the central nervous system to be two complementary hemispheres rather than a single symmetrical hemisphere. Each hemisphere appears to have independent sensors, perceptors, information storage and retrieval systems and data processing capabilities. In addition, the two hemispheres regulate laterality (hand dominance) and aural and visual perception. Consequently, the concept of the two complementary hemispheres has profound significance for musical aptitude testing and will be surveyed in light of the primary purpose stated above.

Definition of Terms

The following conceptual definitions were formulated for use in this study:

Ability was defined as musical skills or understandings which are acquired.

Aptitude was defined as innate potential for the acquisition of musical skills and understandings.

Aural perception was defined as the process of awareness of tonal stimuli.

Holistic was defined as the phenomenon of the right hemisphere to perceive the whole with a simultaneous integration of components.

Laterality was taken to mean right or left hemisphere dominance in regard to preference for handedness.

Linear was taken to mean one-at-a-time or in-a-series processing of information in a logical, sequential mode of reasoning.

Mixed dominance was taken to mean lack of consistent left or right dominance in hemispheric functions.

Preview of the Remaining Chapters

The remainder of this paper is divided into two additional chapters. Chapter II is a survey of the research literature on the functions of the human brain and relationships to musical aptitude testing; a review of various musical aptitude tests which are representative of the

field; and a discussion of laterality as it relates to musical aptitude testing in light of contemporary research findings.

Chapter III contains implications and a general summary of the paper.

CHAPTER II

REVIEW OF THE LITERATURE

Two Independent Brain Hemispheres

The brain is one of the least understood organs of the human anatomy. It operates as both an electrical and a chemical system which Grady (1976) identifies as more complex than the most sophisticated computer. The average weight of an adult's brain is approximately three pounds, yet, it functions as the neurological control center for the entire human body.

Early neurological research found the brain to be a double organ, consisting of right and left hemispheres connected by nerve tissue called the corpus callosum. Surgical severance of the corpus callosum, a medical technique used to control epileptic seizures, disclosed that each hemisphere can function independently without serious impairment of mental faculties. However, all reciprocal functions between the hemispheres are permanently destroyed by the severance of the corpus callosum.

Experimental research by Sperry (1975) found that the left, or dominant hemisphere, processes cognitive information such as reading, writing, and mathematical computations.

Conversely, the right, or minor hemisphere, processes affective information such as composure and balance in art, spatial relationships, intuitions, and aesthetic qualities in music.

The two hemispheres are in some ways as dissimilar in their functions as an accountant compared to an artist. For example, Herron (1976) and Samples (1975) compare the left hemisphere to the function of a digital computer and further identify at least three neurological characteristics. First, the left hemisphere primarily utilizes numerical and linguistic symbols in a linear, sequential, analytical pattern. Second, it processes information input by codifying symbols into logical-rational form for storage and retrieval functions. Third, the left hemisphere is more constrained than the right and requires more time for processing information.

Herron (1976) and Samples (1975) extend the accountant-artist analogy by identifying three neurological characteristics of the brain's right hemisphere. First, the right hemisphere processes information input holistically and intuitively. Second, it primarily utilizes spatial relationships and form as symbols in the information storage

and retrieval processes. Third, the right hemisphere can simultaneously internalize large banks of stored data.

Research supportive of and extending Herron (1976) and Samples' (1975) arguments comes from Ornstein and Galin (1976) and Regelski (1977). Regelski (1977) noted that:

> The analytic and holistic modes complement each other; each provides a dimension lacking in the other. But, at other times the two modes are in conflict . . . The activities of one hemisphere can interfere with the operation of the other hemisphere (p. 34).

Ornstein and Galin (1976) further observed that "Employing the inappropriate cognitive system may not only be inefficient, it may actually interfere with processing in the appropriate system" (p. 54).

Lastly, it should be noted that most individuals are "crosswired" with the left hemisphere regulating the right side of the body and the right hemisphere regulating the left side of the body. The exception to this "crosswiring" is the eyes. The left hemisphere regulates the right field of vision for both eyes, whereas the right hemisphere regulates the left field of vision for both eyes (Kimura, 1973; Sage, 1976). (See Appendix A, Figure 1.)

Hemisphere Dominance and Handedness

The functional operations between the two hemispheres

are highly complex. Left-handers differ in at least two particular ways. First, they use their nonpreferred hand much more often than do right-handers and second, they have a different brain organization pattern. For example, Herron (1976) found that:

> . . . the right-hander's language center is almost always on the left [hemisphere] while only 60 percent of left-handers process language on the left. The remainder use the right hemisphere or both sides for language (p. 50).

A number of investigations (e.g., Barsch, 1968; Collins, 1975; Hicks and Kinsbourne, 1976; Levy and Nagylaki, 1972, 1973; and Witelson, 1976) on handedness in both humans and animals provided evidence supportive of both the genetic and environmental schools of thought.

1. Genetic.

Levy and Nagylaki (1972, 1973) have presented substantial findings as an indictment of early research that attributed handedness to learning or environment. They studied left-handedness in twins and in families with a history of left-handedness and concluded that genetic factors are important in the origin of human handedness.

Hicks and Kinsbourne (1976) extended Levy and Nagylaki's (1972, 1973) studies to two groups of subjects with dissimilar parental backgrounds (genetic vs. nongenetic)

They found the writing hand preference correlation between subjects and genetic parents to be higher (.58) than the writing hand preference correlation between subjects and nongenetic parents (.38).

2. Environment.

Collins (1975) found in tests of mice environments that "Environmental biases, due either to asymmetric worlds or cultural standards can strongly modify lateral preferences" (p. 184).

Barsch (1968) argues that the spatial orientation for young children is partially determined by the unilateral preference of the parent:

> . . . in hundreds of different relationships, the preference of the parent determines the contralateral orientation of the child. In dressing the child, feeding him, bathing, washing face and hands the right handed parent tends to orient the child's position for the parent's ease and comfort in ministering to the child (p. 290).

Barsch (1968) further argues that the exact contribution of this parental lateral orientation to child ministration is probably unmeasurable.

3. Sex and Age.

Utilizing sex and age of subjects as the independent variables and cognitive processing as the dependent variable, Witelson (1976) reported that:

> In boys, the right hemisphere has the dominant role in processing nonlinguistic, spatial information by at least age 6 years; in contrast, in girls the right hemisphere is not dominant even by age 13 years, but rather is a bilateral representation . . . Thus, the same neural structures in males and females may have different functions with respect to cognition during a major period of development. Conversely, the same cognitive processes may be mediated by different parts of the brain in boys and girls (pp. 425-426).

To sum up this section, it can be said that genetics, age, sex, and environment all have an influence on handedness. The precise degree of infuence exercised by each remains in dispute and thus is a field of investigation for future researchers.

Empirical Testing for Hemisphere Dominance

Brain hemisphere dominance may be established empirically through physiological and behavioral tests. However, the majority of the physiological tests reported by McNeil and Hamre (1974) are reserved exclusively for the neurosurgeon. For example, autopsy studies (Boring, 1957), hemispherectomy (Basser 1962, Lenneberg, 1967, Penfield and Roberts, 1966) and the sodium amytal injection techniques (Wada, 1949) require surgical applications or drugs.

The one physiological test most frequently employed by researchers to measure brain activity is Berger's (1929)

electroencephalograph (EEG).

To identify hemisphere dominance, the EEG measures and records the wavelike progression of chemical and electric activity of the brain under structured tasks designed to specifically activate either the right or left hemispheres. Ferguson (1973) describes it as a process whereby,

> The electrodes attached to the head record greatly magnified pulses of electricity that are translated into lines inked on paper [electroencephalogram] feeding through the EEG . . . The results of several elecrodes are interpreted algebraically to determine an overall pattern (pp. 90-91).

Early behavioral tests such as the dichotic technique (Broadbent, 1954) and the dichoptic technique (Dallenbach, 1923) are currently being employed to identify hemisphere dominance and laterality.

Of the dichotic techniques, McNeil and Hamre (1974) report that,

> In 1954 Broadbent devised a technique in which different digits were simultaneously ["dichotically"] presented in groups to the right and left ears with a dual-channel tape recorder and stereo headphones (p. 55).

Using Broadbent's (1954) dichotic technique, Mountcastle (1962) demonstrated that stimuli presented to one ear are transmitted more effectively to the dominant rather than the nondominant hemisphere.

Of the dichoptic techniques, McNeil and Hamre (1974)

further report that,

> As early as 1923, Dallenbach was investigating the relationship between handedness and dichoptically presented flashes of light . . . He reported that these subjects [right-handed] tended to perceive the light on the left of fixation [right hemisphere] as brighter (p. 56).

More recently, subsequent investigators (e.g., Mangrum, 1968; Zurif and Bryden, 1969) have reported the potential of dichoptic research for "clarifying the role each hemisphere plays vis-a-vis visual information" (McNeil and Hamre, 1974, p. 56).

In sum, the research literature suggests that the most reliable and least complicated procedure for empirically identifying hemisphere dominance and laterality can be achieved using the electroencephalogram print-out of the EEG.

Hemisphere Dominance and Handedness in Musical Aptitude and Ability

The primary thrust of this section is to bring some of the existing research on the brain's neurological hemispheric functions and musical aptitude and abilities into one common focus. Several investigations in both areas (e.g., Deutsch, 1975; Ferguson, 1973; Gordon, 1965, 1967, 1970, 1971; Heller, 1962; Lehman, 1968; Seashore, 1919,

1938, 1956, 1960; Shuter, 1968; Stanton, 1935; Vaughan, 1971; Whybrew, 1971; and Wing, 1939) provide a substantive basis for the notion that (1) aural perception, (2) laterality and brain hemisphere dominance, and (3) the creative processes are conceptually linked.

Taken together, these findings provide music educators and researchers with an additional dimension for testing musical aptitude and abilities. In order to more accurately assess the relationship of this added dimension to the field of music, the backgrounds of both traditional and contemporary music aptitude testing should first be examined in detail.

Lehman (1968) identifies nine ways in which music aptitude tests are used by music educators. Namely, for (1) identification of talent, (2) adaptation for individual differences, (3) educational guidance, (4) vocational guidance, (5) discovery of learning difficulties, (6) ability grouping, (7) assignment of instruments, (8) studies of musical talent, and (9) psychological studies.

Previous tests and testing techniques used for the prediction of musical aptitude have had as a basis for their rationales a heavy reliance on either genetic or environmental factors as the significant influence for the

prediction of success in music.

To structure the review of various tests of musical aptitude the following format has been utilized: (1) tests based primarily on genetic or inherited factors, (2) tests utilizing environmental factors, and (3) contemporary research which relates neurological perception and creativity to musical aptitude. The following body of research literature (e.g., Deutsch, 1975; Gordon, 1965, 1967, 1970, 1971; Heller, 1962; Seashore, 1938, 1960; Stanton, 1935; Vaughan, 1971; and Wing, 1939) was found to be substantive and representative and will be discussed chronologically in each of the following three sections.

1. Heredity Based Aptitude Tests.

The Seashore Measures of Musical Talents (1919, 1938, 1956, 1960) have born the brunt of the controversy surrounding testing for musical aptitude mainly because they are the oldest, most widely used, and have been subjected to more intensive study (Whybrew, 1971) than other musical aptitude tests. Seashore (1938) argues that the musical talent is "not one, but a hierarchy of talents . . . which we call the 'musical mind'" (p. 38). He asserts that the musical mind is a normal mind that contains usable capacities essential

for hearing, feeling, understanding, and capable of some form of expressions of music with a "resulting drive or urge toward music" (Seashore, 1938, p. 2).

Seashore (1938) further argues that the basic sensory capacities of pitch, time, loudness, and timbre are elemental, which makes them largely inborn, and that they exist in all humans regardless of later training and experience. He recognizes that some physical limitations may influence measurement. For example, the inability of a young child to comprehend the requirements of the test, or hearing disabilities in older persons.

Much of the controversy over the Seashore (1938) battery has arisen when music educators have tried to apply the results of tests. Misinterpretation of test results by untrained individuals, and misunderstanding of what Seashore (1938) actually claims the battery to measure, form the major problems. For example, if a subject scores high (99th percentile) on the pitch test, it does not necessarily mean he is musical. The investigator can only conclude that the subject has an extraordinary sense of pitch. The subject may be completely lacking in other basic music talents (Lehman, 1968). Seashore (1938) further contends that if the measurement of capability is made in a subject by the

age of 10 years, the results are likely to remain relatively stable throughout his life.

Stanton (1935) employed a profile technique for use at the Eastman School of Music from 1925 to 1928. She tested freshman classes using the Seashore Measures (1919) and the Iowa Comprehension Test (intelligence). On the basis of the subjects' scores, Stanton (1935) grouped them in five classifications as to chance of graduation. The five classes were: (1) safe, (2) probable, (3) possible, (4) doubtful, and (5) discouraged. This was an attempt to validate material used in the Seashore Measures of Musical Talent (1919). There has been some discussion of her methodology which critics claim adds to the confusion because of the interaction between intelligence, as measured by the Iowa Comprehension Test (intelligence) and the Seashore Measures (1919). However, Shuter (1968) argues that:

> This procedure, using the Seashore Measures, interpreted in broad grades along with an intelligence test, has greatly improved the quality of Eastman students (p. 29).

Seashore (1938) regarded his efforts as based on scientific methods which utilized psychological terms and illustrations. Since the Seashore (1938) battery of tests

had no precedent to follow, it should be recognized as a remarkable accomplishment for its time.

The Wing Musical Intelligence Tests (1939, 1948, 1957, 1960, 1961) were generated from an emperical perspective to determine what types of tests "prove most efficient as judged by their agreement with music teachers' estimates" (Heller, 1962, p. 2). Wing (1939) found that with post-testing following music training, there was no perceptible improvement in performance on the test. Therefore, he concluded that the battery was not unduly affected by training and that the traits being measured were largely inherited or genetic.

The battery is based on an omnibus approach reflecting Wing's (1939) belief that there is a general factor of musical talent. It uses (1) chord analysis, (2) pitch change, (3) memory, (4) rhythmic accent, (5) harmony, (6) intensity, and (7) phrasing. Because it has not been used as extensively as the Seashore tests, its validity and reliability appear to be in need of additional investigation. It is, however, a carefully constructed test and Wing (1939) claims .90 reliability or above for older children and .70 reliability for younger children (Lehman, 1968, p. 48).

Heller's (1962) doctoral study is an attempt to investigate one aspect of the Wing battery - the effects of formal music training on the test scores. Documentation supportive of the importance of interpretation of the test results is stated throughout.

Listening skills were found to improve appreciably with formal training (3.4 points) but the instability of the Wing (1939) scores proved a serious weakness of the total battery reliability (Heller, 1962, p. 69).

Heller (1962) offers several important suggestions regarding control groups, pre-testing techniques, and delineation of the usefulness of certain sections of the Wing (1939) battery. For example, the time emcompassed by the pretest-posttest was only four months (one music course) and Heller (1962) suggests a retest at an interval of one year of further music training for higher reliability.

2. Environment Based Aptitude Tests.

Gordon's (1965) Musical Aptitude Profile is recognized as one of the most sophisticated instruments used to measure musical aptitude. Even though music educators complain that the Musical Aptitude Profile is too long, too complicated, too expensive and the terminology employed too confusing, (Lehman, 1968), the high degree of validity and reliability

achieved by "longer tests" appears to counterbalance negative complaints.

A Three-Year Longitudinal Prediction Validity Study of The Musical Aptitude Profile (Gordon, 1967) has provided additional evidence of validity. Correlation coefficients were made of the study's scores in three comparative areas: (1) rating of judges, (2) teacher evaluations of student achievement, and (3) students' scores on a music achievement test over a three-year period. The coefficients for Profile Composite Scores compared significantly with those reported for general academic and vocational aptitude tests (Gordon, 1967; Whybrew, 1971).

Gordon (1967) devised a comprehensive manual for the Musical Aptitude Profile which provides interpretative data for the various components of the test. Namely, a table for conversion of raw scores to standard scores; percentile norms for all standard scores at nine grade levels for unselected students (4 through 12); and percentile norms for three grade levels of musically select students (4-6, 7-9, 10-12).

Gordon (1967) conceptually defines musical ability as "those skills learned formally or informally which enable the reproduction of musical behavior" (p. 96). Even though

Gordon (1967) generally is identified in the environmental-based aptitude category, in Experimental Research in the Psychology of Music (1970) he argues that:

> In related psychological research, the nature-nurture debate has been actively transferred into a search for the dynamic relationship between these two elements . . . a search for how environment and heredity interact, rather than whether one is more important than the other (p. 98).

Gordon (1971) acknowledges the importance of nature and affirms the fact that a "good musical environment is necessary for one to be able to realize his maximum innate potential, whatever that level may be" (p. 36).

3. Contemporary Research

At least two contemporary investigators (e.g., Deutsch, 1975, and Vaughan, 1971) have demonstrated a relationship between the neurological functions of the brain and musical aptitude.

In a study not specifically couched in neurological terms, Vaughan (1971) established a neurologically-based relationship between music creativity (ability) and musical intelligence (aptitude). Her research focused on "building a model of creativity which would help form a bridge from philosophical theory and existing research to the building of a musical creativity test" (p. 33). Vaughan (1971)

identified the components of the tests as: (1) symbolic transformation, (2) personality attributes, (3) ego regression, (4) problem solving, (5) transfer, (6) intuition, (7) sense of aesthetic fit, and (8) the ability to synthesize.

Rhythm provided the structural basis for the model which was cyclic in nature. This allowed for input and revision. Elements used in the study corresponded to many types of qualities used in the studies previously reported (i.e., pitch, rhythm, timbre, memory, and improvisation). Unfortunately, discrepancies among adjudicator reporting (the method used for evaluation) appear to have produced reduced validity and reliability findings, but did not invalidate the potential of the test.

Deutsch (1975) found that the right hemisphere has specialized functions such as recognition of timbre, complex tones, and chords whereas, the left hemisphere has specialized functions in the ordering of sounds and sequences, and in the processing of rhythmic values.

More specifically, in an investigation of the principles by which successive tones are linked into musical sequences, Deutsch (1975) employed a dichotic presentation (i.e., simultaneous presentation of tones to both ears) and

found that right-handed and left-handed subjects perceived auditory illusion in different ways. For right-handed (left hemisphere dominant) subjects, primary auditory input came from the right ear. For left-handed subjects, either hemisphere was dominant. Of this, Deutsch (1975) observed that:

> The difference in localization of the tones in right-handed and left-handed subjects suggests that high tones are perceived as coming from the ear that provides the strongest input to the dominant hemisphere, and that low tones are perceived as coming from the ear that provides the strongest input to the non-dominant hemisphere (p. 92).

Deutsch (1975) also found two additional and significant differences. First, that there was a higher proportion of left-handed subjects reporting complex perceptions than right-handed subjects, and second, that all subjects tended to refer the higher tones to the dominant side of auditory space and the lower tones to the non-dominant side.

To sum up this chapter, the research efforts in brain neurology and musical aptitude testing were surveyed in light of establishing a common referent for further discussion of the relationship between the two dissimilar disciplines.

Neurological research has established that the brain's left hemisphere functions in linear, logical and verbal

operations whereas, the right hemisphere functions in intuitive, holistic and nonverbal operations (Herron, 1976; Ornstein and Galin, 1975; Regelski, 1977; Samples, 1975; Sperry, 1975). Right- and left-handedness is regulated by: (1) brain hemisphere dominance (Hicks and Kinsbourne, 1976); (2) sex and age (Witelson, 1976); and (3) environment (Barsch, 1968). However, the precise degree of influence has not been established. Among the physiological and behavioral tests used to empirically identify hemisphere dominance and laterality, use of the electroencephalograph (Berger, 1929) appears to be the most functional and reliable.

Musical aptitude testing was discussed in light of: (1) heredity based tests, (2) environmental based tests, and (3) neurological factors affecting musical aptitude.

The pioneering efforts of Seashore (1919, 1938, 1956, 1960) and Gordon (1965, 1967, 1970, 1971) have resulted in tests that have become benchmarks in the measurement of musical aptitude. Seashore's heredity based Measures of Musical Talents (1919) purports to measure innate sense for six musical factors whereas, Gordon's environmental based Musical Aptitude Profile (1965) assigns greater importance to environmentally nurtured perceptual responses than to

sensory capacities.

Finally, the more recent investigations by Vaughan (1971) have established a linkage between musical intelligence (aptitude) and musical creativity (ability). And, the research by Deutsch (1975) concerns the neurological factors affecting musical aptitude in which hemisphere dominance appears to be predictive of specialized functions in musical aptitude.

CHAPTER III

IMPLICATIONS, DISCUSSION AND SUMMARY

The primary purpose of this paper is to survey research in the field of brain hemispheric functions and to link this research to musical aptitude testing.

This chapter contains the discussion and implications of the research reported in Chapter II, followed by a general summary.

As previously stated, neurological research has found the brain to be a double organ, consisting of two complementary hemispheres. Table 1 presents a summary and comparison of the functions and characteristics of the brain's left and right hemispheres. Table 2 reports an extended summary and comparison of brain hemisphere dominance and handedness in relation to aural perception.

At the onset of this section it can be reiterated that the precise degree of influence exerted by heredity or environmental factors on handedness and musical talent has eluded investigators in both neurological brain research and musical aptitude and ability testing. This does not dismiss the concepts posited by the nature-nurture arguments. It does, however, de-emphasize the exclusivity of

Table 1.

Summary and Comparison of the Functions and Characteristics of the Brain's Left and Right Hemispheres

A. Left Hemisphere	B. Right Hemisphere
1. Dominant hemisphere for right-handed individuals.	1. Dominant hemisphere for left-handed individuals.
2. Processes cognitive information such as: a. reading b. writing c. mathematical computations.	2. Processes affective information such as: a. composure and balance in art. b. spatial relationships. c. aesthetic qualities in music.
3. Functions in a linear, sequential, verbal, analytical mode.	3. Functions in a holistic, nonverbal, intuitive mode.
4. Codifies symbols into logical-rational forms for storage and retrieval purposes.	4. Utilizes spatial relationships and form as symbols for storage and retrieval purposes.
5. Requires more time (than the right hemisphere) for processing in the linear mode.	5. Simultaneously internalizes large banks of stored information.

Table 2.

Summary and Comparison of Brain Hemisphere Dominance and Handedness in Relation to Aural Perception

A. Right-Handed Individuals	B. Left-Handed Individuals
1. Use nonpreferred hand less frequently than left-handed individuals.	1. Use nonpreferred hand more frequently than right-handed individuals.
2. Consistant brain hemisphere dominance: a. 99% have left hemisphere dominance.	2. Nonconsistant brain hemisphere dominance: a. majority have right hemisphere dominance. b. a portion have either hemisphere dominance or mixed dominance.
3. Left hemisphere functions in the ordering of sounds and sequences and processing of rhythmic values.	3. Right hemisphere recognizes timbre, complex tones and chords.
4. Perceptions of auditory space: a. high tones referred to dominant left hemisphere b. low tones referred to nondominant right hemisphere.	4. Perception of auditory space: a. high and low tones referred to either left or right hemisphere contingent upon which is dominant in a given left-handed individual. High tones to dominant; low tones to nondominant.

Table 2. Continued

Summary and Comparison of Brain Hemisphere Dominance and Handedness in Relation to Aural Perception

A. Right-Handed Individuals	B. Left-Handed Individuals
5. 1 through 6 successive varied pitches are processed exclusively by the left hemisphere.[1]	5. 1 through 6 successive varied pitches are processed by either hemisphere contingent upon which is dominant in a given left-handed individual.[1]

[1] Regardless of handedness, successive varied pitches beyond six are processed in a holistic mode by the right hemisphere.

both arguments when categorizing tests of musical aptitude and ability and should be held as a relative condition in light of the discussion of implications that follow.

Implications and Discussion

A large body of the neurological brain research literature summarized in Tables 1 and 2 (pages 26 through 28) was quite possibly not considered significant to musical testing or not yet identified by research when Seashore (1938), Wing (1939), Gordon (1965) and Vaughan (1971) (hereafter identified as the Investigator Group), formulated their test instruments.

Table 3 reports a summary of the various musical test items employed by the Investigator Group. Taken together, the summarized data reported in Tables 1, 2, and 3 (pages 26 through 28 and page 30) implies that many of the various test items were not structured to achieve maximal validity and reliability. That is, if contemporary neurological research had been incorporated in the methodological framework of the Investigator Group's testing procedures, test validity and reliability could have been significantly strengthened with only slight modifications.

More specifically, contemporary research findings

Table 3.

Summary of Musical Test Items Employed By Seashore (1938), Wing (1939), Gordon (1965) and Vaughan (1971) Relative to Hemisphere Functions

	Seashore	Wing	Gordon	Vaughan
Left Hemisphere				
Pitch	X	X		
Rhythm	X	X	X	X
Time	X			X
Tempo			X	
[1]Tonal Memory	X	X	X	
Right Hemisphere				
Timbre	X			
Loudness (intensity)	X	X		X
Harmony (chords)		X	X	
Phrasing		X	X	X
Balance			X	X
[1]Tonal Memory	X	X	X	

[1]May be either hemisphere

provide implications for strengthening various musical test items in at least five areas.

First. In testing for pitch, the perception of high and low tones is processed differently in left- and right-handed individuals. The audio oscillator signal presented should be uniform across all testing situations. The use of stereophonic headphones in place of randomly positioned loud speakers would minimize pitch perception distortions by directing oscillator signals to the appropriate dominant hemisphere of the individual being tested.

Second. Presentation of musical test items should be redirected based on research findings that suggest pitch, rhythm, time, and tempo to be primarily left hemispheric functions; timbre, loudness, harmony, phrasing, and balance to be primarily right hemispheric functions; and tonal memory to be a function of either hemisphere (Table 3, page 30).

Third. The mode in which rhythm patterns are processed by the two hemispheres is complex and varies according to handedness and hemisphere dominance.

In left-handed individuals, 1 through 6 note patterns are processed sequentially by either the left or right hemisphere depending upon dominance in a given left-handed

individual.

In right-handed individuals, 1 through 6 note patterns are also processed sequentially but only by the left hemisphere.

The complexity developes when rhythm patterns in excess of seven are presented. Beyond this number rhythm patterns are processed abstractly and holistically which activates switching between the sequential (left-hemisphere dominance) and holistic (right-hemisphere dominance) modes (Miller, 1957). This reciprocal switching between the two modes appears to cause interference with musical item processing.

The reciprocal switching concept posits implications especially significant in the testing of rhythmic patterns and to a lesser degree in the testing of tonal memory.

Rhythm is the only musical test item common to each of the Investigator Group's instruments. That is, rhythm appears to be an inherent characteristic in human beings (e.g., rate of heart beat and rate of respiration cycle) and thus provides the theoretical basis for musical aptitude testing. Unfortunately, the Miller "Majic Number Seven" concept (Buck, 1976) is not held constant by any of the Investigator Group. For example, Seashore (1938) used a

maximum of seven note patterns in both tests for rhythm pattern and tonal memory whereas, Gordon (1965) employed from 3 to 10 note patterns for tonal memory alone. Consequently, Seashore (1938) limited the processing of rhythm patterns and tonal memory primarily to the dominant hemisphere of the brain while Wing (1939) and Gordon (1965) structured tonal memory in a framework triggering the reciprocal switching process.

Fourth. Hemisphere dominance is not stabilized in most boys until around age six to ten and not in girls until as late as the early teens. These research findings suggest that it would be difficult to accurately identify the mode younger children are utilizing to process the different sections of musical tests for either aptitude or ability.

Under these circumstances validity and reliability factors may be lowered in that the test results may not be predicting the same aptitudes or abilities for (1) younger children as for older children, and (2) for boys as for girls.

Fifth. Even though many of the Investigator Group advocated the use of supplemental intelligence scores, case histories, interviews and auditions, contemporary research

methodology argues that the independent variables of an empirical investigation be scientifically established for each individual or group of individuals tested.

For musical testing this variable could be established by formulating a thorough case history through a battery of pretests designed to identify (1) brain hemisphere dominance (other than the visual observation of handedness), (2) sex, (3) age, (4) formal academic education, (5) formal music training, (6) socioeconomic background, (7) psychomotor ability levels, and (8) acoustic hearing levels. Once identified, the pretest data would enable testors to assign the presentation of musical test items to the appropriate ear for a more accurate hemispheric processing and measurement of the testee's musical aptitude or ability.

Before summing up, three observations regarding Vaughan's (1971) investigational methodology should be noted: (1) Although not specifically reflected in Table 3 (page 30), Vaughan (1971) uses more right hemispheric functions (viz., [1]symbolic transformation, [2]transfer, [3]intonation, [4]sense of aesthetic fit, and [5]ability to synthesize) than others of the Investigator Group. (2) Instead of using rhythm in the conventional manner, Vaughan (1971) uses it as the vehicle for testing aptitude

for all eight musical test items in the battery. Consequently, this minimizes interference in hemispheric processing generated by reciprocal shifting. (3) Vaughan's (1971) test construct is grounded in proven creativity testing principles applied to musical aptitude testing. Each task has a specific purpose leading to successively more unstructured activities resulting in a greater reliance on right hemisphere functions to process item input. Especially significant is the use of intuition, sense of aesthetic fit and the ability to synthesize which are quasi-structured improvisational problems dealing almost exclusively with right hemisphere functions.

Summary

Research suggests that investigators may not always be testing what they plan to test in every individual. Individual differences in the processing of information may alter not only the information received by the information evaluated.

Employment of the wrong system (cognitive versus affective) in music aptitude and ability testing may do two things: (1) It may reduce the reliability of the tests to predict musical aptitude because of the use of an

inappropriate hemisphere function. (2) It may discriminate against individuals who process information differently due to handedness.

Finally, it can be restated that the functions of the brain in relation to (1) the auditory perception and processing of music and (2) the correlations with handedness, appear to indicate that variation in auditory perception may result as a difference between individuals at a basic neurological level. These basic neurological differences may be responsible for individual variations in musical creativity, ability, preference, and appreciation. For music education researchers these findings provide a theoretical framework for the structuring of new instruments to test musical aptitudes and abilities.

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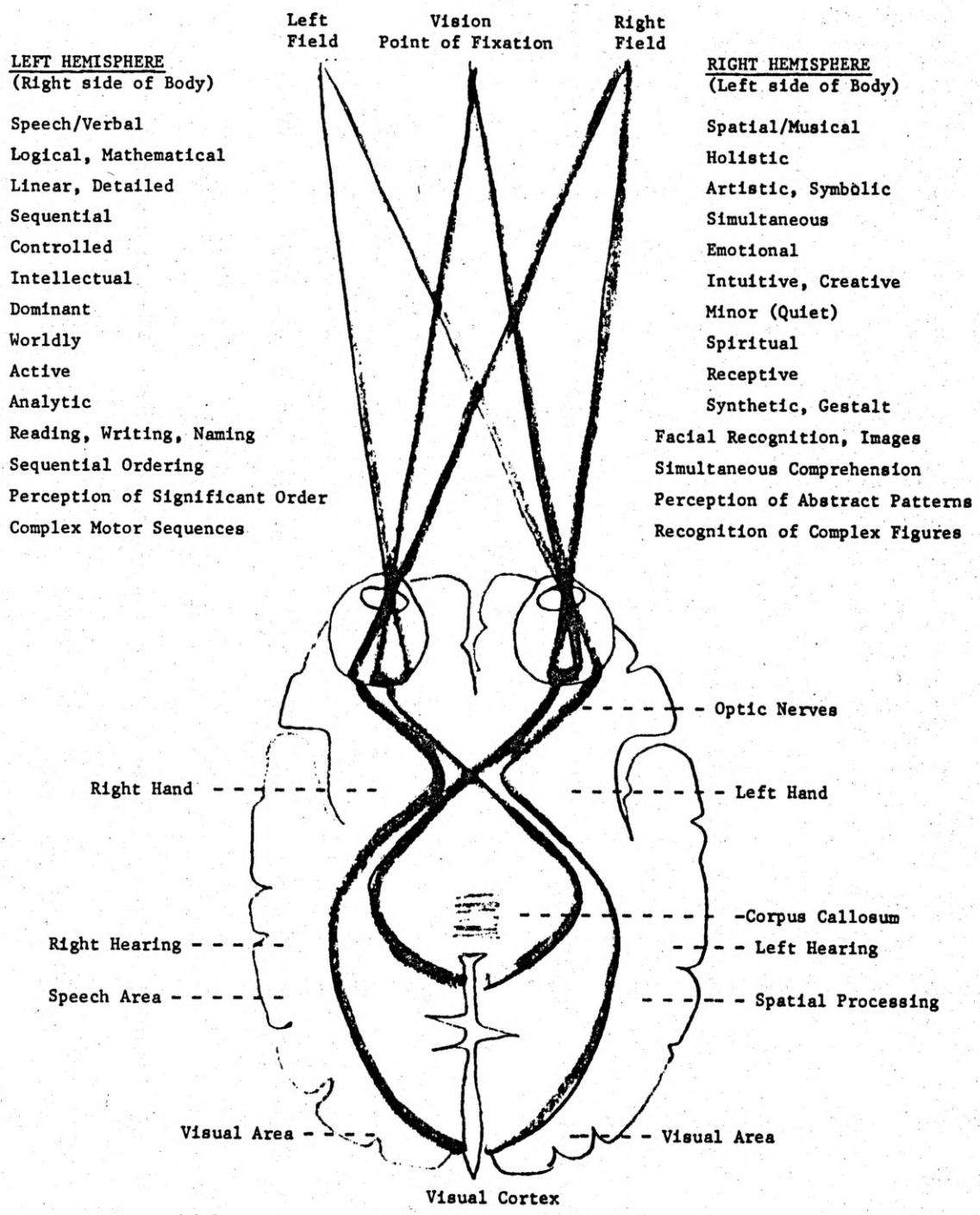
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APPENDIX

APPENDIX A


Left Field
Vision Point of Fixation
Right Field
LEFT HEMISPHERE
(Right side of Body)
Speech/Verbal
Logical, Mathematical
Linear, Detailed
Sequential
Controlled
Intellectual
Dominant
Worldly
Active
Analytic
Reading, Writing, Naming
Sequential Ordering
Perception of Significant Order
Complex Motor Sequences
RIGHT HEMISPHERE
(Left side of Body)
Spatial/Musical
Holistic
Artistic, Symbolic
Simultaneous
Emotional
Intuitive, Creative
Minor (Quiet)
Spiritual
Receptive
Synthetic, Gestalt
Facial Recognition, Images
Simultaneous Comprehension
Perception of Abstract Patterns
Recognition of Complex Figures
Optic Nerves
Right Hand
Left Hand
Corpus Callosum
Right Hearing
Left Hearing
Speech Area
Spatial Processing
Visual Area
Visual Area
Visual Cortex