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Chapter II

BRAIN MECHANISM IN MUSIC
Prolegomena for a Theory of the Meaning of Meaning

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INTRODUCTORY REVIEW

Research into the relationship between musical abilities and the brain has benefited from a series of recent technical innovations. These have made possible two basic approaches: One involves the use of dichotic listening techniques and infers hemispheric specialization on the basis of comparing performance between the left and right ears. A second approach is to construct musical tasks which are similar to those in classical experimental psychology and where brain-behavioral correlates have been demonstrated in animal models. Thus by delineating similarities and differences in processing between musical and non-musical tasks, models or theories of brain function can be attempted.

Recent research results, bearing almost exclusively on the problem of hemispheric specialization, have been collected into a volume entitled "Music and the Brain" edited by MacDonald Critchley and R.A. Henson (1977). I will very briefly summarize the findings reported in this volume. Though basic to the purpose of this paper which is to understand the manner in which musical meaning is generated, many of these studies appear as isolated reports whose only reason for being seems to be that they do relate brain function to one or another aspect of musical experience and expression.

1. Musical rhythm is apparently a deep-seated function since unilateral injection of intracarotid barbiturates (the Wada test) fails to interfere with rhythm even though injection of the right carotid (producing a reversible right hemispherectomy) produces severe melodic distortion and injection of the left carotid produces difficulties in singing words that might accompany these melodies (Bogen and Gordon, 1971). When the temporal sequences become more complex, however, the number of correct identifications made by the right ear (and therefore the left hemisphere) in a dichotic listening experiment were significantly greater than those made with the left ear (Robinson and Solomon, 1974).

2. Musical competence is an important determinant of the pattern of cerebral organization. There is a relationship between musical sophistication and pitch discrimination (McGuinness, 1974), and left ear (right hemisphere) superiority has been demonstrated for pure tone discrimination in dichotic listening experiments (Haydon and Spellacy, 1973). Timbre, as examined by a musical chord test, is similarly represented (Gordon, 1970; Kallman and Corballis, 1975). In general, the greater the musical sophistication of the subject, the more the left hemisphere is brought into play. Thus, as noted above, melodic line is represented in the right hemisphere as is the processing of single musical notes presented in a brief visual display to naive subjects. When, however, these same displays were shown to sophisticated subjects they processed the notes equally well in both the right and left visual fields (Oscar-Berman et al., 1974).

3. Musical memory appears to involve interacting hierarchies of representations of sequences of pitch, melodies, timbre and harmonies, as well as contextual considerations such as overall phrase interval and scale thus involving both cerebral hemispheres. A review of what is known, much of it her own work, is presented by Diana Deutsch (1977) in the Music and the Brain volume.

4. Musical attention is reviewed in the same chapter. Deutsch distinguishes attentional 'channels' for spatial location, frequency range and timbre. In addition, Efron and Yund (1975) have demonstrated a dissociation in the processing of the frequency and intensity dimensions of sounds by the auditory system. The experimental studies on musical attention have in general focused on identifying such separations of processing 'channels' which must not be confused with separations of processing hemispheres. The experiments reviewed above (paragraph 2) noted that often such channels are modified by experience to become more complex and competent to process musical input. When that input is discriminated into attended alternatives it becomes appropriate and useful to describe it as musical information. Pribram and McGuinness (1975) have defined channel competence as the inverse of its equivocation (the sum of internal redundancy - the complement of information - plus noise). Channel organization and therefore musical attention is thus dependent on the competence to process musical information. Thus competence is, in turn, dependent on the organization of musical memory.

NEW DEPARTURES

Nowhere in the volume on Music and the Brain is there an attempt at providing a neurological theory of musical competence or of the meaning which music generates. Without such a theory, the findings reported become fragments of little concern to either the brain scientist or the musician interested in how he came to his current state. Theory, especially when it essays into a new domain, is perforce sketchy and may be proved wanting by subsequent test. But the essence of theory is that it is testable and that modifications of a theory on the basis of fact are possible. With these caveats before us, I shall venture a neurological theory of musical competence and some experimental tests that address this theory.

A brain theory of musical competence and musical meaning must be compatible with known facts about brain function, with known facts about psychological processes and with known facts about the physics, i.e. the tools, of music. These facts are most easily encompassed by taking seriously the analogy of music to language. In a sense, music is a language-like form by which humans express themselves and communicate with each other. Musical competence and meaning are not dependent on the tongue (lingua) as is verbal language but neither are gestural languages (such as American Sign Language), nor is the written word.

The study of natural languages is encompassed by the discipline of semiotics, the study of signs. Semiotics is customarily divided into semantics, pragmatics, and syntactics (see e.g. Websters 3rd International Dictionary; Charles Peirce, 1934; Morris, 1946). Semantics deals with the meaning of signs, i.e. what they refer to, indicate, denote, or connote; pragmatics with their use, i.e. how signs relate to their user; and syntactics with the rules of relationships among signs per se.

I have elsewhere identified, on the basis of neuropsychological data, brain mechanisms responsible for the semantic, pragmatic and syntactic organization of languages (see e.g. Pribram, 1971, 1976, 1979). The proposal can be summarized as follows:

1. Sensory input is initially processed into images (icons) and information. Iconic images have wholistic "Gestalt" properties; information, as noted above, is based on the discrimination of differences between alternatives in the input. There is now a considerable body of evidence that the right hemisphere of the brain (of right handed persons) is somewhat more specialized for image processing while the left hemisphere is more adept at processing information.

2. In man. image and information undergo further processing: Indicants (deictic pointers, icons) become derived from images; symbols from information. The process of derivation is a complex one which involves a stepwise interaction between brain competence and cultural invention (Pribram, 1976, 1978). For instance, a gestural sign will come to indicate an image through repetitive consensual validation. The indicant (an iconic gesture) will then become discriminated from others, thus providing information about what is indicated. Once this information processing competence has become sufficiently developed, the information is encoded in memory and when communicated tells as much about the use of the information as about what the information indicates. If, for instance, a routine gesture is under certain circumstances accompanied by a vocalization, that vocalization may initially convey urgency. When the vocalization becomes more and more regularly associated with the gesture because it is found useful over distances, the vocalization can become an arbitrary token, a symbol of the information. However, the communicative value of the symbol depends as much on the history of its usage as on what it refers to because there is nothing intrinsic in the vocalization which indicates

that to which it refers. This historical aspect of symbols makes them especially amenable to two separate types of processing: Semantic which establishes their original referential meaning, and pragmatic which deals with the historical and current use to which the user puts the symbols. Also, because of this arbitrary nature of symbols, and their historicity, i.e. dependency on their historical development, rules of usage, syntactical structures of arrangement of symbols become especially effective.

3. Semantic processing, which relates indicant and symbol to the sensory input from which they derive, is carried out by systems which involve the posterior cortical convexity of the brain, especially in the intrinsic "association" areas that surround the cortex which initially receives the input (the primary sensory projection areas).

4. Pragmatic processing which relates sign and symbol to their user is carried out by systems which involve the frontolimbic cortical formations of the brain. These systems intimately interconnect the core portions of the brain such as the mesencephalic reticular formation and hypothalamus with the frontal lobes of the cerebral cortex.

5. Syntactic processing, the arrangement of indicants and symbols, is carried out by the motor systems of the brain to which both posterior and frontal cortical formations project. Since the motor systems carry out the computations of both the posterior cortical convexity and the frontolimbic formations, the problems of syntax are on the one hand similar to those that characterize motor behavior of any kind (see e.g. Reynolds, 1970 for such communicative behavior as play, assertive and sexual interactions) and on the other hand these problems are dependent on the particular computations that determine semantic and pragmatic processing.

To return to brain and music a theory of musical competence and musical meaning can be outlined on the basis of this theory of semiotics. Such a neurological theory of music would specify a distinction between indicants of musical images and symbols of musical alternatives and between musical semantics, pragmatics and syntactics. Experimental tests of the theory would involve showing that processing of musical indicants such as melody and harmony are predominantly right hemisphere related and that processing of musical symbols such as hierarchically arranged phrase structures predominantly involve the left hemisphere. Further, such tests would be directed at relating the posterior cortical convexity to the processing of sensory input into musical indicants and symbols while showing that the frontal (and limbic) portions of the brain involve the user in musical experience and expression. A grammar of music should, according to the theory, be related to the motor systems of the brain.

As reviewed in the introductory section of this essay, there is a considerable data base which indicates that indeed musical image processing is predominantly a right hemisphere and musical information processing a left hemisphere function. Furthermore, there is some evidence (reviewed in the Introduction) that brain lesions (or intracarotid barbiturate injections) which interfere with grammatical constructions of spoken language also interfere with the ordering of any but the simplest melodic structures in music.

There is also a body of evidence which relates the motor aspects of syntactic structure of music to that of verbal languages, notably the detailed analysis of Leonard Bernstein (1976) and the even more detailed and sophisticated elaborations of a Chomskian approach bv Lerdahl and Jackendoff (1977) and Jackendoff and Lerdahl (1979). However, these scholars fail to emphasize sufficiently that the syntactic structure of music is more dependent on pragmatic processing while that of natural language is more dependent on semantic processing, a difference which provides a point of entry into examining some persistent problems that have plagued linguists as well as those interested in music for several decades.

REFERENCE AND MEANING

In this last section I wish therefore to explore to somewhat greater depth the similarities and differences between musical and linguistic communication by developing further the insights on this topic provided by Leonard Bernstein (1976). Bernstein brings to this work his prodigious and deep knowledge of music and considerable analytic skills. He is excited by Chomsky's "Language and Mind" (1972) and presents the case for considering music in the same terms as those in which Chomsky considers natural language. Chomsky, himself, has responded to this attempt by insisting on the uniqueness of the language system (1980), while others (for example, Lerdahl and Jackendoff, 1977) have been more overtly critical of some of the technical details of Bernstein's position. I will here emphasize the positive aspects of Bernstein's overall approach by showing that in addition to providing a more universal framework for understanding music, it is at the same time extremely valuable in illuminating some hitherto difficult reaches of linguistic analysis. Any such approach must, however, (as Chomsky rightly emphasizes) also account for the major differences between natural language and musical systems.

Bernstein begins with phonology. He suggests that the first communicative uses of sounds were sung. His conjecture is supported by the fact that the vocalizations of non-human primates consist almost entirely of changes in pitch and duration - articulations appear to be characteristically human to such an extent that early attempts at eliciting communicative competencies in apes foundered on just this point. Such observations would suggest that at the phonological level music and speech begin in phylogeny and ontogeny with a common expressive mode.

As noted above. this common expressive phonology apparently was brought into the service of gestural communication in situations where vision had become restricted. The course of events allowed a distinction to arise between a categorical expression and one based on the more continuous aspects of phonology sensitive to octaval relationships. The categorical expressions became useful phonemic tokens representing gestures which in turn represented occurrences. This hierarchical representational system gave reference to the phonemic tokens - words had been developed.

The study of the reference of words is thus a legitimate central concern of linguistics. A great deal of this concern becomes transferred to the more encompassing study of the semantics of natural languages. The obvious direction of inquiry is to ascertain the referential roots of the indicants and symbols that constitute utterances in the natural languages.

But philosophers* have long held that there is an important distinction to be made between reference and meaning. Meaning in any non-referential sense has, however, eluded precise definition.

I have elsewhere (Pribram, 1973a, 1975) attempted such a definition in terms of the structure of redundancy. Following the lead of information - theoretic formulations which take up the philosopher's distinction - I equated information with reference (correlations between input and output, between sender and receiver) and meaning with the structure of redundancy in the sense that Garner (1962) uses this phrase. Whereas information processing reduces redundancy, meaning enhances it by innumerable variations on the structure of a theme. In subsequent publications a case was made for relating competence to information processing and meaning: As noted earlier, competence was defined as the reciprocal of equivocation where equivocation is the sum of noise and redundancy in an information transmission channel (Pribram and McGuinness, 1975; Pribram, 1976).

What this definition of meaning means for utterances is that meanings are conveyed by patterns of repetitions of referents, repetitions of the information to which the elements of the utterances (phonemes. words) refer. The information conveyed by a literary masterpiece may be encapsulated in an abstract or digest - what makes the original exercise a masterpiece is the meaning generated by slight variations on the informative theme, a theme that is perhaps endlessly repeated as in the repetitions of behavior that characterize the tragic hero in Greek drama. The very variations themselves assume some basic repetitive pattern so that variation can be assessed.

Recently, Zajonc (1968) has performed a series of experiments which resulted in data of central concern to this issue of the effect of repetition. Zajonc showed that subjects would express a liking or dislike for a verbal or geometric pattern simply on the basis of how often that pattern had been repetitiously experienced and that this liking or dislike appeared to be relatively independent of what the pattern referred to in cognitive consiousness. Furthermore, reaction times in expressing the feelings were shorter than those expressing recognition.

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* For example, Rudolf Carnap in Meaning and Necessity (947, p.126): "In traditional logic we often find two correlated concepts: on the one hand, what was called the "extension" or "detonation" (in the sense of J.S. Mill) of a term or a concept; on the other hand what was called its "intention", "comprehension", "meaning" or "connotation".

In another series of experiments performed in my laboratory (Pribram, Lim, Poppen and Bagshaw, 1966; Pribram and Tubbs, 1967; Pribram, Plotkin, Anderson and Leong, 1977) it was shown that the amygdala of the limbic systems and the related frontal cortex are critically involved in processing redundancy. In still other experiments also carried out in my laboratory (Schwartzbaum and Pribram, 1960; Schwartzbaum, Wilson and Morrissette, 1961; Kimble, Bagshaw and Pribram, 1965; Bagshaw, Kimble and Primbram, 1965 Bagshaw and Benzies, 1968; Luria, Pribram and Homskaya, 1964) these frontolimbic formations were shown to be involved in habituation to novelty. The major finding in these experiments was that while repetition produces behavioral habituation in normal human and non human primates, subjects with frontolimbic lesions failed to habituate. Further, this loss of behavioral habituation is accompanied by loss of visceroautonomic responses to dishabituation (orienting) when the repititious stimulus is varied, i.e. made novel. These results were interpreted to suggest that behavioral habituation was dependent on the visceroautonomic components of the orienting reaction. Loss of habituation and visceroautonomic reactions did not, however, preclude repetition from producing discrimination learning (Douglas and Pribram, 1966). On the other hand, lesions of the posterior cortical convexity result in severe disturbances of discrimination learning and performance (see reviews by Pribram, 1954, 1960, 1971, 1974).

Thus the neurobehavioral and psychophysiological data obtained in these experiments are in consonance with the distinction resulting from the Zajonc experiments that repetition is processed by two separate mechanisms. What is added by the Zajonc results is that liking (and disliking) are produced by habituation. Clinically, lesions in the region of the amygdala produce a syndrome of "deja or jamais vu", an inappropriate feeling of familiarity or unfamiliarity. The neurobehavioral and psychophysiological data had always been interpreted in the context of these clinical observations in terms of a novelty-familiarity dimension. The new evidence suggests that this reading of the clinical data was in error. It is the feeling of familiarity (or unfamiliarity) that should have been emphasized. The fact that the feeling was inappropriate to the circumstance (as indicated by a recognition measure) clearly supports the newer conceptualization.

To summarize these findings: Repetition results in habituation and recognition. Variations on a repetitive pattern (novelties) evoke dishabituation (orienting) which is felt and the feeling is generated independently of recognition of the variation. The thesis to be pursued here is that while the aesthetics of music is a function of the recognition of variations, musical meaning results from the generation of feelings produced by these same variations on patterns of repetition. Clynes (1977; this volume) has a considerable body of research on this issue: He has demonstrated which patterns (essentic forms) evoke which feelings in a variety of different peoples and cultures.

MUSICAL MEANING

Bernstein struggles with these very same ideas in his analysis of musical meaning (pp 119-122): "Ah Meaning. There's the rub." In the next paragraph he begins an analysis of ambiguities of meaning which he claims to be neither exclusively phonological nor syntactic but both. He uses Chomsky's ambiguous sentence, "The whole town was populated by old men and women". The ambiguity stems, of course, from the fact that "old" could modify only "men" or both "men and women". Bernstein points out that the ambiguity in meaning has been produced by a deletion which produces a figure of speech known as "zeugma", meaning in this case two nouns yoked to one adjective.

He goes on to draw the musical analogy: "Try to think of all that melodic material on top as a series of nouns. Now think of the harmonic support underneath as verbal adjective. Put it all together, and what have we got? A zeugma; with the same unchanging adjective modifying all those different nouns."

Bernstein goes on to suggest that by reapplying the transformation rule of deletion to the sentence "The whole town was populated by old men and women", this already ambiguous sentence can be turned into an even more ambiguous sentence: "The whole town was old men and women", which could be a line of poetry. a poetic statement. He defines poetry in terms of its potential to evoke multiple meanings (see also Jakobson and Halle, 1956).

What is lacking in Bernstein's analysis is the recognition of a branch of linguistics (and cognitive science as a whole) which Charles Peirce called Pragmatics (1934). Bernstein does emphasize the historicity involved in making the deletions which result in ambiguity and therefore allow what Peirce calls abductive, metaphorical meanings to emerge. But the centrality of use, the pragmatics of the constructions, have not been as clearly recognized as they might have been - either by Bernstein or Chomsky or for that matter any other linguist. Philosophers, on the other hand, have joined the issue in terms of the distinction between intension and extension (Searle, 1979).

What Bernstein does provide is a framework for understanding the structure of pragmatics of use. He clearly distinguishes this form of meaning from reference although reference must underly it. He notes, for instance, that in musical metaphor the computations that are needed to unravel linguistic reference (which he calls semantic weights: my dog, your dog, all dogs etc.) are totally absent (pp 126-127).

Nor are references to the feelings of the composer or performer to be mistaken for musical meaning: "Music has intrinsic meanings of its own which are not to be confused with specific feelings or moods and certainly not with pictorial expressions or stories" (p 131).

No, meanings are derived from the intrinsic organization of the music, its structure. This structure intends and evokes feelings rather than referencing them. As noted above, this evocation derives from repetition and variations on these repetitions. As also noted, the most pervasive generative transformations (in the Chomskian sense) that evoke such feelings are deletions: "we delete all those logical but unnecessary steps that are built into the deep structure of any comparison and wind up with our conclusive simile" (p 124). Note that the logic of the structure (its deep or underlying structure) has a repetitive familiar core before deletion can be used effectively: "In other words variation cannot exist without the previously assumed idea of repetition. This assumption explains the deletion we heard at the beginning of the symphony" (p 161).

Repetition, redundancy, is therefore the key to the problem of meaning in music. "How many times have I repeated the word "repeat" in this short development?" (p 161). But as Bernstein and others (Garner, 1962; Pribram, 1976) have emphasized, redundancy can be structured and variations can be made on that structure. In terms of the experimental data reviewed above and by Clynes (this volume), such structured variation generates feelings and it is these feelings which give meaning to music.

In fact, as noted earlier, there is ample evidence that semantic reference and pragmatic meaning are processed separately, that the back and front parts of the brain work differently and that in this difference lies the distinction between semantic reference and pragmatic generative meaning as it has been pursued here (Pribram, 1954, 1958a, b, 1960, 1971, 1973, 1976, 1979). The frontolimbic portions of the forebrain have been shown by experiment to be involved in the generation and control of feelings produced by repetition (see above paragraph and review by Pribram and McGuinness, 1975). Furthermore, the processing of variations on repetition, especially temporal variations, has been demonstrated to be a function of the frontolimbic formations of the forebrain (Milner, 1954; Pribram and Tubbs, 1967; Pribram, Lim, Poppen and Bagshaw, 1966).

By contrast, the posterior cortical convexity is involved in image and information processing - the processing (recognition) of the invariances that can be extracted from sensory input to the brain (reviewed by Pribram, 1954, 1958a, b, 1960). These posterior cortical systems operate to reduce redundancy(by correlation, not deletion) , acting much as an editor searching for novelty (Barlow, 1961). Redundancy reduction, the processing of information, constitutes the aesthetics of music (Pribram, 1969a, 1979b) but does not provide "meaning" in the sense that this concept has been pursued here.

In short, neurobehavioral evidence clearly supports the distinction between referential information and meaning generated, as in Bernstein's analysis, by variations on repetitions - the structure of redundancy. What remains to be accomplished is some agreement as to what to call the distinction. Cognitive psychologists use the term semantic store or lexicon to deal with the organization of indicants (derived from images) and symbols (derived from information, i.e., categorical alternatives). They apply the term "episodic" or episode specific to constructions that cluster about some specific incident or context. I have followed the usage of computer scientists and termed image and information processing (of indicants and symbols) "context-free" and episodic processing "context dependent" or "context sensitive" (Pribram, 1971, 1977). These terms were meant to convey the fact that processing by the posterior cortical convexity proceeds hierarchically while processing by the frontolimbic mechanisms has a more web-like "associative" organization. The emphasis by Bernstein on deletion which is also found in Chomsky's work (1980) makes me wonder whether a web-like structure (Quillian, 1967) is secondarily derived from a more hierarchical logical structure by deletion or whether associative structures form independently of logical ones.

MUSIC AND LANGUAGE

The answer to this question may come from an examination of the types of grammar that have been found useful in analyzing linguistic performances. The simplest of these are the stochastic and state dependent grammars in which any particular utterance falls out, as it were, of the probabilities set up by previous utterances. Flesch counts of the incidence of usage of words in the English language are based on such a model and have been found wanting in explaining not only natural speech (Miller, Galanter, and Pribram, 1960) but also language disabilities due to brain damage (Howes, 1957a, b, 1964). A more effective though still limited model has been phrase structure grammar in which the hierarchic relationships between groupings of utterances are mapped. One of Chomsky's major contributions has been to demonstrate the limitations of the phrase structure grammar and to suggest:

(1) that transformations occur in language;

(2) that these transformations are rule governed by rules which transcend the hierarchical organizations of phrase structures; and

(3) that these rules evoke meaning.

What has occupied Chomskian linguistics for the past twenty years is the attempt to specify clearly what such rules might look like.

Meanwhile, computer scientists have been developing organizations of programs that can make them function more usefully. These organizations have departed from simpler hierarchical organizations of list structures which characterized earlier attempts in enhancing artificial intelligence. The new developments go under such names as procedures (Winograd, 1977). scripts (Schank and Abelson, 1977). They are eminently pragmatic in that they group together in a cluster those routines (parts of programs) that are repeatedly used, mark the cluster and call up that marked cluster whenever it is needed. The advantage of such procedures is that computation can simultaneously proceed in several clusters and the results of the computation flexible addressed in response to some overarching "executive" program.

I have elsewhere (Pribram, 1973b) drawn the comparison between the functions of the frontal cortex of primates and such flexible noticing orders and executive programs. The neurobehavioral evidence thus suggests that a procedural pragmatics is the basis for transformational rules. Bernstein has identified in his pursuit of a linguistic analysis of music one very powerful set of procedures for us:

(a repetition
(b) variation in repetitions that generate novelty (note that invention and inventory share the same root), and
(c) deletions of repetitions which generate potential meanings through ambiguity.

My neurobehavioral results obtained on non human primates suggest that this set of procedures is generally applicable to the problem of specifying the nature of transformations and of a generative grammar. It is for this reason that I found Bernstein's contribution exciting and valuable.

The analysis, should it prove viable, has an interesting consequence for understanding music and natural language, especially as used in poetry. These consequences are that the evocative aspects of cognitive competencies are not so much due to transformational rules as they are to transformational procedures. The search for hierarchically organized rule-structures leads in every instance to a phrase-structure grammar. Transformations on these phrase structures are episode specific, involve a large amount of historicity, occur within the context of phrase structures and are extremely context sensitive. Whether one wishes to call such relatively arbitrary (i.e., context dependent) procedures 'rule' governed remains an open question. The resemblance is more to a case than to a phrase structure as has been emphasized by Fillmore (1968). The important point is that the structure of transformational procedures is distinct from a hierarchically organized phrase structure grammar and that different brain systems are involved in organizing the hierarchical and transformational structures.

I believe that comparing music with natural language has been most rewarding: Despite the severely limited information processing and resulting referential semantics, music is rich in meaning. This meaning is derived from pragmatic procedures which also enrich natural languages especially in their poetic usages. Pragmatic procedures are based on repetition, on variations of repetitions and on deletions of expected repetitions. It is processes such as these which have been shown to be functions of the frontolimbic formations of the forebrain which can therefore be considered to construct the long sought-after principles of transformations which are the cornerstone of Chomskian generative grammar. Transformations are shown, however, to be procedural in that they are episode and context specific rather than hierarchically organized: case structural rather than phrase structural. Pragmatic variations on repetitions, deletions of expected phrases, associative clusterings involving a large amount of historicity can be sharply distinguished from hierarchically organized rule structures. This analysis based on the study of music has thus proved a fascinating and unsuspectedly fruitful foray into cognitive science.

SUMMARY

This chapter reviews experiments that relate brain function to musical ability. The results of these experiments are then related to others on natural language in order to construct a theory of how the brain functions when music is created and appreciated. On the level of music the theory involves the work of Chomsky, Bernstein and that of Lerdahl and Jackendoff. On the level of brain function evidence is reviewed to show that different neural systems are involved in syntactic, semantic and pragmatic processing.

The suggestion is made that music and natural language share syntactic structuring. However, music and natural language differ in that natural language is primarily referential (i.e. semantic) while music is primarily evocative (i.e. pragmatic). These suggestions are applied to a theory of meaning which distinguishes reference and evocation not only on logical but also on neurological grounds.

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