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Music Perception

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THIS essay on music perception is divided into two parts. Part I will be a brief historical review of the thinking in this field; Part II will explore certain issues of current interest.

The study of music perception has a fascinating history. From the time of Pythagoras in the sixth and fifth centuries B.C., the subject was dominated by two factors: a profound distrust in the evidence of our senses and an obsession with numerology. Heraclitus (ca. 536-470 B.C.) wrote that "the eyes and ears are bad witnesses for men";[1] later Anaxagoras (ca. 499-428 B.C.) stated that "through the weakness of our sense-perceptions we cannot judge truth,"[2] an attitude that continued into the Middle Ages, and prompted Boethius (A.D. 480-524) to write: "For what need is there of speaking further concerning the error of the senses when this same faculty of sensing is neither equal in all men, nor at all times equal within the same

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[1] K. Freeman, *Ancilla to the Pre-Socratic Philosophers* (Cambridge, 1948), p. 32.

[2] *Ibid.*, p. 86.

DEUTSCH, DIANA, ***MUSIC PERCEPTION***, Musical Quarterly, 66:2 (1980:Apr.) p.165

man? Therefore anyone vainly puts his trust in a changing judgment since he aspires to seek the truth."[3]

This rationalistic stance was reinforced by the strong theoretical link, also stemming from the Pythagoreans, between music and astronomy. It was argued that the planets as they moved must produce sounds, which would vary with their speeds and distances from the earth. It was further argued that the distances between the earth and the various planets were such that the combination of sounds produced must form a harmony. Figure 1 shows the Pythagorean view of the universe, giving the distances of the heavenly bodies relative to each other, and the musical intervals thus formed. The distance from the Earth to the Moon comprised a whole tone, from the Moon to Mercury a semitone, from Mercury to Venus a semitone, from Venus to the Sun one and a half tones, from the Sun to Mars a tone, from Mars to Jupiter a semitone, from Jupiter to Saturn another semitone, and from Saturn to the Supreme Heaven, yet another semitone.[4]

Considerable discussion centered on the issue of why, if the heavenly bodies produce this harmony, we are unable to hear it. Censorinus suggested that the loudness of this sound is so great as to cause deafness.[5] Another view, described by Aristotle (who did not however endorse it), was that since this sound is present at all times, and since sound may be perceived only in contrast to silence, we are not aware of its presence.[6]

Nevertheless, the connection between music and astronomy in ancient and medieval times was so strong that the scientific part of the program of higher education developed into the Quadrivium, the "related studies" of astronomy, geometry, arithmetic, and music. And even in this century Paul Hindemith endorsed this association, writing that Kepler's "three basic laws of planetary motion, expounded at the beginning of the seventeenth century, could perhaps not have been discovered, without a serious backing of music theory."[7]

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[3] Boethius, *De Institutione Musica*, trans. C. M. Bower as *Boethius' The Principles of Music* (Ann Arbor, 1967), p. 58.

[4] Sir John Hawkins, *A General History of the Science and Practice of Music* (1853; reprint, New York, 1963), I, 64.

[5] *Ibid.*, p. 65.

[6] Aristotle, *De Caelo*, trans. J. L. Stocks in Vol. II of *The Works of Aristotle* (Oxford, 1930), 290.

[7] *A Composer's World* (New York, 1961), p. 9.

DEUTSCH, DIANA, ***MUSIC PERCEPTION***, Musical Quarterly, 66:2 (1980:Apr.) p.165

However, the Copernican revolution weakened the connection between music and astronomy, since it became clear that the planets did not form a harmony. But the strongly rationalistic and numerological approach to musical issues persisted. There were a few enlightened thinkers who pleaded for empiricism; notable among these was Galileo's father, Vicenzo Galilei, and another, interestingly, was Descartes. Yet their writings had little impact, and in 1862 Hermann von Helmholtz expressed his concern on this issue in *On the Sensations of Tone*. In his Introduction he wrote: "Up to the present time, the apparent *connection* of acoustics and music has been wholly external, and may be regarded as an expression given to the feeling that such a connection must exist, than as its actual formulation."[8] And yet, despite these writings, the numerological approach has prevailed until recently.

However, we are now witnessing a very interesting phenomenon. The development of electronic music and the increasing use of the computer as a tool in musical composition have caused a profound change in the thinking of many music theorists, particularly those who are also composers. In order to make effective use of this new technology, they need to obtain answers to various questions in perceptual psychology. For example, they need to ascertain the characteristics of a complex sound spectrum that give rise to a single sound image, and those that give rise to several simultaneous but distinct sound images. Since sounds of any spectral composition can now be produced electronically, they wish to characterize the dimensions underlying the perception of musical timbre, so that they can create sounds that vary systematically along these dimensions; and since they are no longer restricted to sounds generated by natural instruments, they need to understand the perceptual and mnemonic constraints of the listener, so that their music will not fall on uncomprehending ears.[9]

This same technological development has provided psychologists with the tools with which to explore the brain mechanisms underlying our processing of music, a field of investigation that has been severely hampered by technological difficulties involved in generating complex auditory stimuli with precisely controlled parameters.

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[8] *On the Sensations of Tone*, 4th ed., trans. A. J. Ellis (1885; reprint, New York, 1954), p. 1.

[9] M. Babbitt, "Past and Present Concepts of the Nature and Limits of Music," *Perspectives on Contemporary Music Theory*, ed. B. Boretz and E. T. Cone (New York, 1972), pp. 3-9.

DEUTSCH, DIANA, ***MUSIC PERCEPTION***, Musical Quarterly, 66:2 (1980:Apr.) p.165

However, with present-day computer technology, these problems have essentially disappeared, and we can now capitalize on advances made in other areas of cognitive psychology to investigate attentional mechanisms in music, the organization of systems underlying memory for musical information, and so on. Similarly, the field of psychoacoustics has tended, mainly for technological reasons, to be restricted to the investigation of narrow stimulus parameters. This field is now expanding to include perception of complex acoustic configurations, and the questions posed by scientists here interface heavily with those posed by musicians.

Because of this new interest on the part of both scientists and musicians, there is at present an explosion of collaborative work involving both disciplines, for example at Bell Telephone Laboratories, Stanford University, the University of California, the University of Pennsylvania, IRCAM in Paris, and the University of Melbourne in Australia. This type of interaction is developing so rapidly that we are at a turning point in the history of the subject.

II

One field of investigation concerns the ways in which musical information is organized by our perceptual system. When we listen to music, we do not simply process each element as it arrives; rather we form simultaneous and sequential groupings out of combinations of elements. Listening to music therefore involves a continuous process of decision as to which elements should be linked together. This leads us to inquire into the principles whereby such linkages are formed.

Over half a century ago, the Gestalt psychologists proposed that we group stimuli into configurations on the basis of various simple perceptual principles.[10] One of these is the principle of Proximity, which states that nearer elements are grouped together in preference to elements that are spaced farther apart. An illustration of this principle is shown in Figure 2a, where the closer dots appear to be grouped together in pairs. Another is the principle of Similarity, which is illustrated in Figure 2b. Here configurations are formed out of like elements, so that we perceive one set of vertical rows formed by the filled circles and another formed by the unfilled circles. A third is

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[10] M. Wertheimer, *Untersuchungen zur Lehre von der Gestalt.* II. *Psychologische Forschung* (1923), IV, 301-50.

DEUTSCH, DIANA, ***MUSIC PERCEPTION***, Musical Quarterly, 66:2 (1980:Apr.) p.165

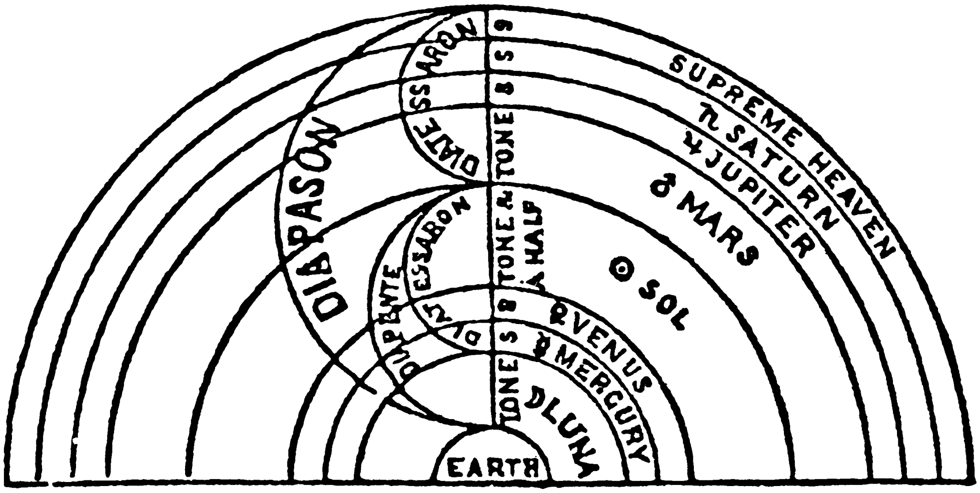

Figure 1. Pythagorean view of the universe, in musical intervals. From Sir John Hawkins *A General History of the Science and Practice of Music,* I (1853; reprint, London, Dover, 1963), 65.

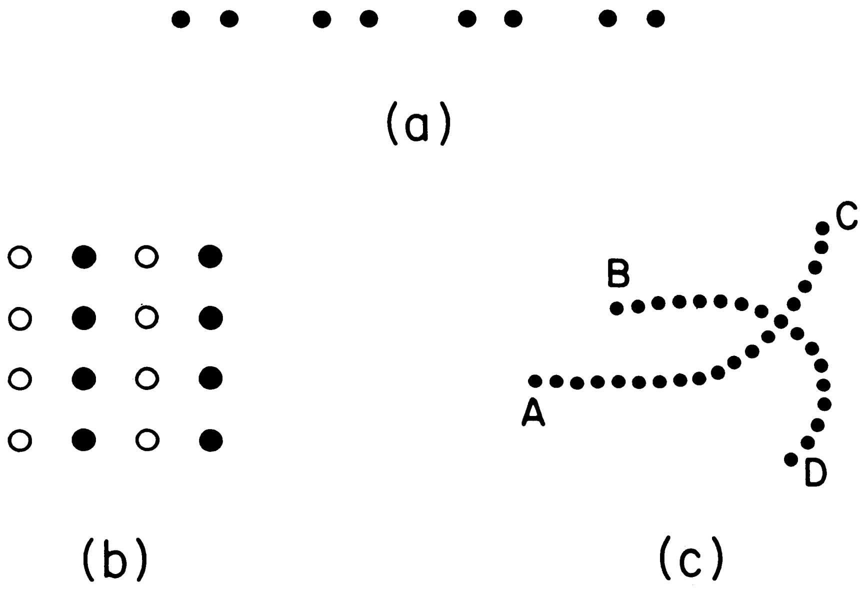

Figure 2. Illustrations of the Gestalt principles of Proximity, Similarity, and Good Continuation.

DEUTSCH, DIANA, ***MUSIC PERCEPTION*** , Musical Quarterly, 66:2 (1980:Apr.) p.165

the principle of Good Continuation, which states that elements that follow each other in a given direction are perceived as grouped together. For instance, the dots in Figure 2c are perceptually grouped so as to form the two lines AC and BD. A fourth, the principle of Common Fate, states that elements which tend in the same direction are perceived as grouped together.

It has been demonstrated that these principles are important determinants of grouping in the case of visual arrays,[11] and this has also been found true of music. It seems reasonable to suppose that grouping in conformity with these principles enables us to interpret our environment most effectively [12] For example, in the case of vision, proximal elements are more likely to belong to the same object than those that are spaced farther apart. The same argument holds true for similar elements compared with those that are dissimilar. In the case of hearing, similar sounds are likely to be coming from the same source and different sounds from different sources. A sequence of sounds that changes smoothly in frequency is likely to be coming from a single source, as are components of a complex sound spectrum that rise and fall in synchrony.

Considerable interest has focused on frequency proximity as an organizing factor in music, using the technique of presenting a single stream of tones in rapid succession. When such tones are drawn from two different frequency ranges, the listener perceives, not a single stream of tones, but two parallel streams. This perceptual phenomenon forms the basis of the technique of pseudopolyphony. A sequence of tones, drawn from two different pitch ranges, is played in rapid succession with the result that the listener hears two parallel melodic lines. With such rapid sequences, temporal relationships are easily perceived between tones in the same frequency range, but are poorly perceived between tones in different frequency ranges, a phenomenon that manifests in several different ways. For example, if you present a sequence of tones drawn from two different frequency ranges in rapid succession (i.e., at a rate of about ten per second), perception of the orders of these tones can be very difficult.[13] When

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[11] R. L. Gregory, *The Intelligent Eye* (New York, 1970); N. S. Sutherland, "Object recognition," in *Handbook of Perception*, Vol. III of *Biology of Perceptual Systems*, ed. E. C. Carterette and M. P. Friedman (New York, 1973), pp. 157-86.

[12] *Ibid.*

the presentation rate is slowed down, so that order perception is readily accomplished, there is still a gradual breakdown of temporal resolution, as the frequency disparity between two alternating tones increases. For example, it becomes increasingly difficult to detect a rhythmic irregularity in a pattern of such alternating tones.[14]

Another technique which demonstrates the importance of frequency proximity as an organizing principle involves presenting two simultaneous streams of tones in different spatial locations. Just as rapid sequences of single tones are disorganized in the temporal domain to accommodate frequency proximity, so sequences of simultaneous tones are disorganized in the spatial domain to accommodate this principle. The illusion is created that tones in one frequency range are emanating from one region of space, and tones in another frequency range from a different region.

The sequence that I first used to demonstrate this illusion, shown in Figure 3a, consisted of a major scale, played simultaneously in both ascending and descending form. The sequence was presented through earphones, such that when a tone from the ascending scale was in one ear, a tone from the descending scale was in the other ear, and successive tones in each scale alternated from ear to ear. The most common percept is illustrated in Figure 3d, which consists of two melodies, one formed by the higher tones and the other by the lower tones. The higher tones all appear to be emanating from one earphone and the lower tones from the other. When the earphone positions are reversed there is often no corresponding change in the percept. This creates the further illusion that the earphone that had been emitting the higher tones is now emitting the lower tones, and that the earphone that had been emitting the lower tones is now emitting the higher tones.[15]

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[13] A. S. Bregman and J. Campbell, "Primary auditory stream segregation and perception of order in rapid sequences of tones," *Journal of Experimental Psychology* (1971), LXXXIX, 244-49. See also W. J. Dowling, "The perception of interleaved melodies," *Cognitive Psychology* (1973), V, 322-37.

[14] L. P. A. S. Van Noorden, "Temporal Coherence in the Perception of Tone Sequences" (Ph.D. diss., Technische Hogeschoel Eindhoven, Eindhoven, The Netherlands, 1975).

[15] D. Deutsch, "Two-channel Listening to Musical Scales," *Journal of the Acoustical Society of America* (1975), LVII, 1156-60.
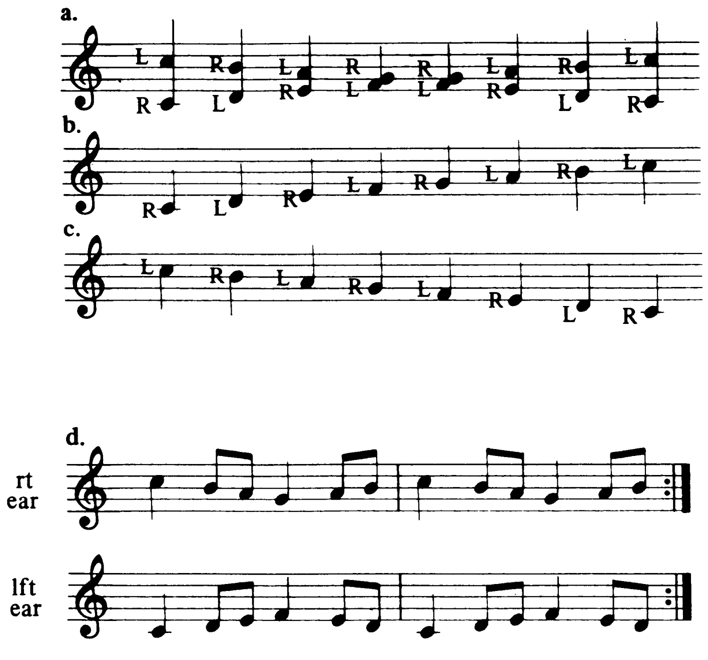
Figure 3. (a) Sequence giving rise to the scale illusion; (b) the ascending component alone; (c) the descending component alone; (d) illusory percept depicted by a listener with absolute pitch. This percept was the one most frequently obtained. (Deutsch, *Journal of the Acoustical Society of America,* LIX, 1156-60. Copyright 1975 by the Acoustical Society of America. Used by permission.)

In a recent study, David Butler at Ohio State University has extended these findings to a broad range of musical situations.[16] This sequence was presented to music students through spatially separated loudspeakers in a free sound-field environment. The listeners notated separately the sequence that they heard as emanating from the speaker on the right and the one that they heard as emanating from the speaker on the left. In some instances, the tones were generated on a piano. In addition, differences in timbre and loudness were sometimes introduced between the stimuli presented through the

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[16] "A Further Study of Melodic Channeling," *Perception and Psychophysics* (1979), XXV, 264-68.

DEUTSCH, DIANA, ***MUSIC PERCEPTION***, Musical Quarterly, 66:2 (1980:Apr.) p.165

different speakers. It was found that, despite these variations, almost all responses reflected groupings by frequency proximity, so that higher and lower melodic lines were perceived, each apparently emanating from a different speaker. A further interesting finding was that when differences in timbre were introduced between the stimuli presented through the two speakers a new tone quality was perceived, but it appeared to be coming simultaneously from both speakers. Thus not only were the spatial locations of the tones perceptually rearranged in these configurations but their timbres were rearranged also.

In order to determine whether these findings generalize to other melodic configurations, listeners were presented with further two-part contrapuntal patterns. It was found that again almost all responses reflected grouping by frequency proximity. The two simultaneous sequences were perceptually reorganized so as to produce the illusion that a melody corresponding to the higher tones was emanating from one speaker, and a melody corresponding to the lower tones from the other.

How can we explain these mislocalization effects? Our auditory environment is very complex, and the assignment of sounds to their sources is made difficult by the presence of echoes and reverberation.[17] Thus when a sound mixture is presented so that one ear receives one component and the other ear a different component, it is unclear from first-order localization cues alone which elements of this mixture should be assigned to which source. Other cues must also be utilized to determine the sources of these different sounds, one of which is similarity of frequency spectrum. Similar sounds are likely to be coming from the same source and different sounds from different sources. So with these examples it would be reasonable to assume that tones in one frequency range are emanating from one source, and tones in another frequency range from another source. Our perceptual system therefore reorganizes the tones on the basis of this interpretation.[18]

Another principle by which musical configurations are organized is that of Good Continuation. Ira Hirsh and his colleagues at the Central Institute for the Deaf have shown, for example, that listeners can better identify the orders of tones presented in rapid sequence

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[17] A. H. Benade, *Fundamentals of Musical Acoustics* (New York, 1976).

[18] D. Deütsch, "Musical Illusions," *Scientific American* (1975), CCXXXIII, 92-104.

DEUTSCH, DIANA, *MUSIC PERCEPTION* , Musical Quarterly, 66:2 (1980:Apr.) p.165

when these tones follow a unidirectional frequency change than when they do not.[19]

A further principle is that of Similarity, which is reflected in grouping on the basis of timbre, a grouping that occurs frequently in natural musical situations. Overlaps in pitch range between figure and ground are far more common when different instrument types are involved, reflecting the greater perceptual separation provided by the timbral difference. The technique is often used of presenting adjacent phrases on different instruments to enhance their distinctiveness.[20]

A striking demonstration of the perceptual separation arising from differences in timbre was produced by Richard Warren and his colleagues at the University of Wisconsin[21] in which they generated repeating sequences of four unrelated sounds: a high tone, a hiss, a low tone, and a buzz. Each sound lasted for 200 milleseconds, and the sounds followed each other without pause. It was found that listeners were quite unable to name the orders of the sounds in these repeating sequences. In order to achieve correct naming, it was necessary to increase the duration of each sound to over half a second.

The question then arises: If groupings are formed between first-order acoustic elements, how are these abstracted so as to give rise to perceptual equivalences and similarities? We recognize a visual shape when it is presented in a different size, or a different orientation, or a different position in the visual field. What transformations result in an analogous equivalence in music?

This question can be examined at several levels. First we may inquire into the types of abstraction that result in the perception of local features. Such features may be considered similar to those of orientation or angle size in vision. Other low-level abstractions give rise to the perception of global features, such as contour. We can then consider how such features are further combined so as to produce perceptual equivalences and similarities.

One of the most compelling features based on pitch is termed "tone chroma" by psychologists and "pitch class" by music theorists. Tones which stand in octave relation have a strong perceptual simi-

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[19] P. L. Divenyi and I. J. Hirsh, "The Effect of Blanking on the Identification of Temporal Order in Three-Tone Sequences," *Perception and Psychophysics* (1974), LVI, 144-51.

[20] R. Erickson, *Sound Structure in Music* (Berkeley, 1975).

[21] R. M. Warren, C. J. Obusek, R. M. Farmer, and R. P. Warren, "Auditory sequence: Confusions of Patterns and other than Speech or Music," *Science* (1969), CLXIV, 586-87.

DEUTSCH, DIANA, ***MUSIC PERCEPTION***, Musical Quarterly, 66:2 (1980:Apr.) p.165

larity under certain conditions. For this reason, pitch has been described as a bidimensional attribute; the first dimension being a monotonic function of frequency and the second defining the position of a tone within the octave.[22] Various representations of pitch have been proposed that accommodate these two dimensions. For example, M. W. Drobisch in 1855 suggested that pitch be represented as a helix, with tones separated by an octave lying most proximal within each turn of the helix.[23]

The bidimensional nature of pitch has been exploited to produce compelling illusions. Roger N. Shepard, then at Bell Telephone Laboratories, reasoned that since one of the components of pitch is circular one might, by appropriately exaggerating this component and minimizing the dimension of height, manage to map all tones an octave apart onto the same tone, so that the helix would essentially be collapsed onto a tonal circle. Judgments of relative pitch should as a result become completely circular. So, using a computer program for sound synthesis generated by Max Mathews, Shepard produced a set of complex tones, each of which consisted of several sine-wave tones separated by octaves. When these tones were presented in ascending semitonal steps, listeners perceived a set of tones that constantly increased in pitch and never decreased. The percept thus generated was of a set of tones that endlessly climbed up an abstracted octave.[24]

Later Jean-Claude Risset reasoned that the dissociation between these two pitch dimensions could be further exploited in the following way. By keeping all the frequencies fixed, but gradually enhancing the higher components relative to the lower, one can obtain a sound where tone chroma is invariant but tone height rises. Alternatively, one can keep the spectral envelope constant but systematically decrease the fundamental frequency. So by combining these two principles one can construct a sequence where tone height systematically increases, but tone chroma systematically decreases. In this way, the impression is obtained of a sequence that paradoxically ascends and descends at the same time.[25]

[22] G. Révész, *Zur Grundlegung der Tonpsychologie* (Leipzig, 1913).

[23] *Über die mathematische Bestimmung der musikalischen Intervalle*, Abh. d. Kgl. Sachs. Ges. D. Wiss. math-phys. Cl. b. II. (1885), 35.

[24] "Circularity in Judgments of Relative Pitch," *Journal of the Acoustical Society of America* (1964), XXXVI, 2345-53.

[25] "Paradoxes de Hauteur: Le Concept de Hauteur Sonore n'est pas le Meme Pour Tout le Monde," *Seventh International Congress on Acoustics* (Budapest, 1971), pp. 613-16.

DEUTSCH, DIANA, ***MUSIC PERCEPTION***, Musical Quarterly, 66:2 (1980:Apr.) p.165

If the perceptual similarity of tones separated by octaves can be so compelling, one might be tempted to assume that it holds true for all types of musical processing. But this is not necessarily the case. Some time ago, I proposed a neurophysiological model for the abstraction of pitch relationships which assumes that this takes place along two separate and parallel channels. Along one of these channels, there is convergence of information from neural units underlying tones separated by octaves; this gives rise to octave equivalence effects. Along the second channel, there is no such octave convergence, but instead abstraction of frequency ratios takes place. This second channel therefore mediates transposition of tonal sequences.[26]

This two-channel hypothesis makes a prediction that would seem rather implausible a priori; namely that it should be very difficult to identify well-known tunes when their component tones are placed randomly in different octaves. (This prediction only holds true if the listener is not informed of the identity of the tune before hearing it.) To examine this prediction, the following experiment was performed. The first half of "Yankee Doodle" was chosen as the test sequence, which was generated in three different ways: first, it was produced without transformation of each of three adjacent octaves; then it was generated so that each tone was in its correct position within the octave, but the choice of octave placement varied randomly within these same three octaves; and then it was generated as a series of clicks so that the pitch information was removed entirely but the rhythmic information was retained. This was to provide a measure of identification performance on the basis of rhythm alone.

The three versions of the tune were played to different groups of listeners, who were given no clues as to its identity besides being assured that it was well known. It was found that although the untransformed melody was identified correctly by all the listeners, identification of the version with octave displacements was no better than when the pitch information was removed entirely. This simple experiment demonstrates the need for caution in the matter of octave equivalence. Clearly it is a powerful principle in some musical situations, but does not operate at all in others.[27]

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[26] D. Deutsch, "Music Recognition," *Psychological Review* (1969), LXXVI, 300-7.

[27] D. Deutsch, "Octave Generalization and Tune Recognition," *Perception and Psychophysics* (1972), XI, 411-12.

DEUTSCH, DIANA, ***MUSIC PERCEPTION***, Musical Quarterly, 66:2 (1980:Apr.) p.165

Another area where progress has been made concerns the features that give rise to the perception of musical timbre. Classically, experiments on timbre perception have been concerned with tones in the steady state. Especially noteworthy is the work of Reinier Plomp and his associates in Soesterberg, for instance in demonstrating the role of the critical band[28] in timbre perception.[29] Other work has focused on analyzing timbre perception for natural instrument tones. The work of Jean-Claude Risset and Max V. Mathews has been particularly influential here.[30] They used the technique of digitizing and analyzing samples of natural instrument tones, extracting a set of physical parameters from this analysis, and then synthesizing tones according to these parameters. Listeners then judged the similarity between the real and synthesized tones, so that the relevant perceptual features could be identified. Such work has demonstrated that temporal characteristics of a tone are critical determinants of its timbre, with the attack segment being most salient.

Recently, interest has developed in plotting the perceptual similarities between different instrument tones in a multidimensional timbre space. As a result of such work, the dimensions underlying timbre perception can now very effectively be harnessed.[31] For example, in a study by John M. Grey at Stanford University, a series of tones was created which traversed this multidimensional space in small steps, so that the listener first perceived one instrument, say a clarinet, and at some point in the series realized that he was in fact hearing a different instrument, say a cello. Yet the perceptual transition between one instrument and the other appeared quite smooth.[32] Such work is clearly of interest to composers who can now designate series of tones that take specified paths in this timbral space, and so create what Schoenberg called "Klangfarbenmelodie" or melody composed of timbres.

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[28] The critical band is that frequency band within which the loudness of a band of sound of constant sound pressure level is independent of bandwidth.

[29] "Timbre as a Multidimensional Attribute of Complex Tones," in *Frequency Analysis and Periodicity Detection in Hearing*, ed. R. Plomp and G. F. Smoorenburg (Sijthoff, 1970).

[30] "Analysis of Musical Instrument Tones," *Physics Today* (1969), XXII, 23-30.

[31] D. L. Wessel, "Psychoacoustics and Music," *Bulletin of the Computer Arts Society* I (1973), 30-31; J. R. Miller and E. C. Carterette, "Perceptual Space for Musical Structure," *Journal of the Acoustical Society of America* (1975), LVIII, 711-20.

[32] "An Exploration of Musical Timbre" (Ph.D. diss., Stanford University, 1975).

DEUTSCH, DIANA, ***MUSIC PERCEPTION***, Musical Quarterly, 66:2 (1980:Apr.) p.165

Progress has recently been made in our understanding of the mechanisms underlying perception of musical intervals and intonation.[33] Particularly influential work has been performed by Dixon Ward and his associates at the University of Minnesota. One important finding from this group is that identification and discrimination judgments involving melodic intervals exhibit categorical perception under certain conditions.[34] Intervals falling within a category are reliably judged as equivalent, and the boundaries between such categories are sharply defined. Such categorical perception is remarkably similar to that found for the perception of speech sounds.

These are just a few areas of research on music perception; however, work of importance to both scientists and musicians is proceeding in several other areas. Following the pioneering of Paul Fraisse and his colleagues in Paris,[35] we are developing an understanding of the cognitive mechanisms involved in rhythm perception and production. Hierarchical schemes developed by music theorists such as Leonard Meyer[36] are being investigated with the techniques of experimental psychology. Representational schemes for tonal music are also being developed by psychologists,[37] analogous in some respects to those proposed by Noam Chomsky[38] and others for linguistics. These are paralleled by formulations developed by Heinrich Schenker and his followers in music theory.[39]

The outlook for this new area of research is indeed promising. Musicians and scientists are rapidly arriving at theoretical agreement and are together pursuing common goals; scientists are bringing to

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[33] P. Boomsliter and W. Creel, "Extended Reference: An Unrecognized Dynamic in Melody," *Journal of Music Theory* (1963), VII, 2-22; W. D. Ward, *Musical Perception*, Vol. I of *Foundations of Modern Auditory Theory*, ed. J. V. Tobias (New York, 1970), 407-47.

[34] E. M. Burns and W. D. Ward, "Categorical Perception — Phenomenon or Epiphenomenon: Evidence From Experiments in the Perception of Melodic Musical Intervals," *Journal of the Acoustical Society of America* (1978), LXIII, 456-68.

[35] *Les Structures Rhythmiques* (Paris, 1956).

[36] G. W. Cooper and L. B. Meyer, *The Rhythmic Structure of Music* (Chicago, 1960); L. B. Meyer, *Explaining Music: Essays and Explorations* (Berkeley, 1973).

[37] H. A. Simon and R. K. Sumner, "Pattern in Music," in *Formal Representation of Human Judgment*, ed. B. Kleinmuntz (New York, 1968), pp. 219-50; F. Restle, "Theory of Serial Pattern Learning: Structural Trees," *Psychological Review* (1970), LXXVII, 481-95; H. C. Longuet-Higgins, "Perception of Melodies," *Nature* (1976), CCLXIII, 646-53; D. Deutsch and J. Feroe, "A Hierarchical Model for the Generation of Tonal Sequences" (in preparation).

[38] *Aspects of the Theory of Syntax* (Cambridge, 1965).

[39] M. Yeston, ed., *Readings in Schenker Analysis and Other Approaches* (New Haven, 1977).

DEUTSCH, DIANA, ***MUSIC PERCEPTION*** , Musical Quarterly, 66:2 (1980:Apr.) p.165

this new collaboration their technological expertise, their understanding of methodology, and knowledge of related disciplines, and musicians are bringing their invaluable intuitions concerning the building blocks of musical experience and the ways in which these are organized. Given this powerful combination, we should expect to see exciting developments in the years ahead.