Hentet fra Grove, så huske å se på ex på nettet, som ikke kommer med her: http://www.oxfordmusiconline.com/subscriber/article/grove/music/42574?q=psychology+of+music&search=quick&pos=1&_start=1#firsthit

**Psychology of music.**

Psychology of music is the discipline that studies individual human musical thought and behaviour from a scientific perspective. Activities that have been studied using the tools of psychology include sensation and perception, listening, performing, creating, memorizing, analysing, learning and teaching. These activities have been studied across the lifespan of individuals, from birth to old age, and in a variety of social contexts, from domestic, through educational, to therapeutic and professional.



**Psychology of music, §I: History**

## I. History

### 1. Antiquity to the 19th century.

Speculation concerning sound and music goes back to ancient times. The first reported experiments relating to the psychology of music are credited to Pythagoras in the 6th century bce. He is said to have demonstrated that the perceived pitch of a vibrating string varies inversely with its length, and is also credited with establishing that the musical consonances of the octave, 5th and 4th correspond to simple ratios formed by different lengths of string. His followers, however, lost faith in the experimental method and instead attempted to explain musical phenomena purely in terms of mathematical relationships. For example, Anaxagoras (*c*499–428 bce) held that the sense perceptions were too weak to permit the establishment of scientific truth. Later, the music theorist Boethius (480–524 ce), a dedicated Pythagorean, wrote in *De institutione musica* (Eng. trans. in Bower, 1967, p.58): 'What need is there to speak 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 man? Therefore anyone vainly puts his trust in a changing judgment since he aspires to seek the truth'.

An important dissenter from the numerical stance of the Pythagoreans was Aristoxenus (*c*320 bce), who argued forcefully that music could not be understood solely by considering mathematical relationships. He foreshadowed modern study of the psychology of music by arguing that musical phenomena were perceptual and cognitive in nature and should be studied as an experimental science. In his treatise *On Harmonics* he wrote (Eng. trans. in Macran, 1902, pp.102–4):

"It is plain that the apprehension of a melody consists in noting with both the ear and intellect every distinction as it arises in the successive sounds – successive, since melody, like all branches of music, consists in a successive production. For the apprehension of music depends on these two faculties, sense perception and memory; for we must perceive the sound that is present and remember that which is past. In no other way can we follow the phenomenon of music."

Aristoxenus was not understood by his contemporaries, nor by the music theorists of the

Middle Ages and Renaissance, whose thinking was firmly rooted in the numerical approach of the Pythagoreans. However, because of the Pythagorean influence, music was included in the scientific programme of higher education, the *quadrivium* of the ‘related studies’ of astronomy, geometry, arithmetic and music; as a result, most of the leading figures of the scientific revolution wrote extensively on music and the way it is perceived (Hunt, 1978).

The generation of thinkers preceding those of the scientific revolution included some remarkable musical empiricists. Two in the 16th century were particularly noteworthy. G.B. Benedetti is considered to have been the first to relate the sensations of pitch and consonance to vibration frequencies. Vicenzo Galilei, the father of Galileo, made a number of important discoveries. He showed by experiment that, although consonant intervals were associated with simple numerical ratios for pipe and string lengths, this was not true, for example, for the relative weights of hammers nor for the relative volumes of pipes. He also showed that, with the length of a string held constant, varying its other parameters, such as material, thickness and tension, resulted in alterations in its perceived pitch. From such findings Galilei argued against a rationalistic approach to music, in particular explanations based solely on simple numerical ratios, and contended that music perception should be considered an empirical science. In the same vein, anticipating many present-day psychologists, Galilei claimed that disputes over tuning systems were useless, since the small differences in tuning that are at issue were not detectable (Palisca, 1961).

Scientists of the early stages of the scientific revolution, such as Mersenne, Galileo, Kepler, Huygens and Descartes, all made important contributions to the understanding of music perception. At this time, relationships between pitches and rates of vibration were established in strings, pipes and bells, with careful documentation of the involvement of other factors such as material, thickness and tension in the case of strings. The phenomenon of beats was discovered, as was the harmonic series, and sympathetic resonance was explored. Issues such as tuning and temperament were extensively discussed, as were consonance and dissonance (Cohen, 1984). This last issue was particularly strongly debated. Galileo favoured a low-level approach, arguing that consonance was perceived when there occurred a distinct pattern of beating on the eardrum (*see* **CONSONANCE**), and that dissonance was perceived when the beating was irregular (Eng. trans., repr. in Lindsay, 1972, p.151):

“The offence [the dissonances] give, proceeds, I believe, from the discordant and jarring pulsations of two different notes, which, without any proportion, strike the drum of the ear … Those pairs of sounds shall be consonances and will be heard with pleasure, which strike the *timpanum* in some Order … that the cartilage of the *timpanum* or drum may not be subject to a perpetual torment of bending itself in two different ways, in submission to the ever-disagreeing percussion.”

Mersenne placed the site of the interactions giving rise to the perception of consonance and dissonance further along the auditory pathway. But Kepler argued that high-level factors were instead responsible (Eng. trans. in Cohen, 1984, p.31):

“It seemed best to me to define any sense organ in such a way that the sense perception that brings forth pleasure or grief is not completed until the species of the organ that is destined for the perception in question, as it is affected from outside, has reached inwards, through the guidance of the spirits, the tribunal of the general sense.”

Descartes presented what is essentially the present-day view of this issue by distinguishing between sensory consonance on the one hand and musical consonance on the other, the first being considered a low-level and the second a high-level phenomenon (Eng. trans. in Cohen, 1984, p.169):

“But in order to determine what is most agreeable, one should consider the capacity of the listener, which changes like taste, according to the person in question… But one can say absolutely which consonances are the most simple and the most accordant ones; for that depends only on how often their sounds unite, and how closely they approach the nature of the unison.”

Among the remarkable group of scientists of this period, the one who contributed most to the empirical study of music was Mersenne, whose *Harmonie universelle* (1636–7) is a landmark in the history of the subject. He is credited with several notable discoveries. He devised an ingenious experimental method by which he showed that the vibration frequency of a string varies inversely with its length. In this way, he was able to relate the sensation of pitch to vibration frequency, and so to explain the inverse relationship between pitch and string length that had been known since Pythagorean times. Also using this method, Mersenne was able to estimate the vibration frequency that corresponded to a particular pitch.

Mersenne also noticed and investigated the phenomenon of beats – the waxing and waning in loudness that occur when tones that are close in frequency are sounded together. In addition, he discovered that complex instrument tones were composed of a fundamental together with a number of harmonics, and was even able to identify by ear the first five components of the harmonic series. Mersenne anticipated later work on timbre by hypothesizing that the sounds produced by different musical instruments could be characterized by the mixtures of harmonics they contain.

Notable among scientists of the late 17th and the 18th centuries who contributed to the understanding of sound were Wallace, Sauveur, Newton, Bernouilli, d'Alembert and Euler. The invention of calculus by Newton and Leibniz was a breakthrough of fundamental importance to the understanding of acoustics. An important mathematical contribution was later made by Fourier (1822) who showed that any curve can be represented by the superposition of a number of simple harmonic curves. Later, Ohm (1843) extended Fourier's analysis to sound waves. Specifically, Ohm's acoustical law states that any complex periodic sound wave can be analysed into an appropriate set of simple waves of specified frequency, amplitude and phase; this mathematical analysis formed an important basis for later theorizing about sound and its perception. Technological advances about this time enabled experimenters to explore the perception of simple sounds with carefully controlled parameters. Such work included the invention of the siren by Cagniard de Latour (1819) and the invention of the tonometer by Scheibler (1834). Resonators, first described by Helmholtz (1863; see §I, 2, below), enabled investigators to analyse complex tones into their constituent frequencies.

Armed with these new technologies, scientists began the systematic exploration of certain basic characteristics of the hearing mechanism. A number of investigators, including Savart (1830), Helmholtz (1863) and Koenig (1899), made determinations of the lowest frequencies that could be heard, and arrived at values ranging from 8 to 32 Hz. Later, Wegel (1922) measured the threshold of audibility as a function of frequency in the range from 20 Hz to 20 KHz. Other scientists, such as Luft (1888) and Vance (1914), attempted to measure the smallest detectable difference in pitch.

**Diana Deutsch**

### 2. 1860–1960.

An empirical psychology of music slowly began to develop during the latter half of the 19th century – that is, at the same time as psychology became established as an independent scientific discipline. Initially, most studies were limited to the perception of single tones or tone combinations. Helmholtz aimed to provide a scientific foundation for musical aesthetics by attempting to demonstrate how pitch is analysed by the ear and how timbre, intervals, chords, scales, keys and tonality may ultimately be related to the structure of harmonics in tones. The complete title of his *Die Lehre von den Tonempfindungen als physiologische Grundlage für die Theorie der Musik* (1863) indicates his ambition to bridge the gap between physical and physiological acoustics on the one hand and musicology and aesthetics on the other. Helmholtz emphasized that music had a closer relationship to pure sense impressions (‘reine Sinnesempfindungen’) than any other art form. At the same time, however, he noted that the same properties of the human ear apparently could serve as foundation for quite different musical systems, thus pointing to the importance of artistic invention and cultural differences.

Unlike Helmholtz, the philosopher Carl Stumpf (1848–1936) had no laboratory of his own but had to make his observations in other institutions in physics or physiology or by using church organs, working with musicians – for instance, the violinist Joseph Joachim – and, not least, relying on his own experience as musician (he played the violin). His *Tonpsychologie* (1883–90) is an extensive treatment of perception and judgment of tones, in succession (vol.i) and heard simultaneously (vol.ii). On several topics he was able to predict results that could be confirmed only much later in more controlled investigations. Thus he discussed perceptual dimensions of timbre such as brightness and darkness, sharpness, fullness and roughness, and the physical correlates of perceived timbre. He observed that the same musical interval seems perceptually larger in higher octaves than in lower, a phenomenon later observed in connection with the mel scale (*see* **SOUND, §4**). A possessor of absolute pitch, he noted the advantages of this ability, for instance, when following complex modulations, but stressed that good relative pitch is generally more important for musicians. He described consonance in terms of perceptual fusion of the component tones into a single impression, most pronounced for the octave, followed by the 5th, the 4th, 3rds and 6ths, whereas other intervals show little fusion (and are dissonances). Earlier, Helmholtz had described dissonance in terms of rapid beats, an explanation not far from the much later explanation of sensory consonance and dissonance as related to critical bandwidths in hearing (Plomp and Levelt, 1965).

The emphasis on single tones rather than on real music was probably also due to so-called structuralism or association psychology, the first school in empirical psychology. According to this view, psychology should analyse experiences in our consciousness, using analytical introspection by trained observers in order to find the smallest elements in experiences and the principles for how they were combined (‘mental chemistry’). The chief proponent of this school was Wilhelm Wundt (1832–1920), who founded the first experimental psychological laboratory in Leipzig in 1879. In the third volume of his monumental *Grundzüge der physiologischen Psychologie* (1911) he devoted much space to rhythm. Results from analytical introspection indicated that experience of rhythm included recurring auditory and kinaesthetic sensations and feelings of tension and relaxation. Rhythm was a popular subject for research by psychologists around 1900, and Wundt and many others studied how successive elements were grouped depending on tempo and on varying types of accent (see Gabrielsson, 1986). Wundt's (1905) emotion theory postulated three bipolar dimensions – pleasantness *v.* unpleasantness, excitement *v.* calmness and tension *v.* relaxation – which recur in many later studies of emotional expression in music.

Beginning in the 1910s, structuralism and analytical introspection were soon abandoned in favour of Gestalt psychology in Europe and behaviourism in the USA. Gestalt psychologists claimed that perception aims at finding good ‘figures’ (patterns, Gestalts), and that the whole is more than the sum of its parts. Gestalts are formed according to various principles (Köhler, 1929; Koffka, 1935) such as proximity (elements close to each other tend to form a Gestalt), similarity (similar elements tend to form one) and good continuation. Most examples were drawn from visual perception; there was little discussion of music. For instance, a melody (or a Gestalt) may be transposed to another key so that only a few or even none of the original tones appear in the transposed version, yet the melody is perceived as the same. Melodies are usually dominated by small intervals (principle of proximity) and performed using the same timbre (similarity). Of course, rhythms too are obvious examples of Gestalts. Fraisse (1956, 1974) described rhythm in terms of 'temps longs' and 'temps courts'. In production as well as reproduction of rhythms a clear distinction tends to be made between long and short elements, whereas elements of slightly different durations tend to be assimilated (that is, perceived or reproduced as of the same length). Both principles can be regarded as examples of a striving to achieve good Gestalts. Further applications of Gestalt principles to music, using somewhat different terminology, appeared much later (Bregman, 1990).

Gestalt psychology also influenced Géza Révész (1878–1955), the best-known European music psychologist during the first half of the 20th century. His most important contribution to music psychology was probably the so-called two-component theory of musical pitch (1913), meaning a distinction between tone height, continuously rising from low to high pitch, and tone quality ('chroma'), recurring anew in each octave (**fig.1**). The independence of these two components was later illustrated in a well-known demonstration by Shepard (1964). The German music psychologist Albert Wellek (1904–72) further elaborated this distinction, going as far as indicating the existence of two types of listeners, a 'linear' type who mainly attends to tone height and a 'cyclic' type who focusses on tone chroma (Wellek, 1939, 1963). Such typologies, however, are not now generally accepted. In *Einführung in die Musikpsychologie* (1946), Révész discussed colour hearing, music experience in deaf persons, and such controversial questions as whether different keys have different characters and whether there is any connection between mathematical and musical abilities. Révész described several tests of musicality devised by himself; however, they were never standardized and are thus practically forgotten. He also wrote a monograph (1925) about a musical prodigy.

Two-component theory of musical pitch. Tone height is represented by the vertical dimension, tone qualities (chromas) by the circle. Tone quality repeats itself through each octave (each new round of the rising helix): reproduced from E.G. Boring, H.S. Langfeld and H.P. Weld: Foundations of Psychology (New York, 1948), 320 after A. Gabrielsson (contributer)

In the USA, psychology was much influenced by the school of behaviourism. Behaviourists claimed that, in order to become a science, psychology had to abandon the study of phenomena in consciousness ('mentalism') and instead concentrate on the study of behaviours. Although music psychology too has been influenced by this school – see, for instance, the textbook by Lundin (1953) – behaviourism has perhaps had more impact on music education, emphasizing the importance of proper reinforcement to improve the learning of various musical skills, than on music psychology. Indeed, the pioneer of music psychology in the USA, Carl E. Seashore (1866–1949), was not fond of behaviourism. He gathered a large group of researchers at the University of Iowa who investigated the performance of music on the piano and the violin and in singing, using specially designed equipment for accurate recording of timing, dynamics and intonation; he thereby demonstrated numerous 'deviations' from the designations in the musical score (Seashore, 1937, 1938; Gabrielsson, 1986, 1999). This research was interrupted by World War II, but many of the results (e.g. on vibrato) are now standard material in texts on music psychology. It was some decades before studies of music performance again received attention (Gabrielsson, 1999; see also §IV below).

The best-known part of Seashore's work was the *Seashore Measures of Musical Talents* (1919, 1939, 1960), which consisted of tests of elementary abilities such as discrimination of pitch, loudness, duration and timbre, as well as further tests of rhythm and tonal memory. They have been much criticized as lacking real musical content (e.g. Mursell, 1937). However, Seashore's conception of musicality was much broader than is usually supposed. In *The Psychology of Musical Talent* (1919) he described the musical mind in terms of musical sensitivity, musical action, musical memory and imagination, musical intellect and musical feeling, each of these areas including several factors. To find a person's capacity in these different areas, he proposed about 30 different measures, including the six mentioned above and many others, such as acuity of hearing, auditory and motor imagery, precision of movement, timed action, voice control, musical association and emotional reaction to music. These latter measures, however, never came into general use.

The concept of musicality was also discussed by Billroth (1895), von Kries (1926), Révész (1946), Wing (1948), and Lundin (1953). The *Wing Standardized Tests of Musical Intelligence* (1948, 1960) include tests of chord analysis, pitch change, memory, appreciation of rhythm, harmony, intensity and phrasing.

Besides the works already mentioned, a number of textbooks demonstrated the increasing breadth of music psychology during this period: various topics in musical listening and performance (Schoen, 1927, 1940; Mursell, 1937; Seashore, 1938, 1947; Truslit, 1938), the effects of music on behaviour (Diserens, 1926), musical composition (Bahle, 1936) and the social psychology of music (Farnsworth, 1958). An individual treatment of music psychology was proposed by the Swiss musicologist Ernst Kurth (1931), mainly based on his own musical experience and with a terminology much borrowed from physics (‘musikalische Energie’, ‘Kraft, Raum, Materie’). Later reviews on activities during this time are, among others, of works on psychoanalytic approaches to music (Feder, Karmel and Pollock, 1990) and on performance (Gabrielsson, 1999).

**Alf Gabrielsson**

### 3. The late 20th century.

Music psychology of the late 20th century focussed on four main topics: (*a*) the cognitive representation of pitch and rhythm (and the emergent properties of harmony and melody); (*b*) the development of musical competence and skill; (*c*) processes underlying musical performance; and (*d*) the affective processes associated with music listening (e.g. preference, emotion). Almost all this work has been directed towards the music of the Western tonal tradition, with particular concentration on the period from Bach onwards.

Since the 1960s the dominant force shaping psychological investigations into music has undoubtedly been cognitive psychology. This sub-branch of psychology grew out of applied research during World War II into such phenomena as the capacity of radar operators to maintain vigilance. Sophisticated experimental techniques were developed which used quantitative aspects of performance on carefully controlled tasks (rather than introspective report) to infer the nature of underlying mental processes (Broadbent, 1958). The main theoretical tool was (and remains) the computational metaphor. The human mind was conceptualized as a complex set of interlinked but specialized programmes. Just as the early (and to a certain extent continuing) preoccupation of cognitive psychologists was with perception and representation of complex inputs (such as language; see Neisser, 1967), so the vast bulk of music psychology research of the late 20th century was concerned with the psychological processes underlying hearing, perception and memory for music (following the seminal lead of, for instance, Deutsch, 1982). The reasons for this are complex (see Sloboda, 1988) but include the scientific wish to control as many aspects as possible of an experimental situation. Performance studies must loosen these controls, studies of composition must almost abandon them.

However, the emphasis on reception over production has important resonances with the nature of music engagement in contemporary urban and technologically orientated cultures. The vast majority of people in these cultures hear music many times a day but seldom compose or perform it. Psychology, like all sciences, seeks to generalize, and therefore has a predisposition to study phenomena that can be found in the many in preference to those to be found only in the few.

Cognitive psychology has also achieved its greatest successes in advancing the understanding of processes that span seconds rather than minutes or hours. For instance, a great deal is known about how human beings process words and a lot about how they process sentences, but almost nothing about how they process extended discourse, as found in books or plays. Similarly, music research has yielded immense dividends at the level of notes, chords and phrases, but very little at the level of complete works.

It is significant to note how a few core themes run through much of the work on music psychology:

(*a*) The relationship between measurable properties of sound and mental events is not straightforward. The human mind both adds to and subtracts from the acoustic surface in complex and sometimes counter-intuitive ways.

(*b*) These relationships are made more complex by a range of differences between people based on such factors as age, musical experience, social context and biological development.

(*c*) Music is multi-dimensional in its essence, and although it is possible to obtain some understanding of the operation of each dimension in isolation, the interplay of these dimensions in real music creates combinatorial complexities which severely limit the rate of progress of scientific understanding of anything but the most simple musical sequences.

(*d*) The dimensions of music that figure in traditional musical discourse (pitch, rhythm, metre, harmony, form) have proved fruitful concepts for psychological research, and have generally been clarified, rather than challenged, by psychological results.

(*e*) Despite demonstrable abilities of the perceptual system to learn to deal with increasing levels of musical complexity, there are psychological limits that place boundaries on the type of information that human listeners could, even in principle, extract and store from a musical source. Psychology, therefore, offers a strong challenge to the claim that audiences are infinitely educable by the avant garde. It is possible that music could be written that is not comprehensible by listeners, even in principle (Lerdahl in Sloboda, 1988).

Although the cognitive approach dominates music psychology, it has not totally inhibited other approaches. For instance, the study of musical skill and its acquisition has combined insights from cognitive theory with developmental, social, emotional, personality and motivational psychology. The study of the musical capacities of babies and young children has also integrated evolutionary, socio-biological and cross-cultural perspectives within a broadly cognitive approach. Neuropsychological approaches have gained significant momentum following the availability of new methods of recording brain activity during normal perception.

Because music psychology concentrates on the listener, it has yielded fewer practical outcomes than some might wish for. In general, listeners simply enjoy the music they choose and do not feel it necessary to inquire into the processes that lead to their enjoyment. Performers are often similarly reluctant to understand too much about the scientific basis of their art lest it somehow be corrupted by such knowledge. They might rather look to psychologists to offer advice on how to deal with performance anxiety and other psychological problems associated with the life of a musician. Although there exists useful research on these topics (e.g. Wilson, 1994), such research should perhaps be seen as an application of general psychology to musical life rather than an exploration of central themes in the psychology of music. Possibly the psychology of music tends to stand back from these applied problems, focussing instead on more philosophically based questions such as ‘what elements is music in the mind made up of, given that it is demonstrably not an acoustic replica of the sound source?’, ‘what is it that makes a set of sounds cohere together in the mind as a musical unit?’ and ‘how is it that music can be the mediator of such strong and significant emotion?'. Applications of these questions to performance and composition will come indirectly out of the deepening understanding of the psychological bases of the underlying processes, as much as from piecemeal attempts to provide 'fixes' for particular limited-scale problems. For this reason, a strategic decision has been taken to limit the scope of the following sections of this article to fundamental, rather than applied, research. Much of the applied research focusses on educational problems; a representative body of such research is to be found in the *Journal of Research in Music Education* (1942–).

Although music-related research has been published in almost every psychological journal of note, since 1970 several specialist journals have emerged that cater exclusively to music psychologists: *Psychology of Music* (1973), *Psychomusicology* (1981), *Music Perception* (1983) and *Musicae Scientiae* (1997). They and the sources they cite constitute an almost complete record of the progress of the discipline over the last decades of the 20th century. In addition, the following books provide authoritative overviews of music-psychological research: Howell, Cross and West, 1985; Dowling and Harwood, 1986; Miller, 1989; Riess-Jones and Holleran, 1990; Butler 1992; McAdams and Bigand, 1993; Aiello, 1994; Deliège and Sloboda, 1996, 1997; and Hargreaves and North, 1997.

**John Sloboda**

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## II. Perception and cognition

### 1. Pitch.

#### (i) Introduction.

In listening to a piece of music one may experience pitches that are sounded successively or simultaneously as forming coherent patterns which unfold as the piece progresses; one may hear both melody and harmony. Many aspects of these heard patterns – such as the sense that particular pitches seem more 'stable' than others, or that simultaneously sounding pitches fit more (or less) well together, or that the occurrence of certain pitches is highly predictable – appear to conform to the theoretical precepts of tonality or part-writing. Research, however, indicates that several factors that are not reducible to a single principle play a role in our experience of pitch.

There are two main approaches to the study of pitch cognition, one centring on sensitivity to acoustical frequency and to frequency relations, the other on the influence of generic cognitive processes. Research in the early 20th century generally conformed to the first approach, developing from the pioneering work of Helmholtz. Its proponents, notably Seashore (see Seashore, 1938), believed that pitch constituted the direct correlate of acoustical frequency, the relation between pitch and frequency being mediated solely by the dynamics of our peripheral auditory mechanisms. Hence the experience of a difference between two pitches was identified with the perception of a difference, or a ratio, between two frequencies. Empirical studies conducted within this research tradition tended to focus on the perception of isolated tones or tone combinations. However, some of the results of this reductionist approach proved difficult to square with the intuitions of musicians and theorists. For instance, Stevens's *mel* scale of pitch (see Stevens and Volkmann, 1940) could be interpreted as implying that the same interval would differ considerably in size according to the register in which it occurred. This type of disparity, together with the emergence of cognitive psychology in the 1950s, stimulated research that focussed on the role of generic cognitive factors in shaping the experience of musical pitch (see Shepard, 1982).

### (ii) Cognitive approaches.

Early work within this second approach, such as that of Francès (1958), indicated that factors other than frequency relations motivated many types of musical judgment, such as the tendency of performers to flatten or sharpen particular notes of the scale in particular melodic contexts. Dowling (1978) revealed the importance of notions such as scale and contour in musical perception, while Longuet-Higgins (1976) and Deutsch (1982) concentrated on providing accounts of the types of cognitive representation that could underlie the experience of pattern in musical pitch.

The most substantial research programme to have explored the role of generic cognitive factors in organizing pitch is that of cognitive-structuralism, developed initially by Shepard and Krumhansl, and elaborated and extended by the latter and others (see Krumhansl, 1990). The cognitive-structuralist view is that, underlying our perceptions and judgments of pitch relations, there is some form of schema (a mental structure that organizes the information received from our senses and is itself altered by that information, shaping our interpretations of what we encounter and determining the nature of our experiences: see Neisser, 1976). It postulates that the experience of pattern in musical pitch is better explained in terms of a multi-dimensional model than in terms of a one-to-one correspondence between pitch and frequency. In this view, pitches separated by the interval of a semitone can be thought of as being experienced as similar in a manner different from that in which pitches separated by the interval of an octave are similar, semitonal similarity and octave similarity corresponding to different and distinct psychological dimensions. The addition of another dimension, representing perceived similarity of pitches separated by the interval of a 5th, produces a model with structural properties similar to those proposed by Longuet-Higgins and by Balzano (1980, 1982). **Fig.2** combines the 'circle of 5ths' dimension and the semitonal or 'chroma' dimension, collapsed across octaves.

Multi-dimensional, cognitive pitch representation: the 'circle of 5ths' dimension and the semitonal ('chroma') dimension (after Shepard, 1982, p.363)

A comprehensive series of experiments (many detailed in Krumhansl, 1990) appears to substantiate the existence of a multi-dimensional cognitive representation of pitch. These experiments examined the perception of pitch in a musical context. Listeners were presented with short sequences of pitches or chords; then a single pitch or chord was played and listeners were asked to indicate how well it fitted with the context. Further experiments involved pairs of pitches or chords, with listeners being asked to indicate how similar these were to each other. The listeners were not required to respond in explicitly musical terms; they merely provided numerical ratings of degree of fit or similarity. Researchers were able to infer from their responses that particular pitches and chords were perceived as being consistently more or less stable or referential according to their relation to the contexts in which they were heard. For example, pitches interpretable as the tonic, mediant or dominant of a preceding major or minor context were judged to fit the contexts better than other scale notes, which themselves fitted better than non-scale chromatic notes (**fig.3**). Similarly, in both geometric and formal logical representations of listeners' responses to chords that followed harmonic contexts, it was found that triads on the tonic, subdominant and dominant were clustered more closely than were triads on other scale degrees, and that such representations produced coherent 'maps' of inter-key harmonic relations. These results were found even when listeners had only moderate amounts of formal musical training.

Cognitive pitch perception in relation to harmonic context (after Krumhansl, 1990, p.31)

These representations of intra-key and inter-key pitch relations are interpreted by the cognitive-structuralists as constituting components of long-term musical memory, and as embodying a tonal hierarchy. It is suggested that the 'tonal hierarchy' is established in the long-term memory of a listener through long-term exposure to music that exhibits consistent and systematic features of pitch usage that conform to principles of Western tonality. Each instance of a tonal piece is experienced as embodying a specific and unique hierarchy of pitches, its 'event hierarchy' (see Bharucha, 1984); the importance of any particular pitch within the event hierarchy is determined by factors such as its frequency of occurrence or total sounding duration, and the salience accorded to it by its occurrence on metrically strong beats or at phrase boundaries. The regularities of all the different event hierarchies that a listener abstracts through exposure to many tonal works give rise to the tonal hierarchy in long-term memory (see §4 below).

Theoretical studies (see Krumhansl, 1990, chaps.3 and 5) and empirical research (Cuddy, 1997) appear to confirm the outlines of this process in which representations of tonal pitch relations, and tonal harmonic relations, are built up in long-term memory through abstraction and schematicization of the regularities of pitch usage in tonal works; these long-term representations play a significant role in shaping the experience of pitch relations in future listening. Developmental research (Krumhansl and Keil, 1982) has indicated that children systematically acquire sensitivity to tonal-hierarchical relations, with young children differentiating first between diatonic and non-diatonic pitches and later between more and less stable diatonic pitches. However, a number of subsequent studies (Speer and Meeks, 1985; Cuddy and Badertscher, 1987; Lamont and Cross, 1994; Lamont, 1998) suggest that the acquisition of a sense of pitch organization is strongly affected by formal musical training rather than simply emerging with increasing age and experience. Nevertheless, even the responses of very young children were found to be structured in ways that seemed to reflect pitch usage in the music to which they had been exposed.

The model of pitch cognition provided by the cognitive-structuralist research programme provides empirically grounded support for several significant theoretical accounts of pitch organization in music, for example Schoenberg (1954) and Lerdahl (1988), the latter an extension of Lerdahl and Jackendoff's generative theory of tonal musical cognition (1983). Nevertheless, this model has been criticized both by musicologists (Cook, 1994) and by other researchers in pitch cognition, who have objected that the experimental methods employed by the cognitive-structuralists tapped into short-term memory rather than long-term representations and that the model of pitch cognition presented in the tonal hierarchy was too static, taking little account of the dynamic attributes of tonal structure. These objections motivated the 'intervallic rivalry' theory (Butler, 1989), which takes explicit account of the fact that certain intervals such as tritones and semitones are less common than others such as perfect 4ths or 5ths within a diatonic framework (Browne, 1981) and may therefore serve to orientate listeners within such frameworks. In this view, the dynamic apprehension of the commonality or rarity of intervals, rather than the application of a static and hierarchical grid of pitch relations, motivates listeners' judgments of pitch stability.

Experimental research (Brown and Butler, 1981; Howell, West and Cross, 1984; Brown, 1988; Brown, Butler and Jones, 1994) indicates that listeners' responses are affected by diatonic rarity or ubiquity of musical intervals, and also that other factors – notably the ordering of pitches within intervals – play a significant role. On the basis of these findings, Brown, Butler and Jones suggest that the two theories accentuate different aspects of tacit knowledge about tonality: the intervallic rivalry model centres on processes of key discovery, the cognitive-structuralist account on processes of reinforcement of tonal function. Nevertheless, both are necessary for a listener to follow tonal music in real time.

### (iii) Psychoacoustical approaches.

In parallel with research focussing on generic cognitive factors, advances in the understanding of peripheral or sensory auditory mechanisms (*see* **HEARING AND PSYCHOACOUSTICS**) spurred the production of theories of pitch perception rooted in the operation of auditory processes. Boomsliter and Creel (1961) suggested that the experience of musical intervals and chords as consonant or dissonant could be accounted for in terms of the periodicities of the neural impulses to which they gave rise. Terhardt (1974, 1978) proposed a theory based on the processes involved in the perception of complex sounds, relying on the fact that a complex periodic sound is usually heard as having a unitary pitch identity (the virtual pitch of the sound, which may or may not correspond to a frequency component physically present in it). He suggested that this perception results from a process of analysing the complex tone into its component frequencies, weighting those components and re-integrating the results of weightings so as to derive a 'virtual' pitch identity for the complex periodic sound. He theorized that processes similar to those involved in complex tone perceptions account for the notion of chords as possessing roots (Terhardt, Stoll and Seewan, 'Pitch' and 'Algorithm', 1982).

This theory has been developed and extended by Parncutt (1988, 1989, 1997), whose account operates on more abstract entities (such as note names) and provides estimations of strengths of pitch relationships between successive chords as well as taking into account musical contextual factors in determining the chords' identities. Like Terhardt, he suggests that the same factors constrain perception of single pitches and chords, these factors deriving from the frequency-resolving power of the inner ear, the latency-period of the auditory nerve and the establishment of a system of pattern recognition based on 'best fit' to the harmonic series. His theory posits that hearing a chord involves an analysis of its constituent pitches, a weighting of these and the assignation of a set of 'virtual' roots to the chord that are weighted according to their likelihood of being noticed. These roots may confer on the chord a unitary identity in perception. The set of chord roots provides an index of the chord's perceptual stability and hence of its capacity to be used referentially; if one root is more more highly weighted than the others the chord is probably stable – a major triad is likely to have a fairly unambiguous root – whereas if several different roots are given the same weighting, the chord is likely to be perceived as unstable (e.g. the *Tristan* chord, which generates several equally likely roots). Parncutt's account provides a rationale for harmonic stability or instability – functionally, consonance and dissonance – that is rooted in the nature of the sensory processes involved in hearing.

### (iv) Auditory scene analysis.

The theories and findings emerging from cognitive and psychoacoustical research on pitch perception should be viewed as complementary rather than antithetical. Researchers in both traditions acknowledge the influence of both sensory and cognitive factors in shaping our experience of pattern in pitch, and any theory of pitch perception that aims to be comprehensive must take account of both (for a more extensive review see Cross, 1997). Despite the inclusiveness of these theories, there remain aspects of our experience of pitch patterning – such as the experience of a melody as a unitary entity rather than as a succession of isolated sound events – that they do not address. Such concerns are central to the theory of 'auditory scene analysis' which emerged from the Gestalt theories of the 1920s and received its most coherent and complex form in the work of Bregman (1990). He defines it (1993, p.11) as 'the process whereby all the auditory evidence that comes, over time, from a single environmental source is put together as a perceptual unit'. This theory focusses on the ways in which details of an environment may be inferred from the regularities of the auditory events that it incorporates, and describes how such inferences might arise from the operation of acoustical, psychoacoustical and cognitive processes. Hence a succession of sounds that are heard as coming from the same location might lead to the inference that a single source is producing them, and on that basis the sounds may be experienced as grouped. Similarly, a succession of sounds that vary gradually and slowly in pitch, or vary by small pitch intervals, is more likely to be experienced as emanating from a single source and hence grouped in perception than is a series of sounds that vary rapidly and by large pitch intervals.

Within Bregman's theory, the 'Gestalt laws' (of similarity, proximity, good continuation etc.) are held to constitute 'best guesses' about the nature of the auditory environment, based either on prior knowledge or on the automatic functioning of the auditory system. These best guesses play a significant role in the operation of auditory scene analysis processes, and contribute to our experience of melodies (and of voices in polyphonic textures) as integrated entities in perception. Auditory scene analysis provides an empirical underpinning for aspects of both the expectation-based theories of Meyer (1956, 1973) and the implication-realization accounts of Narmour (1990, 1992). These theories (particularly that of Narmour) are intended to provide accounts of the dynamical flux experienced by a listener as a piece of music progresses, focussing on the principle ways in which a listener's ongoing expectation can be explained by reference to features of melodic structure as they unfold in time.

### (v) Unified models and unresolved issues.

The disjunct nature of the existing accounts of pitch perception – implicating not only cognitive but also psychoacoustical and ecological factors – derives in part from the strategies adopted by different research traditions, but it reflects a real need to draw on many different sources to account for our experience of pitch pattern in music. It appears that the operation of peripheral auditory mechanisms may determine aspects of harmonic and melodic stability; generic cognitive processes may provide the basis for the abstraction of statistical regularities of pitch usage and for the formation of dynamic and hierarchical schemas; and ecological considerations may determine aspects of temporal integration and segregation of pitches.

A number of theories attempt to integrate peripheral auditory, cognitive and ecological factors within unified frameworks, generally relying on distributed or connectionist ('neural network') models of human cognition. Bharucha's model (1987) is intended to exhibit the sensitivities to pitch structure shown by listeners through a process of unsupervised learning; it embodies multiple levels of pitch representation, ranging from the 'spectral' level (reflecting many of the characteristics of the acoustical signal) to the 'invariant pitch class' level (a highly abstract level of representation in which pitch classes are differentiated by tonal function). Similarly, Leman (1995) has developed a connectionist model that, through exposure to pieces from the tonal repertory, derives a representation of the tonal hierarchy matching that found by the cognitive-structuralists.

Notwithstanding the success of these theories in accounting for our experience of pitch patterning, they require modification to account adequately for the interaction of pitch with other pattern-bearing dimensions of music. Studies such as those of Monahan and Carterette (1985) and Schmuckler and Boltz (1994), and the research of Jones (1993), indicate that temporal structure plays a significant role in determining perception of pitch patterns. Moreover, most of the research elucidating the experience of musical pitch has been directed to the experience of tonal music; little attention has been paid to the perception of post-tonal musics (but see Krumhansl, Sandell and Sergeant, 1987; Dibben, 1994; Stammers, 1995) and almost none to the experience of non-Western listeners of pitch organization within their own music. Castellano, Bharucha and Krumhansl (1984) examined the responses to North Indian music of listeners familiar with the idiom as well as those with little experience of it. Similar processes of abstraction and schematicization appeared to govern the responses of both groups, but only the Indian listeners' responses exhibited a tonal-hierarchical organization appropriate to the music. This study suggests that factors involved in the perception of tonal music by Western listeners may be generalized to the perception of pitch pattern within other cultures, although further research is needed.

*See also* **PITCH** and **TONALITY**.
**Ian Cross**

## 2. Rhythm.

The perception of **RHYTHM** involves the perceptual and cognitive organization of events in time, whereby each sound event is situated in relation to those that have already occurred (memory) and those yet to come (expectancy). Different cognitive processes occur over short and long time-spans.

### (i) Surface organization.

The acoustical signal is first perceptually segmented into separate events corresponding to the attack points of musical elements such as tones and chords (Köhlmann, 1984; Vos and Rasch, 1981). The moment at which an event is perceived to occur is its 'perceived onset' (related to the perceptual centre of phonemes). The time interval between the onset of one event and the onset of its successor is called the 'inter-onset interval' (IOI). The physical duration of an event (i.e. the time interval between its onset and offset) may be shorter than its IOI (e.g. in staccato) or longer (overlapping legato). Rhythmic organization is generally influenced more by IOI than by physical duration (Vos, 1976–7; Vos, Mates and van Kruysbergen, 1995).

IOIs are often perceived categorically in relation to surrounding IOIs (Schulze, 1989). The categories tend to correspond to the note values of music notation and are usually unaffected by typical deviations from metronomic timing (such as rubato). The category to which an IOI is allocated depends on its metrical context (Clarke, 'Categorical', 1987) and the categorization process may be modelled using neural networks (Desain and Honing, 1989). A listener may assign all notes in a rhythm to as few as two IOI categories (e.g. quavers and semiquavers or simply long and short). This is an appropriate strategy, given that 80% of the notes of typical short classical pieces or movements correspond to just two note values, in the ratio 1:2 or (less often) 1:3 (Fraisse, 1982).

### (ii) Grouping and metre.

The events of a rhythm are hierarchically organized in two distinct ways, known as grouping and metre (Cooper and Meyer, 1960; Deutsch, 1982; Lerdahl and Jackendoff, 1983; Handel, 1998; Drake, 1998–9). From a perceptual viewpoint, rhythm is characterized by, and may even be defined as, a combination of these two forms of organization.

A rhythmic or temporal group is defined as a series of events that are close to each other in time. Perceptual groups are formed by segmenting the musical surface at events with relatively long IOIs, or at changes of timbre, register, loudness or articulation (Handel, 1981; Deliège, 1986–7; Palmer and Krumhansl, 1987; Clarke and Krumhansl, 1989–90). When grouping occurs on several hierarchical levels at once, the resultant organization is called a 'hierarchical grouping structure'. At the musical surface, groups correspond to short motifs. Motifs combine to form phrases, which in turn group into longer phrases, extended passages, movements and eventually whole pieces. In experiments to investigate grouping structure, listeners may be asked to listen to a long piece of music and indicate where sections begin and end. Segmentations between groupings spanning longer time periods tend to be associated with longer pauses or striking changes in physical event characteristics (Deliège and El-Ahmadi, 1990). Further evidence for the psychological reality of temporal groups has been obtained by adding clicks to a melody and asking listeners to recall their positions (the clicks tend to 'migrate' in the direction of group boundaries: Sloboda and Gregory, 1980), and by counting errors in musical performances, which tend to occur more often at group boundaries than within groups (Palmer and van de Sande, 1995).

**METRE** is a form of perceptual organization based on temporal regularity (underlying beat or pulse). A sensation of pulse may be evoked by temporal regularity at any level within a sound sequence, or whenever relatively salient events (or motivic patterns) are perceived as roughly equally spaced in time. The musical behaviour that perhaps most clearly reflects the perception of pulse is foot-tapping to music. Cognitively, the process of regularity extraction may be regarded as one of synchronizing an internal time-keeper or clock to music (Wing and Kristofferson, 1973; Povel and Essens, 1984–5; Essens, 1995), tolerating musically typical deviations from periodicity (Shaffer, Clarke and Todd, 1985; Large and Jones, 1998). Temporal regularity may be perceived in the face of considerable deviations from mechanical regularity or rubato. If a sequence abruptly stops, the listener expects the pulse to continue; attention is enhanced at the temporal locations of expected events (Jones and Boltz, 1989).

The perceptual salience of a pulse sensation depends on its **TEMPO**. Musical pulses are confined to a tempo range of roughly 30 to 300 beats per minute, or an IOI range of 200 milliseconds to 2 seconds (Fraisse, 1982), known as an 'existence region' (Jones and Boltz, 1989). The most salient pulses usually have tempos in the vicinity of 'spontaneous tempo' (the tempo at which a participant in an experiment will tap if asked to do so at equally spaced intervals that are otherwise unspecified: Fraisse, 1957). Spontaneous tempo varies widely from one person to another: inter-tap intervals mostly lie in the range of 400 to 900 milliseconds, with a mean (relative to a logarithmic scale) of about 600. A similar range is observed when listeners are asked to tap in time with a piece of music. Sensitivity to small changes in tempo is most acute in the range 300 to 800 milliseconds (Fraisse, 1967; Drake and Botte, 1993). These phenomena appear to have their origins in the physical properties of the human body and suggest a strong connection between perception of rhythm and human movement (walking, dancing, heartbeats): Truslit, 1938; Gabrielsson, 1973; Fraisse, 1974; Clynes and Nettheim, 1982; Kronman and Sundberg, 1987; Todd, 1992; Davidson, 1993; Shove and Repp, 1995; Krumhansl and Schenk, 1997; Parncutt, 1997.

A metrical structure consists of hierarchical levels of pulsation or rhythmic strata (Yeston, 1976). For example, the cognitive structure corresponding to 3/4 metre includes pulses of crotchets and dotted minims, and usually also includes faster pulses (e.g. quavers) and slower pulses (e.g. groups of two bars, or hypermetre: Rothstein, 1989). The multiple pulses that make up a conventional musical metre are mutually consonant in the sense that every event at every level (except the fastest) corresponds to an event at the next-faster level. Simultaneous pulses can also be dissonant (Hlawicka, 1958; Krebs, 1987). From least to most dissonant, three cases can be distinguished: rhythmic displacement, as in fourth-species counterpoint (same period, different phase); polyrhythm (cross-rhythm) such as three against two (same phase, different period: Handel and Oshinsky, 1981; Beauvillain and Fraisse, 1983–4); and both displacement and polyrhythm (different period, different phase), such as the start of Gershwin's 'I got rhythm' (a displaced series of semiquavers against an accompaniment of crotchets). Complex metres such as 9/8 (when arranged (2+2+2+3)/8), in which the crotchet pulse is effectively displaced by a quaver at every bar-line, have not yet been the subject of psychological investigation (but see London, 1995–6).

Whenever temporal regularity is perceived at different levels – whether consonant or dissonant – listeners tend to focus on, or attend to, a single level of moderate tempo (period near 600 milliseconds) and perceive other levels (and hence all events) relative to that level. In the case of the consonant levels that make up a metre, this level is called the 'tactus' (Lerdahl and Jackendoff, 1983) or 'referent level' (Jones and Boltz, 1989). It may be determined experimentally by asking listeners to tap at regular intervals in time with the music. Listeners can switch their attention to faster and slower rhythmic levels at will. In an oscillator model of metre perception, a primary oscillator (corresponding to the tactus) is situated within the optimum tempo range, and may become coupled with other oscillators tuned to other hierarchical levels (Large and Jones, 1998).

Metre also involves characteristic alternations of weaker and stronger beats within each bar or period. Cognitive representations of metres such as 2/4 and 6/8 have been established experimentally using 'probe-tone' methodology (more usually used in investigations of tonality see C.L. Krumhansl: Cognitive Foundations of Musical Pitch

(London, 1990)); the relative strengths of beats within the metre are quantified on a continuous scale (Palmer and Krumhansl, 1990). Such patterns are presumably learnt by repeated exposure to music in given metres and subsquently recognized during listening.

Grouping and metrical structures are intertwined at all levels of rhythmic organization. For example, the first ten notes of the main melody of Mozart's G minor Symphony k550 (**ex.1**) imply as many as four different hierarchical levels of grouping (from two-note phrases to all ten notes) and five metrical levels (quavers, crotchets, minims, semibreves, double-semibreves). The second-last note (*d*″) bears the greatest metrical accent because it belongs to all five metrical levels.

Ex.1 Mozart: Symphony in G minor k550, 1st movement

Over longer time spans, perceptual hierarchies of grouping and metre are generally neither clearcut nor complete (Clarke, 1988). For example, a listener may be uncertain as to whether bars 1 and 2 of a piece, or bars 2 and 3, group together to form a hypermetre. Similarly, there may be ambiguity as to which motifs at the musical surface belong to which phrases at adjacent structural levels. At any given moment in a piece, a listener will have organized past events into incomplete, tentative hierarchies, and on this basis will have expectations regarding how these structures will be maintained as the piece progresses. In the case of two competing, incompatible metrical descriptions of the same musical surface, a listener may switch from one hierarchical description to another, when evidence in favour of the second becomes stronger than that in favour of the first. It is thus not generally possible to give a definitive hierarchical description of the rhythmic perception of a piece of music.

Metrical ambiguity may be said to occur when two incompatible metrical interpretations exist for the same musical surface – in other words, there are two (dissonant) alternatives for the tactus. Metrical ambiguity is more commonplace in musical works than their notation would suggest (Vos, Collard and Leeuwenberg, 1981; Parncutt, 1993–4). In ambiguous cases, listeners tend to choose one interpretation soon after the piece begins and stick to it in the face of evidence to the contrary (Longuet-Higgins and Lee, 1982; Lee, 1991). The cognitive process of switching attention between dissonant rhythmic levels requires either considerable mental effort or a considerable change in performed accentuation (Tuller and others, 1994).

### (iii) Accent.

Everyday usage equates **ACCENT** with loudness: attention can be attracted to an event simply by playing it more loudly (or sometimes more softly) than events in its context. Here accent will be considered synonymous with event salience. Anything that makes an event sound more important than adjacent events, or which attracts the attention of a listener to an event, may be regarded as an accent (Jones, 1987).

The grouping and metrical structures perceived in a piece of music depend ultimately on the timing and 'phenomenal accent' of the events at the surface (Lerdahl and Jackendoff, 1983). The most important contributor to phenomenal accent is typically the IOI between the event and its successor (Steedman, 1977): the longer the IOI following an event, the stronger the accent. The IOI preceeding an event can also contribute to its perceived accentuation, but to a lesser extent (Lee, 1991). Apart from IOI, phenomenal accents are generated by relative loudness (dynamic accents); by articulation (e.g. by switching from legato to staccato); by timbral variation (manipulating the temporal or spectral envelope of events); by adjusting intonation; by melodic contour (melodic accents occur at peaks and valleys in the melodic contour and follow melodic leaps: Thomassen, 1982; Huron and Royal, 1995–6); and by harmonic progressions (harmonic accents occur at dissonances and harmonic changes: Smith and Cuddy, 1989; Dawe, Platt and Racine, 1994–5).

Structural and metrical accents are associated with grouping and metrical structures respectively. At the simplest level, a structural accent occurs at the start and at the end of every rhythmic group (Povel and Essens, 1984–5; Drake, Dowling and Palmer, 1990–91), and a metrical accent occurs at every event in a pulse (or potential tactus). Structural and metrical accents are most likely to be perceived if they occur simultaneously on several hierarchical levels: the greater the number of levels, or the greater the accent at each level, the more salient will be the accent (Todd, 1985–6; Parncutt, 1987; Rosenthal, 1992).

Accents may be either immanent to a (notated) musical work or added to the music during performance. Structural accents are normally regarded as immanent, although they can also be affected by performance (Lester, 1995). Apart from dynamic (loudness) accents, the most important performed accents are **AGOGIC** (Riemann, 1884). Agogic accents are produced by delaying event onsets or lengthening IOIs relative to the prevailing metrical framework (Gabrielsson, 1974; Sloboda, 1983; Clarke, 1988; Palmer, 1989; Repp, 1990;).

Timing variations in rhythmic performance have various functions. A performance that sounds perfectly regular (mechanical, metronomic) is not generally physically regular (Seashore, 1938; Drake, 1993; Gérard, Drake and Botte, 1993; Penel and Drake, 1998) but deviates from physical regularity in the same direction as, but to a smaller degree than, a typical expressive performance (Repp, 1997–8). Thus one function of timing variations is to make a performance sound regular – paradoxically, by making it physically irregular. Timing variations also have the function of clarifying the grouping and metrical structures, rendering them less ambiguous (Sundberg, 1988; Drake, 1993). Agogic accents can tell the listener where to hear the downbeat of a bar (Sloboda, 1983) or the start of a long phrase (Todd, 1985–6). Finally, timing variations affect the emotional character of a rhythm (Gabrielsson and Juslin, 1996). Timing variations are perceptible when they exceed about 20 milliseconds in typical musical performances (Clarke, 1989), falling to six in monotonic isochronous sequences faster than four events per second (Friberg and Sundberg, 1999).

The ease with which a rhythm can be cognitively processed depends on the way different kinds of accent are distributed within the rhythm. Performances tend to be easier to understand, remember and reproduce when performed accents correspond to immanent accents (Drake, Dowling and Palmer, 1990–91; Clarke, 1992–3; Tekman, 1996–7). In the absence of performed accents, rhythms are easier to process when different kinds of immanent accent (e.g. melodic, IOI) coincide (Jones, 1987).

### (iv) Rhythmic organization and tempo.

The perceived organization of a piece of music depends on the tempo at which it is performed (Handel, 1993). Tempo may affect both grouping and metre. The metrical level at which the tactus is located depends on tempo (Handel and Oshinsky, 1981) because distributions of tapping rates to music (measured absolutely, in beats per second) are almost independent of tempo (Parncutt, 1993–4). For example, a listener might tap out quavers when a piece is played slowly and crotchets when the same piece is played twice as fast, thus keeping the tapping rate in the same absolute range. In the case of grouping, the number of elements in a group increases as tempo increases (Clarke, 1982), keeping their absolute length about constant.

Patterns of agogics and dynamics depend on a performer's perceptual organization of a piece, and thus are also affected by tempo (see Michon, 1974). Effects of tempo on timing and dynamics have been studied (Monahan and Hirsh, 1990; Desain and Honing, 1994); analogous effects of tempo on the perception of music performances were reported by Repp (1995–6).

### (v) Rhythm v. form.

As rhythmic groups become longer and pulses slower, a perceptual transition occurs from the domain of rhythm to that of form (Clarke, 'Levels', 1987). In grouping, the change may be said to occur when a group's duration exceeds that of the psychological present (Fraisse, 1957; Crowder, 1993), defined as a short period of time during which relationships between successive events can be perceived directly, without cognitive reference to earlier periods (memory, rehearsal; similar to Baddeley's 1986 'working memory'). The duration of the psychological present depends on musical tempo and complexity, but it is normally estimated to lie in the range of two to seven seconds. In the case of pulse and metre, the transition from rhythm to form may be said to occur when temporal regularity ceases to imply physical movement or dance (beyond a period of about two seconds: Fraisse, 1974) and rhythmic temporal anticipation is no longer possible (Mates and others, 1994).

**Carolyn Drake, Richard Parncutt**

## 3. Timbre.

### (i) Definition.

Timbre is the auditory attribute that distinguishes two sounds presented in a similar manner and having identical pitch, loudness and duration. This formal definition leaves a wealth of possibilities that resisted scientific experimentation until the late 20th century. Timbre is now understood to have two broad characteristics that contribute to the perception of music: (*a*) it is a multifarious set of abstract sensory attributes, some of which are continuously varying (for instance, attack sharpness, brilliance, nasality), others of which are discrete or categorical (the 'blatt' at the beginning of a *sforzando* trombone note or the pinched offset of a harpsichord sound), and (*b*) it is one of the primary perceptual vehicles for the recognition, identification and tracking over time of a sound source (a singer's voice, a clarinet, a set of carillon bells) and thus involves the absolute categorization of a sound (McAdams, 1993; Hajda and others, 1997).

### (ii) A set of auditory attributes.

This first approach concerns relative perception: the ways in which and the degree to which sounds are perceived to differ. Early research on the perceptual nature of timbre focussed on preconceived aspects such as the relative weights of different frequencies present in a given sound, or its 'sound colour' (Slawson, 1985). A voice singing a constant middle C while varying the vowel being sung, or a woodwind player holding a given note while varying the embouchure and mouth cavity shape, both vary the shape of the spectrum. Helmholtz (2/1885) invented ingenious devices for controlling spectral weighting to explore these aspects of timbre. However, the real advances in understanding the perceptual representation of timbre had to wait for the development of powerful multi-dimensional data analysis techniques in the 1960s.

Multi-dimensional scaling has no preconceptions about the physical or perceptual structure of timbre. Listeners simply rate on a scale from very similar to very dissimilar all pairs from a given set of sounds that are equalized in terms of pitch, loudness and duration. The resulting judgments are then analysed with a computer program that fits the dissimilarity ratings to a distance model in which sounds with similar timbres are close together and those with dissimilar timbres are far apart. The basic model is expressed in terms of continuous dimensions that are shared among the timbres. More elaborate models also include dimensions or features that are specific to individual timbres ('specificities') and different perceptual weights accorded to the dimensions and specificities by individual listeners or classes of listeners (McAdams and others, 1995). Such techniques have been applied to synthetic sounds (Plomp, 1970; Miller and Carterette, 1975), resynthesized, imitated or simulated instrument sounds (Grey, 1977; Wessel, 1979; Krumhansl, 1989; McAdams and others, 1995; Roussarie, McAdams and

Chaigne, 1998), recorded instrument sounds (Iverson and Krumhansl, 1993) and even dyads of recorded instrument sounds (Kendall and Carterette, 1990–91).

Independent acoustic correlates have been determined in many cases for the continuous dimensions (Krimphoff, McAdams and Winsberg, 1994), which is important if these results are to be applied to sound synthesis or the search for sounds in large audio databases. The most common correlates include spectral centroid (representing the relative weights of high and low frequencies), attack time (distinguishing 'continuant' instruments that are blown or bowed from 'impulsive' instruments that are struck or plucked), spectral flux (the degree of evolution of the spectral shape over a tone's duration which is high for brass and lower for single reeds) and spectral irregularity (the degree of jaggedness of the spectral shape, which is high for clarinet and vibraphone and low for trumpet).

Specificities are often found for complex acoustic and synthesized sounds and represent the presence of a unique feature that distinguishes a sound from all others in a given context. For example, in a set of brass, woodwind and string sounds, a harpsichord might have a strong specificity due to the return of the hopper which creates a slight thump and quickly damps the sound at the end; no other sound has such a feature (McAdams and others, 1995).

Individual and class differences are modelled as weighting factors on the different dimensions and the set of specificities. Some listeners pay more attention to spectral properties and ignore temporal aspects while others have the inverse pattern (McAdams and others, 1995). It has yet to be demonstrated that such individual differences have anything to do with musical experience or training. It may be that since timbre perception is so closely allied to sound source recognition in everyday life, everybody is an expert to some degree.

The timbre space models that result from this approach have been useful in predicting listeners' perception in situations other than those specifically measured in the experiments. This suggests that they do in fact capture important aspects of timbre representation and have the most important feature of a scientific model: the ability to predict new phenomena. By exchanging the spectral envelopes on pairs of sounds that differ primarily along the spectral dimension, these sounds have been found to switch positions in the space, as would be predicted by the model (Grey and Gordon, 1978). The timbre space representation has been used as a basis for defining timbral intervals (by analogy with pitch intervals) in terms of directional vectors in the space (Ehresman and Wessel, 1978; McAdams and Cunibile, 1992). Musical transposition is equivalent to a spatial translation of the vector, keeping constant the degree of change along each of the shared dimensions. The difficulty with applying this notion to orchestral timbres is that it does not take into account the specificities of individual timbres that would 'distort' the vector in some sense, and the timbre space available with acoustic instruments and their blends is often full of holes where no instrument exists, limiting considerably the possible transpositions. However, this approach would be quite useful for a palette of synthesized timbres without specificities that were distributed homogeneously in the perceptual space.

Timbre space representations also predict aspects of the phenomenon of auditory streaming – the assignment of successive events to a coherent mental representation – on the basis of which melody and rhythm are then perceived. The further apart the timbres of two instruments are in the perceptual space, the more likely it is that the melodies they are playing will segregate into separate streams (McAdams and Bregman, 1979; Gregory, 1994–5; Iverson, 1995; Singh and Bregman, 1997).

### (iii) A vehicle for source identity.

The second approach to timbre concerns absolute perception, the sound being represented in reference to a particular category. Categorization is a primary reflex in the perceptual process and is particularly evident in the processing of pitch and duration in music. One reasonable hypothesis is that the sensory dimensions that compose timbre serve as indicators used in the categorization, recognition and identification of sound events and sound sources (McAdams, 1993). This is perhaps the more neglected aspect of timbre and brings with it advantages and disadvantages for the use of timbre as a form-bearing dimension in music (McAdams, 1989).

One of the advantages is that categorization and identification of a sound source may bring into play perceptual knowledge (acquired by listeners implicitly through experience in the everyday world and in musical situations) that helps them track a given voice in a complex musical texture. Listeners do this easily and research has shown that timbral factors may make an important contribution in such voice tracking (Culling and Darwin, 1993; Gregory, 1994–5), which is particularly important in polyphonic settings.

The disadvantages may arise when a composer seeks to create melodies across instrumental timbres, as in the *Klangfarbenmelodien* of Schoenberg. The predisposition to identify the sound source and follow it through time would impede a more relative perception in which the timbral differences were perceived as a movement through timbre space rather than as a simple change of sound source. For cases in which such timbral compositions work, the composers have often taken special precautions to create a musical situation that draws the listener more into a relative than into an absolute mode of perceiving.

### (iv) Contributions to perception.

Timbre perception is at the heart of orchestration, a realm of musical practice that has received relatively little experimental study. The creation of new timbres through orchestration necessarily depends on the degree to which the constituent sound sources fuse or blend to create the newly emerged sound. Sandell (1995–6) has proposed three classes of perceptual goals in combining instruments: timbral heterogeneity, in which one seeks to keep the instruments perceptually distinct; timbral augmentation, in which a single instrument embellishes another one that perceptually dominates the combination; and timbral emergence, in which a new sound results that is identified as none of its constituents. Blend appears to depend on a number of acoustic factors such as onset synchrony of the constituent sounds and others that are more directly related to timbre, such as the similarity of the attacks, the difference in the spectral centroids and the overall centroid of the combination.

Timbre is also an important component in the perception of musical groupings, whether they are at the level of sequences of notes distinguished by changes in timbre (Deliège, 1987) or of larger-scale musical sections delimited by marked changes in orchestration and timbral texture (Deliège, 1989).

Work on the perception of musical tension and relaxation has focussed on the role of pitch and rhythm in carrying such structures. Timbral modulation can also play an important role in these large-scale expressive aspects of musical experience. Comparing orchestrated music with direct piano transcriptions of the scores for both tonal/metric and non-tonal/non-metric music, Paraskeva and McAdams (1997) demonstrated a modulating role of orchestration on tension and relaxation profiles measured across the excerpts.

Taken together, these areas of research into timbre perception are moving in the direction of creating a true theory of orchestration and timbral control in sound synthesis.

*See also* **TIMBRE (I)**.
**Stephen McAdams**

## 4. Memory.

### (i) The nature of memory.

Every musical activity, whether it be perception, performance, improvisation or composition, involves memory. For instance, to sight-read notes requires recovery from memory of the arbitrary relationship between specific symbols and pitches and the particular set of body and finger movements needed to execute them. Almost every such item of knowledge about music has to be acquired through learning. This learning can take place in formal instructional settings (education and training) and through the informal experiences of everyday life (enculturation). Memory is thus a capacity that can be improved, not a fixed quantity.

Musicians' interest in memory is often practical rather than theoretical. Performing complex music without the score is a requirement of many professional roles, and accounts of apparently superhuman feats of musical memorizing hold special fascination for performers and audiences alike (Révész, 1925; Marek, 1975). Similarly, musicians at all levels are interested in guidance on how to memorize and how to avoid memory loss. Scientific research on memory, however, has generally been concerned with the broader enterprise of advancing our understanding of the fundamental mechanisms and processes underlying all memory processes, from the exceptional to the ordinary, with issues of applicability following from the research rather than driving it (Baddeley, 1990). Many aspects of musical memory have not received substantial scientific attention: these include optimal strategies for memorization and the nature and time course of memory loss. It is, however, well established that anxiety and emotional distress can cause significant temporary loss of recall, even in cases where appropriate learning has taken place.

Expert memory often entails the ability to make sense of, or to structure, incoming material in terms of previously learnt information. When material cannot be assimilated into familiar structures, memory performance declines. This is shown most dramatically in the case of exceptional memorizers, such as the musical savant ‘NP’ (Sloboda, Hermelin and O'Connor, 1985) who was capable of memorizing classical piano sonata movements within two or three hearings. This outstanding skill was not transferable to non-tonal music. The lack of familiar structures caused reversion to unremarkable, average performance. The importance of familiar structures has been demonstrated for almost every type of task involving musical memory. For instance, listeners are more likely to be able to tell correctly whether two short consecutive pitch sequences are identical or different when these sequences are drawn from familiar diatonic materials than from unfamiliar atonal materials (Watkins, 1985). This comes about through their lifelong immersion in tonal music, and the attuning of their cognitive system to the structures and regularities shared by this body of music (see Krumhansl, 1991, for a comprehensive review).

These findings lead to a crucial distinction between two types of memory: memory for specific pieces of music and memory for norms and prototypes which may be a shared attribute of many pieces of music. Terms coined for the first type of memory include ‘episodic’ (Tulving, 1983) and ‘veridical’ (Bharucha, 1994), for the second type ‘semantic’ or ‘schematic’. If a familiar piece of music is interrupted before its close, veridical memory allows us to reconstruct its actual continuation, whereas schematic memory would allow us to guess a likely continuation (Carlsen, 1981; Schellenberg, 1996; Thompson, Cuddy and Plaus, 1997). Memory failures in performance of a less familiar piece can often be explained as cases of schematic memory overriding veridical memory (Sloboda and Parker, 1985); the performer recalls a plausible continuation rather than the actual one, or confuses two similar junction points and skips or repeats a section (Reason, 1990). Indeed, without a rich schematic memory, veridical memory would be impossible. There would be no way that professional musicians could remember, as by rote, the vast number of arbitrary elements in the large repertory of complex pieces they need to maintain. The more one understands about a piece of music (in terms of awareness of its rich structural interrelationships, both within and outside the specific piece), the easier it is to memorize. In more general terms, the relationship between the level of a specific skill and amount of prior practice on that precise skill is one of the strongest relationships that has been demonstrated in the research literature on expertise (Ericsson, Krampe and Tesch-Romer, 1993). The greater the amount of prior relevant cognitive activity, the greater the skill.

Memory takes two basic forms, namely recognition and recall. Recognition predominates in listening, recall in performance.

### (ii) Recognition.

Recognition is a process that operates in perception to match incoming information to previously stored information. The most basic form of recognition is the experience of similarity. This simply requires that something heard is experienced as being identical to, or sharing important characteristics with, something heard before. Without the ability to recognize similarity between elements within a piece, the apprehension of form would be impossible. Elementary recognition processes can be demonstrated in early infancy (even before birth). A familiar melody will elicit a different pattern of attention from a strange melody (Lecanuet, 1996). More complex cognitive processes allow recognition of themes under various processes of transformation. For instance, in most tonal contexts listeners are less sensitive to the exact pitch level at which a melody is re-encountered than to the diatonic intervals that it contains (Attneave and Olson, 1971; Bartlett and Dowling, 1980). They recognize an intervallically identical repetition as ‘the same melody’ irrespective of the pitch on which it starts. There is evidence that even trained musicians find it hard to keep the starting-key of a heard composition in memory if it modulates several times (Cook, 1987–8). Some transformations of musical materials make recognition harder, and it is such transformations that allow composers partly to disguise their re-use of thematic material, whose belated discovery by a listener after many hearings may provide a source of aesthetic satisfaction. For instance, changing the rhythm of a melody can significantly disrupt recognition even though the pitch pattern may be unchanged (Jones, Summerill and Marshburn, 1987). Transformational devices such as retrogression or inversion can make recognition almost impossible without considerable training (Krumhansl, Sandell and Sergeant, 1987–8). Like most musical skills, recognition ability is not static but can improve with experience and training (Pollard-Gott, 1983).

A second form of recognition is identification or naming. This involves the retrieval of a verbal label which could be for an individual note (as in the case of possessors of absolute pitch), a chord (e.g. minor triad, first inversion), a structural device (an interrupted cadence) or an entire piece. Identification must involve recognition of similarity, although there can be many instances of similarity recognition that do not lead to identification (‘this piece is familiar but I cannot recall its name’). Identification is not an inherent part of musicality and it is possible for someone to be a sophisticated and sensitive listener without possessing the vocabulary with which to describe what is heard. Experimental psychology has made a major contribution by devising testing techniques that can demonstrate recognition without naming (by, for example, measuring the accuracy of a listener's judgment as to whether two successively presented excerpts are the same or different), and which can thus be used to assess the musicality of very young children and those without formal music training (Lamont, 1998). In music, as in many other areas of human activity, these techniques often reveal an unexpected level of sophistication in the recognition skills of people whose identification and naming skills are almost non-existent (Jusczyk and Krumhansl, 1993). Nonetheless, professional musicians could not work effectively without a shared language, and a considerable amount of formal music training is rightly devoted to developing identification skills and technical vocabulary.

### (iii) Recall.

Recall is the reproduction, either in imagination or behaviour, of a previously experienced sequence. Typically, recall requires more mental resources than recognition; a listener will recognize much more than he or she can recall because recall generally requires some form of cue to trigger it. In a situation where, for instance, hearing the name of a piece does not elicit recall, then hearing the first few notes can often trigger it; this explains why prompting is effective in performance situations. Performing learnt music from a score can be seen as a type of cued recall, since an experienced performer will rarely look at every note. For instance, experienced sight-readers use their schematic memory to substitute plausible alternatives for what is actually in the score (Sloboda, 1984). Failures in recall brought about by, for instance, stage fright, can often be explained in terms of unwanted and inappropriate mental contents (such as anxious self-monitoring thoughts) blocking normal retrieval cues (Steptoe, 1989).

Recall can be either an unintended by-product of other activities or the result of deliberate memorizing effort. Most everyday examples of musical recall are involuntary and unintended results of other mental processes. Short pieces of music that are regularly repeated within a culture (such as nursery rhymes, popular songs and television theme tunes) tend to be reproducible without any special effort (Levitin, 1994). Research on involuntary memory suggests that it occurs as a general consequence of any form of attentional processing of material. However, the products of such involuntary processes tend to be rigid and inflexible, recalled as unanalysed wholes. The same can generally be said of the products of rote repetition (Baddeley, 1990).

A flexible and multi-levelled recall complex enough to serve the artistic ends of an expert musician is likely to come about only through a process of deliberate and conscious memorization. Expert memorizers share a number of characteristics (Ericsson, Krampe and Tesch-Romer, 1993; Jorgensen and Lehmann, 1997). First, they have been immersed in the domain for a long time and have had experience of memorizing many pieces. Secondly, they are able to represent the material to be learnt in terms of patterns and structures that have rich interconnections with each other and with pieces previously learnt. Thirdly, they develop multiple interlocking levels of representation, such that if any one of them is temporarily lost it can be re-cued from another level. These levels might include visual, auditory, formal, kinaesthetic and motor. Fourthly, their representations are flexible, so that, for example, they may yield performances with differing styles or levels of expressiveness. An expert piano accompanist will, for instance, rapidly adapt speed, volume and style to match the characteristics of an unfamiliar singer, and may even be able to transpose an accompaniment learnt in one key to a new key with little or no extra rehearsal.

*See also* **ABSOLUTE PITCH**; **CONSONANCE**; **HEARING AND PSYCHOACOUSTICS** and **MEMORY, MEMORIZING**.
**John Sloboda**

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## III. Affect

### 1. Introduction.

Affect encompasses many human mental reactions and states that are not traditionally viewed as intellectual. Feelings, emotions and moods are the principal categories of affect. It is one of the most inescapable and characteristic features of music that people report strong emotional reactions to it. Why this is so, and by what means music creates affect, are questions of central concern to psychologists.

Music seems to elicit strong emotion more reliably and frequently than other art forms (Frey, 1985; Williams and Morris, 1996). Three characteristics seem to be key determinants: (i) Music unfolds over time and so is capable of engaging the emotions of expectation and expectations realized or dashed more effectively than static forms such as painting; drama, dance, film and literature share this feature with music; (ii) music uses directly, and often mimics, the most emotionally important signal of the human species: the voice (only drama shares this feature); (iii) music engages the auditory sense, which gives it a general arousing capacity due to the fact that we cannot escape the source of stimulation (as we can, for instance, for a painting by looking away or closing our eyes), as well as providing a link to the most primitive and fundamental feelings and experiences of human life. Infants have an inter-uterine auditory life of some complexity well before they are able to engage the other senses to the same degree (Lecanuet, 1996). Some psychoanalytic writers have made much of these experiences, as well as early experiences of music during infant–mother bonding (Nass, 1990; Noy, 1968).

There has been a longstanding debate about whether affect is necessary or even relevant to a proper understanding of a piece of music. An extreme position (sometimes taken, for instance, by Stravinsky) denies any relevance of affect to the processes of creating, understanding or interpreting music; affect is an unhelpful by-product. In contrast, theorists such as Meyer (1956) suggest that affect is a natural component of the perception of the formal properties of a piece of music. Instead of distracting a listener from a proper understanding of the music, certain types of affect are proof that a listener has indeed understood it.

In aesthetics, robust arguments for the centrality of affect have been put forward by Kivy (1989) and refined by Davies (1994), Goldman (1995), Levinson (1990) and Radford (1989). Psychology has moved this debate forward by providing concrete data about how and when people experience affect, and also by advancing theories that shed light on the links between music as a structure on the one hand and affective responses on the other. Research has shown that both extrinsic (or associative) and intrinsic (or expressive) processes are at work. Some central themes in this work are discussed below (for more detailed accounts of relevant research and thinking, see Dowling and Harwood, 1986; Gaver and Mandler, 1987; and Sloboda, 1992).

*See also* **EXPRESSION, §II**.

### 2. Extrinsic affect.

Certain types of stimulus (including music, smells and tastes) seem to become associated in human memory with particular contexts or events in earlier life, and provide a trigger to the recall of these events. This seems particularly so when the earlier events were, in themselves, occasions of strong emotion (Dutta and Kanungo, 1975; Rubin and Kozin, 1984). A number of investigators (Gabrielsson, 1991; Sloboda, 1991) have found examples of specific pieces of music that trigger strong emotion in this way. Such emotions generally lead attention away from the present music on to the remembered past event. Waterman (1996) has shown that even when music does not directly trigger past experiences, many of the affective mental processes are self-referring in some way ('I should have recognized that', 'this is not my type of music'). Because these feelings are linked to the life histories of individuals, they are often highly idiosyncratic. However, common cultural experiences can sometimes lead to shared affect which is still fundamentally extrinsic – for example, the extreme negative emotions felt by many Jews after World War II on hearing the music of Wagner; the strong emotional identification of generational cohorts with the popular music prevalent in their teenage years (Holbrook and Schindler, 1989); and the cultural associations formed by film-music pairings, such as Johann Strauss's *Blue Danube* waltz with the spaceship docking sequence in Stanley Kubrick's film *2001: a Space Odyssey*.

### 3. Intrinsic affect.

There are two distinct types of relationship between musical structures and emotional responses; these may be called iconic and symbolic (following Dowling and Harwood, 1986; see also Beardsley, 1958, and Kivy, 1989). Iconic relationships come about through some formal resemblance between a musical structure and some event or agent carrying emotional 'tone'. For instance, loud, fast music shares features with events of high energy and so suggests a high-energy emotion such as excitement. A fairly comprehensive 'dictionary' of such iconic correspondences can be derived from the work of Hevner, 1936; Scherer and Oshinsky, 1977; and Wedin, 1972. One recent strand in this work has been the suggestion that some musical devices directly suggest gestural and other expressions of emotions by the human body (Clynes, 1977; Scherer, 1990). Equally important has been a development of an understanding of how a performer may mediate affective communication from performer to listener (Gabrielsson and Juslin, 1996).

Symbolic relationships come about where the listener's response is determined by an appreciation of formal and syntactic properties of the musical sequence. It is well established that even short and simple musical sequences set up powerful expectancies in listeners for what will follow these sequences (Carlsen, 1981; Krumhansl, 1995–6; Bharucha, 1994). These expectancies can be based on fundamental properties of human perception, such as the so-called gestalt laws of perception (see Narmour, 1990). For instance, a movement from one note to the next scale step sets up a strong expectancy for further stepwise motion in the same direction. Narmour calls this type of expectancy 'bottom-up' because these expectancies are presumed to result from general perceptual principles that do not require learning. Other expectancies are based on familiarity with musical styles and genres. Listeners familiar with Western tonal music will come to expect certain harmonic and melodic sequences (e.g. I–IV–V will set up an expectancy for I, so that the deceptive cadence I–IV–V–vi/VI is felt as surprising). Confirmations and violations of these expectancies, often operating at a subconscious level, are held to be responsible for some emotional responses to music. Confirmatory evidence shows that points in music identified by listeners as emotional peaks share key syntactic features associated with expectancy (Sloboda, 1991), and points in performances obtaining maximum tension ratings from listeners correspond to points of major syntactic change (Lerdahl, 1987–8; Krumhansl, 1995–6; Narmour, 1995–6).

Most research uses conscious report of listeners as the method of identifying the nature and location of emotional response. There have been few systematic efforts to measure physiological response directly (VanderArk and Ely, 1992); more often, listeners have been asked to self-monitor behavioural effects of physiological changes (such as crying and pilo-erection: see Goldstein, 1980; Panksepp, 1995–6).

It is a feature of the intrinsic relationships described above that a listener can recognize or identify the emotion represented without necessarily feeling it. A necessary consequence of iconic recognition is a cognition such as ‘this is happy music’. This may lead to a further cognition, ‘this music makes me feel happy’, but there is no necessity for this further step. That will depend on factors in the listener (including extrinsic factors of the sort discussed above) rather than in the music. In symbolic relationships, feelings (at least of surprise, or of expectations confirmed) are more intimately connected to the musical experience. Whether such feelings lead to the experience of happiness, sadness or some more complex emotion will depend on many factors not yet understood. A particularly interesting problem is created by the fact that strong emotion may be elicited by music with which one is very familiar, and which therefore should not surprise the listener at all. Some of the most basic mechanisms involved in the processing of music may be incapable of learning the particular characteristics of a piece or style (Jackendoff, 1991–2; see also Meyer, 1967); for these mechanisms, every hearing is like the first hearing.

Since both extrinsic and intrinsic affect often depend for their operation on acquired knowledge (whether biographical or related to specific musical styles), cultural and developmental factors will strongly influence emotional response. There is considerable evidence of increasing sophistication with age in emotional response to music (Gardner, 1973; Cunningham and Sterling, 1988; Kastner and Crowder, 1990–91). There has been almost no empirical work on cross-cultural differences in affect, but what little has been done (such as Gregory and Varney, 1996) confirms that significant differences exist, although the increasing penetration of Western music into every part of the world lessens the plausibility of carrying out decisive cross-cultural studies using Western music.

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**John Sloboda**

## IV. Performance

### 1. Introduction.

The psychology of performance has attracted growing research interest since the late 1970s from a number of quarters: to psychologists interested in skill, performance offers an opportunity to study a variety of cognitive and motor skills; to those interested in musical development, it offers concrete musical behaviour that can be observed and assessed over a considerable period of continuous development; from the perspective of music cognition, it offers a window on to musical thinking; and from within musicology it offers the possibility of examining music in a more dynamic manner than the score allows (Dunsby, 1995; Rink, 1995).

Expression is a central concept in the overwhelming majority of work on performance, since it is fundamental to performance of every kind (*see* **EXPRESSION, §II**). It has generally been defined as deliberate departures from the indications of the written score, following Seashore's work on performance (1938), although this definition is not without problems (Desain and Honing, 1992; Clarke, 1995). A particular methodological issue is how to distinguish deliberate departures from mistakes: one approach has been to depend on the statistical notion of reproducibility, and to ask individuals to perform the same music a number of times, or to look at the performances of a number of individuals. However, this runs counter to a fundamental principle in musical performance – the idea that performance is a re-creative rather than reproductive act, and that each performance is a unique realization of the performer's conception of the music. In practice, the approach adopted in the literature has varied according to the nature of the task and the quality of the data. When data come from relatively simple musical materials collected under controlled conditions and from subjects who may not be experts, repeated performances and groups of subjects have been used and standard statistical methods adopted (Sloboda, 1983; Clarke, 1992–3). By contrast, when the data are from expert performers playing concert repertory, authors have appealed to the skill and precision of the performers to justify the analysis of individual data points (Shaffer, 1981; Repp, 1992).

### 2. Performance and skill.

The detailed study of performance as a skill goes back to Seashore and his collaborators, who pioneered the development of quantitative methods for recording performance data. More recent work has, for technical reasons, been almost exclusively confined to the piano (see Palmer, 1997, and Gabrielsson, 1999, for reviews). These studies have been mainly concerned with the control of movement and timing in performance (Shaffer, 1981, 1982; Palmer, 1989); coordination and independence between hands in solo performance, and between players in duet performance (Shaffer, 1984); the manner in which performers process units of musical material (Palmer and van de Sande, 1993, 1995); sight-reading (Sloboda, 1984–5; Banton, 1995); and pianists' fingering strategies (Sloboda and others, 1998). Shaffer has traced the way in which an abstract musical conception is translated into concrete action and has demonstrated that the specification of movement remains quite abstract, and close to the character of musical knowledge, until comparatively late in this process. Error data from piano performance indicate that performers carry out an unconscious parsing of the musical structure that exerts its influence even at quite surface levels: a performer sight-reading a Bach fugue missed a clef change from one page to the next, and produced a sequence of errors that nonetheless preserved the underlying harmony of the passage (Shaffer, 1981).

The control of timing is particularly important for music performance, since the temporal characteristics of a performance are both a crucial aspect of the musical structure and a powerful means of expression. Shaffer and others have shown that expert performers can achieve remarkable precision and stability in the timing of performance at levels ranging from the individual note up to whole sections or complete pieces (Clynes and Walker, 1982; Shaffer, 1984; Clynes, 1986–7), and sometimes over very long periods of time. Some important questions are how this timing control is achieved, how many levels of performance are directly timed and which these levels are (Shaffer, 1982, 1984).

On the matter of coordination, Shaffer (1981, 1984) investigated the considerable degree of independence between the hands that pianists are able to achieve, either where the polyrhythmicity of the music demands it or for expressive purposes. He further demonstrated that the coordination between players in a piano duet does not depend on one rigidly following the other: a significant element of prediction on the part of both about the future course of the other's expressive performance is involved, despite the fact that the two pianists in his study did not play together regularly and had never before played the piece together. This can be explained either by assuming that the two players held a common representation of the musical structure and used this as the stable reference point from which to make their expressive predictions, or that they communicated their intentions, and coordinated with one another, through physical movement or facial gesture.

Finally, a limited amount of work on practice and rehearsal (Gruson, 1988; Miklaszewski, 1989; Hallam, 1995) has looked at the broad strategies used by performers and some of the more specific changes that take place. Equally, there is a literature on performance anxiety and the efficacy of various attempts to relieve it, though with some exceptions (Steptoe and Fidler, 1987; Abel and Larkin, 1990; Valentine and others, 1995) most of this work is practical and prescriptive rather than psychological or exploratory.

### 3. Theories of performance expression.

Empirical studies of performance expression (e.g. Shaffer, 1981; Todd, 1985–6; Clarke, 1988; Gabrielsson, 1988; Palmer, 1989; Repp, 1992) have identified a number of recurring characteristics in performance expression: it can be extremely stable over repeated performances that may sometimes span a number of years (Clynes and Walker, 1982), is found even in sight-read performances (Shaffer, 1981) and can be changed by a performer with little or no rehearsal (Clarke, 1985). These observations have led to the view that expression cannot be understood as a learnt pattern of timing, dynamic and articulation, but must be generated from the performer's understanding of the musical structure.

In principle, every aspect of musical structure contributes to the specification of an expressive profile for a piece, but a number of authors have shown that phrase structure is particularly salient. Todd has described a model which takes the hierarchical phrase structure of the music as its input and gives a pattern of rubato as its output on the basis of an extremely simple rule (1985–6, 1989). The resulting tempo profiles compare well with the profiles of performances by professional players, as Todd's own data, and subsequent data collected by Repp (1992) have shown. A number of other studies have also shown rule-like correspondences between various aspects of musical structure and expression (Sloboda, 1983; Shaffer and Todd, 1987; Clarke, 1988; Sundberg, 1988; Todd, 1992; Palmer, 1995–6). In a study of 28 performances of a short piano piece by Schumann, taken from commercial recordings by many of the 20th century's greatest pianists, Repp (1992) showed a remarkable degree of commonality underlying the expressive profiles of the performances, despite the idiosyncrasies of some of the performers. Although the expressive properties of skilled performances can be extraordinarily subtle, this does not require the expressive rules themselves to be either complex or numerous, since the musical structures that constitute their input can themselves be highly complex. It is this structural complexity which makes the whole expressive system so rich and variable, thus ensuring that the output of even a very simple collection of expressive rules will be quite diverse.

If expression is based on an understanding of musical structure, then expressive features can be regarded as ‘symptoms’ of that understanding. This relationship can be understood in two ways: as the inevitable and insuppressible consequence of a particular conception of the musical structure; and as a conscious and deliberate attempt by the performer to make audible his or her interpretation of the structure. Evidence for the unconscious and insuppressible quality of expression comes from attempts by performers to play without expression: Seashore (1938) showed that, while the degree of expression is reduced under these circumstances, it is never eliminated and retains the same general pattern that is observed under normal circumstances (a finding confirmed by Palmer, 1989). Similarly, pianists who tried to imitate an expressionless performance unconsciously introduced structurally related expression into their imitation attempts (Clarke and Baker-Short, 1987). Finally, Sloboda (1983) showed that a melody presented to pianists in two different metrical notations was played with different, metrically related patterns of expression, even though the players had not noticed that the two melodies were identical in every respect other than metre.

Performance expression under these conditions is related to basic structural features of the material, such as phrase structure and metre, and can be seen as the consequence of the performers' spontaneous and unconscious understanding of the musical structure.

Nonetheless, it is obvious that performers also consciously and deliberately shape expression in their performances in order to achieve particular structural and stylistic results. Performers dedicate enormous amounts of time to practice and rehearsal (Krampe and Ericsson, 1995), the function of which (apart from dealing with purely technical problems) is to make changes in the degree to which a particular expressive device is used; in the selection of particular expressive options to project a feature of the music (for instance using articulation rather than dynamics to shape a phrase); and in the performer's structural understanding of the music.

Although there is a good deal of empirical support for a generative view of expression, there is also evidence that acoustic factors (Clarke, 1992–3), emotional factors (Gabrielsson, 1995; Gabrielsson and Juslin, 1996) and the human body also play a role. (Other factors include the possibilities of the instrument, the acoustics of the performing environment, the nature of the audience, the mood and intentions of the performer and even the performance ideology.) Movement, and the human body, are particularly significant in this complex set of relationships (Shove and Repp, 1995) because the vast majority of music is produced by human and instrumental action, and is thus indelibly stamped with its bodily and instrumental origins (as ethnomusicologists have also observed: Baily, 1985). Research suggests that performers' spontaneous timing patterns follow fundamental physical laws (Kronman and Sundberg, 1987; Todd, 1992; Feldman, Epstein and Richards, 1992–3), and that natural-sounding performance mimics the behaviour of physical objects moving in the real world. In a study that tested listeners' preferences for different expressive timing patterns in a short melody, Repp (1992–3) found that listeners preferred parabolic curves (which mimic physical laws) over other equally systematic timing functions. Somewhat controversially, Clynes (1983, 1986–7) has claimed that expression in performance is linked to a specific ‘pulse pattern’ characteristic of the composer of the music being played. However, the results of empirical investigation by Repp (1988–9, 1990–91; see also Clynes, 1995), in which listeners rated performances with appropriate and inappropriate pulse patterns, are equivocal.

If physical motion is a possible basis for patterns of expression in musical performance, there can be no doubt that physical movement is a crucial factor in our total response to live performance, visual as well as auditory. Davidson (1991, 1993) showed that different degrees of expressivity in performance are conveyed by visual information alone, even when the video images were reduced to points of light at the limb joints and head. Expressive moments could be clearly localized and categorized, suggesting that expert performers employ a vocabulary of expressive gestures, possibly associated with specific structural functions. In a similar manner, Kendall and Carterette (1990–91) demonstrated that listeners were successful in picking up the expressive intentions (neutral, normal, exaggerated) of performers on a variety of instruments, and that there was no difference between musicians and non-musicians in their ability to do so.

Recent advances in understanding performance have been strongly influenced by the same kinds of linguistic and computational models that have profoundly affected psychology as a whole. Greater recognition of the close links between biology and psychology may temper the excessive abstraction of some of the previous work, but it is important to avoid a naive reductionism and steer a course between the literal involvement of physical factors, the role of cognitive representations of the body (Jackendoff, 1987; Lidov, 1987) and the widespread use of metaphors of motion in relation to music. A number of aspects of performance remain virtually unresearched, notably the specific changes that take place during practice, expressive performance on instruments other than the piano, ensemble performance and a whole range of issues that fall under the broad banner of the social psychology of performance.

*See also* **PERFORMANCE**.

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**Eric F. Clarke**

# V. Early development

## 1. Introduction.

The developmental psychology of music, a discipline still in its infancy, is concerned with the scientific study of age-related change and the processes underlying change in skills related to music. Change related to growth or development is to be distinguished from change resulting from systematic exposure or training (i.e. learning). Nevertheless, the two types of change may be seen to interact, in the sense that training may be more potent or effective at some stages than at others.

Research within the discipline of psychology typically differs from research within music education or related disciplines both in the questions of interest and in the methods of study. The primary goal of psychological research in this domain is to shed light on the mental processes that underlie music perception and production. A secondary goal is to document the influence of social factors. The methods employed are those of experimental psychology – highly controlled laboratory contexts (supplemented, at times, by field study), systematic observation and measurement, and data-analytic techniques aimed at ensuring that any particular set of findings is not attributable to chance. Although some of the research may have practical implications, these are not the principal concern of the discipline.

## 2. The infant's environment.

### (i) Parents' speech.

There are indications that infants receive considerable exposure to music or music-like materials apart from the music they might overhear from their parents' stereo, radio or television. Even the speech that parents direct to their pre-linguistic infants incorporates many music-like features absent from typical adult speech. For example, mothers' utterances to infants are characterized by high pitch, rhythmicity, repetition, simple pitch contours and an extended pitch range (Fernald, 1991; Cooper, 1993; M. Papoušek, 1996), features that have been documented in many cultures (Grieser and Kuhl, 1988; Fernald and others, 1989; Papoušek and Hwang, 1991). This vocal register, known as ‘motherese’, ‘parentese’ or ‘infant-directed speech’, is more effective in attracting and maintaining infant attention than typical adult speech (Fernald, 1985; Cooper and Aslin, 1990; Papoušek and others, 1990; Werker, Pegg and McLeod, 1994). Such findings have prompted claims that infants are predisposed to attend to the distinctive pitch contours of maternal speech whose emotional meanings are clear (Fernald, 1992; M. Papoušek, 1996).

### (ii) Caregivers' songs.

The vocal interactions of caregivers and infants go well beyond stereotyped ‘sing-song’. Caregivers around the world also sing while tending their infants and use a distinctive genre of musical materials for that purpose (Trehub and Schellenberg, 1995; Trehub and Trainor, 1998). Despite the great diversity of musical styles across cultures, musically untrained adults can reliably distinguish unfamiliar foreign lullabies from non-lullabies of comparable cultural origin, tempo and vocal style (Trehub, Unyk and Trainor, ‘Adults’, 1993). From the perspective of naive adult listeners, the distinguishing structural feature of these lullabies is their simplicity or repetitiveness (Unyk and others, 1992), which may account for their soporific effects.

Parents' play-songs and lullabies are notable for their highly expressive performances, which are finely tuned to the infant's ability and mood. The expressiveness of caregivers' songs enables naive adults to distinguish performances recorded in an infant's presence from those produced in the infant's absence (Trehub, Unyk and Trainor, ‘Maternal’, 1993; Trehub and others, 1997). Fathers also sing to their infants, but much less frequently than mothers. When they do, however, they adopt the characteristic caregiving style, along with subtly different nuances for their infant sons and daughters (Trehub, Hill and Kamenetsky, 1997; Trehub and others, 1997). Instrumental measurements and expert judgments reveal that, compared to songs performed without an infant audience, performances for infants are higher in pitch, slower in tempo and replete with cues to the singer's heightened emotions (Trainor and others, 1997; Trehub and others, 1997; Trehub and Trainor, 1998). Research on the acoustic cues underlying adults' speech and song has revealed that high pitch signals happiness, affection, tenderness and increased arousal (Fonagy and Magdics, 1963; Ohala, 1984; Scherer, 1986); slow tempo signals tenderness and affection (Davitz, 1964; Juslin, 1997); and perturbations in pitch and loudness signal heightened emotionality (Bachorowski and Owren, 1995).

Improvised aspects of parents' singing include deliberate alterations of lyrics (e.g. word substitutions, pronunciation changes), tempo or metrical structure (Trehub, Hill and Kamenetsky, 1997; Rock, Trainor and Addison, 1999). Presumably, such variations reflect parents' soothing or playful intentions. These expressive performances continue into the toddler and pre-school period, with changes appropriate to the child's development (Trehub and Schellenberg, 1995). For example, mothers use somewhat higher pitch when singing the same song to their infant compared to their pre-school child, but they enunciate the lyrics more clearly for the latter (Bergeson and Trehub, 1999). When young children sing, their performances differ depending upon whether their infant sibling is nearby (Trehub, Unyk and Henderson, 1994).

### (iii) Responsiveness to parents' songs.

It is unclear whether parents' songs to infants are intuitively driven or whether they are encouraged, to some extent, by favourable reactions from the infant audience. For the most part, experimental investigations of infants' responsiveness to singing and their song preferences have been restricted to laboratory settings involving audio recordings of women or men who are not the infant's own parents. These studies reveal that infants are more attentive when listening to lullabies or play-songs recorded while mothers were singing to their infants compared to performances by the same singers with no infant audience (Trainor, 1996). Infants do not exhibit a comparable ‘preference’ for men's performances in infant-present contexts unless the performances are electronically transposed into the vocal range of women (O'Neill, 1997). Whether this finding reflects infants' inherent preference for high pitched voices or their greater familiarity with women's voices remains to be determined. Video recordings of infants as they listen to contrastive audio recordings reveal more visible signs of enjoyment of women's singing than of men's. Greater infant enjoyment is also evident for unfamiliar (i.e. foreign) lullabies than for play-songs or adult songs (Trehub and Kamenetsky, forthcoming).

Unfortunately, the presentation of audio recordings to infants necessarily excludes the very features that distinguish parents' live performances from commercial recordings of lullabies and play-songs. From the infant's perspective, mothers' usual performances feature a familiar, loving voice, a variety of expressive features that are finely tuned to the infant's current mood and coordinated facial and body gestures (M. Papoušek, 1996; Trehub and Trainor, 1998). Mothers' songs to infants are literally captivating (Trehub and Nakata, forthcoming): specifically, infants remain fixated on their mother's face throughout her sung performances. By contrast, mothers' speech, however engaging it may sound, is considerably less successful in sustaining infants' undivided attention. In short, parents in general, and mothers in particular, provide a rich musical environment tailored to the emotional needs and musical interests of infants (H. Papoušek, 1996; M. Papoušek, 1996); infants respond with attention and appreciation. This pleasurable musical interaction provides an appropriate scaffold for the child's subsequent acquisition of musical conventions.

## 3. Perception: infancy and beyond.

### (i) Conceptual and methodological issues.

Human beings, like other species, can be expected to have biologically based dispositions or biases that facilitate skill acquisition in some domains relative to others. It remains to be determined whether music perception and production capitalize on such predispositions. One means of shedding light on this question is to ascertain the initial state of the organism before musical enculturation has a significant impact. Ideally, one should evaluate music perception skills at birth, but methodological and practical considerations favour older infants whose motor ability and general alertness make them more amenable to experimental study. Indeed, six- to nine-month-old infants are prime candidates for research because of their inclination to respond to novel auditory patterns (i.e. those they judge as novel) by means of measurable attentional responses such as turning towards the source of sound (Trehub, 1985; H. Papoušek, 1996). The availability of such measurable responses makes it possible to present a melody or fragment to an infant followed by a comparison melody that alters or preserves certain features. In effect, the infant must judge, albeit non-verbally, whether the comparison pattern is the same as or different from the original pattern. In general, the original and comparison patterns are presented at different pitch levels (i.e. keys) so that infants must make their judgments of sameness or difference on the basis of relational rather than absolute cues. By responding to a particular featural change (e.g. pitch, interval, melodic contour, timbre), infants indicate that feature's detectability and salience. Their failure to respond stems either from their perception of the melody as fundamentally unchanged or from their inability to encode and retain information about the original pattern.

### (ii) Pitch and temporal patterns.

Studies using such methods reveal that infants typically consider a transposed melody as equivalent to the original melody (Trehub, Bull and Thorpe, 1984; Trehub, Thorpe and Morrongiello, 1987); by contrast, robust responsiveness is evident when the original pitches are reordered (Chang and Trehub, 1977) or a single new pitch alters the melodic contour (Trehub, Thorpe and Morrongiello, 1985). Moreover, infants are able to notice subtle distinctions between an original and comparison melody when the comparison is transposed to a related key but not to an unrelated one (Trainor and Trehub, 1993). Infants also respond relationally to rhythmic aspects of auditory patterns, treating faster or slower versions of auditory sequences as equivalent so long as relative durations are preserved (Trehub and Thorpe, 1989). Indeed, disruption of the temporal patterning of musical phrases disrupts infant attention (Krumhansl and Jusczyk, 1990; Jusczyk and Krumhansl, 1993). The available evidence also indicates that brain regions subserving the processing of melodic contour (the right hemisphere) and intervals (the left hemisphere) are comparable in infants and adults (Peretz and Morais, 1987; McKinnon and Schellenberg, 1997; Balaban, Anderson and Wisniewski, 1998).

### (iii) Intervals.

Ancient and medieval scholars considered tones related by small-integer ratios (e.g. the octave, perfect 5th and perfect 4th) as consonant or pleasant and those related by large-integer ratios (e.g. the tritone) as dissonant or unpleasant (Plomp and Levelt, 1965). In the medieval era, authorities prohibited the use of the tritone because of its presumed demonic implications (Piston, 1941). Although experimental investigations with infants do not reveal heavenly or demonic qualities, they lend credence to the special status of intervals with small-integer frequency ratios. For example, infants retain more information from melodies based on the major triad, which exemplifies small-integer relations, than from those based on the augmented triad, which exemplifies large-integer relations (Cohen, Thorpe and Trehub, 1987; Trainor and Trehub, 1993). When intervals are examined outside a musical context, infants still exhibit good retention of melodic and harmonic intervals such as perfect 4ths and 5ths (i.e. small-integer ratios) and poor retention of tritones (Schellenberg and Trehub, 1996; Trainor, 1997); moreover, they are able to classify intervals on the basis of their consonance or dissonance (Schellenberg and Trainor, 1996). Infants also exhibit more sustained attention when they listen to consonant rather than dissonant harmonizations of melodies (Zentner and Kagan, 1996; Trainor and Heinmiller, 1998). This apparent processing bias for consonant intervals is interesting in light of the pervasiveness of octaves, perfect 5ths and perfect 4ths in musics of the world (Sachs, 1943).

### (iv) Scale steps.

Unequal-step scales, which are prevalent across cultures, are thought to facilitate perceptual processing (Balzano, 1980; Shepard, 1982; Butler, 1989). To test this hypothesis, infants and adults were evaluated on their memory for the exact pitch relations (i.e. intervals between adjacent scale steps) within a scale after they had listened to one of three ascending-descending scales: the major scale, a scale constructed by dividing the octave into seven equal steps, and a scale constructed by partitioning the octave into 11 equal subdivisions and selecting a seven-tone subset with adjacent tones separated by one or two steps (Trehub, Schellenberg and Kamenetsky, 1999). Not surprisingly, adults performed well on the major scale and equally poorly on the two unfamiliar ones, showing an overwhelming influence of long-term exposure to music based on the major scale. By contrast, infants performed equivalently on the two unequal-step scales, as indicated by their response to a three-quarter-semitone change in one scale step, but they failed to notice the same change in the context of the scale with equal steps. Such findings make it unlikely that familiarity is the principal contributor to the infant music perception skills that have been reported here and elsewhere (for reviews, see Trehub and Trainor, 1993; H. Papoušek, 1996; Trehub, Schellenberg and Hill, 1997; Trehub, 2000). Other findings consistent with processing predispositions rather than culture-specific learning include comparable performance by six-month-old (Western) infants on melodies based on the major scale and the Javanese *pelog* scale (Lynch and others, 1990).

### (v) Harmony.

Western music historically has highly specific rules for combining simultaneous tones; their cultural specificity makes them unlikely candidates for inherent processing biases. This question has been explored by comparing infants' and adults' ability to detect a small (one-semitone) pitch change that was inconsistent with the key and implied harmony of the original melody and a larger (four-semitone) pitch change that was consistent with the key and harmonic implications (Trainor and Trehub, 1992). Adults detected the smaller pitch change more accurately than the larger, no doubt because their implicit knowledge of musical conventions obscured the ‘lawful’ change. Infants, however, detected both changes with equal accuracy, indicating that implicit knowledge of key membership and implied harmony depend upon enculturation. Subsequent research confirmed that sensitivity to key membership is evident by five years of age; sensitivity to implied harmony is evident by seven but undergoes further refinement as a consequence of musical training (Trainor and Trehub, 1994).

### (vi) Implications.

Infants' precocity in the perception of music and their performance parallels with adults are consistent with a human auditory system biassed to perceive melodies as coherent sequences, to recognize transpositions as functionally equivalent and to favour particular intervals and scales based on unequal steps. Such biases may operate, to some extent, as constraints on the range of possible music or, at least, on music that will be accessible to the untutored masses (Meyer, 1967; Schellenberg and Trehub, 1996; Trehub, Schellenberg and Hill, 1997; Trehub, 2000). Research on infant perception has identified aspects of music that are readily noticed and learnt and those that are likely to require effortful learning or extended exposure. It is clear, then, that infants do not begin life with a blank musical slate but rather with a set of skills that constitute a readiness to listen and learn, at the very least.

Research beyond the infant period is characterized by few central themes, being focussed instead on specific changes in the perception and performance of music that result from enculturation, formal training or environmental circumstances (e.g. Hargreaves, 1986; Pick and Palmer, 1993; Zenatti, 1993; Davidson, 1994; Hargreaves, 1996; Davidson, Howe and Sloboda, 1997; Umemoto, 1997).

### (vii) Absolute pitch.

Some scholars have proposed a critical period during which the ability to identify or reproduce the pitch of specific musical tones without reference to an external standard (Takeuchi and Hulse, 1993) is readily acquired but after which it is highly unlikely to be acquired despite extensive musical training (Sergeant and Roche, 1973; Miyazaki, 1988; Cohen and Baird, 1990; Crozier, 1997; Ward, 1999). The period in question, which relates to the onset of formal musical training, is commonly set at between three and six years of age.

According to some proponents of this early-learning theory, the underlying explanation resides in young children's inclination to focus on the pitches of individual notes rather than on pitch relations (Takeuchi and Hulse, 1993), which would facilitate the learning of pitch labels. The age-related shift of focus to relative pitch is thought to close the window of opportunity for acquiring absolute pitch. Although this explanation may be intuitively appealing, it is at odds with the infancy research documented above, which reveals relative pitch processing from the very beginning. Moreover, song-singing by four-year-old children confirms their continuing focus on relational features such as pitch contour and rhythm, and their inaccurate production of individual pitches (Davidson, 1994).

If young children perceive melodies relationally, as adults do, what facilitates their acquisition of absolute pitch? Children's cognitive inflexibility, particularly their tendency to focus narrowly on one dimension of a multi-dimensional stimulus, may be a contributing factor. For example, when pre-school children are asked to sort items on the basis of one dimension, such as colour, they continue to sort by that dimension when subsequently asked to sort by another such as size (Zelazo and Jacques, 1996). Although these children can report the appropriate rule, this knowledge fails to guide their behaviour. In early musical training, especially when it includes distinctive labels for pitch classes, children's usual focus on pitch relations may be transformed into a temporary fixation on absolute pitch. Aspects of language development during this period may also be implicated. At three years of age, children improve considerably in their ability to acquire new words (object labels) from very limited exposure (Rice, 1990); nevertheless, their understanding of language remains limited in several respects (Nelson, 1996). Only at about six do they begin to understand the arbitrary relations between words and their referents; before then, words are inseparable from the objects that they name (Papandropoulou and Sinclair, 1974; Gartner, Trehub and MacKay-Soroka, 1993). Thus, once 440 Hz is named, it can be nothing other than *a′*.

Other scholars have posited an inherited potential for absolute pitch (Bachem, 1940; Baharloo and others, 1998; Gregerson, 1998), which operates in conjunction with appropriate exposure. Not all children who receive early musical training acquire it (Takeuchi and Hulse, 1993), but it is unclear whether cases of failure implicate the type of training (e.g. whether fixed pitch names are introduced), differences in inherited potential or other factors. The high proportion of children who achieve absolute pitch in Japan (Miyazaki, 1988), where musical training begins most commonly in the pre-school period, offers little support for explanations involving heredity. However, it does not rule out the possibility of individual differences in the potential for absolute pitch or any of its component sub-skills.

*See also* **ABSOLUTE PITCH**.

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## VI. Musical ability

### 1. Lines of investigation.

'Musical ability' is a general term used to describe the level of musical skill and understanding an individual has achieved at any given time (Boyle, 1992). The level of ability displayed by any individual will be a joint result of aptitude and learning. Aptitude, which refers to the potential or capacity that an individual possesses to acquire musical skills, may limit the nature and time-course of what can be achieved through learning experiences and activities. Four key questions recur when considering this area: (*a*) Are there reliable ways of measuring ability? In particular, can musical aptitude be detected in the absence of significant achievement, and can such aptitude predict later achievement? (*b*) Is musical aptitude made up of a number of independent sub-skills that can be present or absent in differing degrees or combinations, or is there some single factor (musicality) which underlies all types of musical achievement? (*c*) Does aptitude have an innate or inherited component? Is it helpful to explain aptitude in terms of gifts or talents, and can characteristics such as gender be linked to this? and (*d*) What implications do conceptions of ability have on the way in which musicians are selected and trained?

These questions have, of course, been asked of many areas of human behaviour besides music, with the bulk of the research focussing on the concept of general intelligence or IQ (Sternberg and Grigorenko, 1997). Although there is a fair degree of consensus on the way they should be answered with respect to intelligence, the picture is much less clear for music (see Sloboda, 1985; Gordon, 1986; Hargreaves, 1986; Boyle, 1992). Our most reliable knowledge relates to the factors (e.g. cognitive, motivational, social and cultural) that determine how effectively individuals acquire and use musical skills.

### 2. Assessment.

Assessment of ability in musical contexts is normally subjective, unlike competitive sport, where winning a match is an objective measure of skill. Judges, who are often music professionals, listen to prepared performances and then rate these according to implicit or explicit criteria. It is well established that such assessments, even if offered by experienced and trained judges, have limited reliability (Laming, 1990). Ratings may change according to such variables as the gender or attractiveness of the performer (Landy and Sigall, 1974) and are extremely vulnerable to order effects (Hales and Tokar, 1975): for instance, judges often rate a performance in relation to the one they have just previously heard. Jury members of a leading international piano competition gave quite different ratings to the same performance when it was repeated twice within a sequence of recorded performances (Manturszewska, 1970).

For such reasons, it has been a tradition in psychology to attempt to devise objectively scored alternatives to expert judgment, in the form of standardized psychometric tests. Such tests have been applied in three broad areas: assessing aptitude or predicting musical ability, diagnosing musical strengths and weaknesses, and evaluating musical achievement (usually following some type of formal training). However, because it is hard to devise objective measures for qualities such as interpretative power, the most widely used psychological tests have tended to concentrate on relatively simple and short-term perceptual sub-components of musical skill, such as the ability to tell whether two short musical sequences are the same or different in pitch and/or rhythm (e.g. Seashore, Lewis and Saetveit, 1960; Bentley, 1966; Sergeant and Boyle, 1980). A number of comprehensive reviews of standardized musical tests have been published (e.g. Shuter-Dyson and Gabriel, 1981; Abeles, Hoffer and Klotman, 1984; Boyle and Radcoy, 1987). Because, however, most tests are limited in what they can measure, their general use and influence within the world of music have been negligible, except at very elementary educational levels where they have sometimes been used as selection instruments to decide which children should be offered specialist music programmes.

It has often been asserted that some standardized tests assess aptitudes on the grounds that no specific performance skills (such as those acquired through formal instrumental training) are needed to participate in them. However, great caution is required in drawing conclusions from performance in such tests. Few longitudinal studies have investigated the extent to which specific musical tests can predict long-term future achievement in music, and those that have been conducted have produced equivocal results. For example, Gordon (1968) found that musical aptitude scores predicted children's subsequent instrumental performance achievement after three years of training. However, a number of other studies have confirmed that measures of musical aptitude are not reliable predictors of children's success in music (e.g. Huftstader, 1974; Mota, 1997). Klinedinst (1991) found that musical aptitude scores accounted for less than 10% of the variance of the performance achievement of 205 children (aged ten and 11) who had just completed their first year of formal instrumental music training. A variety of non-musical factors such as boredom, fatigue and confidence in one's ability during test situations can influence an individual's performance in a musical test. O'Neill and Sloboda (1997) demonstrated that fluctuations in children's performance in a musical test were not influenced by differences in individual levels of cognitive skill but by their emotional and motivational behaviour during the test situation. In general, therefore, there is little evidence to suggest that it is possible to pick out those who are going to excel at music in adult life by the administration of aptitude tests at an early age.

### 3. Talent, inheritance, environment.

The question of whether musical ability is influenced primarily by differences in aptitude or training is often argued within the context of the nature–nurture debate (i.e. the extent to which ability is influenced by biological or environmental factors). There is general scientific consensus that the most fruitful question is how the environment and heredity interact, rather than whether one is more influential than the other (e.g. Sternberg and Davidson, 1986; Storfer, 1990; Ericsson, Krampe and Heizmann, 1993; Gardner, 1993; Plomin and Thompson, 1993; Terwogt, Hoeksma and Koops, 1993). However, in Western cultures in general, and in music education circles in particular, it is widely believed that innate talent provides an explanation for exceptional musical ability (Davis, 1994). It is often asserted that precocious musical accomplishment or particularly rapid progress can be explained only by special innate gifts and talents (for examples see Radford, 1990; Gardner, 1993; Winner, 1996). Direct evidence for genetic contributions to musicality, however, is hard to find (Howe, Davidson and Sloboda, 1998), and the limited evidence available suggests that musical ability is less heritable than characteristics such as intelligence (Coon and Carey, 1989). This is consistent with the view that most individuals have the capacity for musical competence (Ericsson, Krampe and Tesch-Romer, 1993). Early musical opportunity and experience may provide better predictors of eventual musical expertise than the presence or absence of early signs of musical ability (Howe and others, 1995). For instance, Ericsson and Lehmann (cited in Lehmann, 1997) have shown a direct relationship between childhood achievements by historically significant musical figures and the presence of a live-in teacher, in the form of a parent or personal tutor.

### 4. Gender differences.

Although no reliable gender differences in musical ability and aptitude have been found (see review by Shuter-Dyson and Gabriel, 1981), a gender reversal is apparent in musical involvement and achievement. More girls than boys are involved in, and successful at, musical activities at school (*Music for Ages 5 to 14*, 1991), and yet men continue to have more prominent roles in the music profession, achieving higher levels of success in their music careers. It has been pointed out that instrumental music is the only known area in which the gender-role differentiated beliefs and self-perceptions in childhood are opposite to the gender differences in participation seen in the adult world (Eccles and others, 1993, p.845). Gendered expectations that boys who engage in music have more natural ability and therefore greater potential for musical careers compared with girls (who are viewed as having to work hard in the absence of any real talent) continue to be transmitted through socialization processes and internalized by girls through gendered musical practices in education, the family, peer groups and the media (O'Neill, 1997). Historical definitions of femininity appear to orientate girls towards musical activities deemed appropriate for their sex, such as singing, and away from forms of public performance that receive the highest recognition and status in society. Sexual difference expresses itself not only in the musical practices and tastes of boys and girls, but also through multiple discourses that are constructed and perpetuated through diverse outlets such as music criticism and journalism, music academia and education, music professionalism, music marketing or musical sub-cultures (Green, 1997). According to Maccoby (1988), once a child understands gender categories, subsequent information may be integrated in terms of this influential classification and gender schemas (e.g. concepts such as masculine and feminine) are extremely resistant to change and contradiction (see O'Neill and Boulton, 1996, for research on children's gender-typed preferences for musical instruments). Increasing individuals' awareness of gendered musical meaning and its influence on identity and subjectivity may assist girls and boys to challenge and transcend accepted gendered assumptions and practices in music.

*See also* §VII, 2(ii) below and **WOMEN IN MUSIC**.

### 5. Practice, motivation, training.

One of the best predictors of musical competence in children and adults is the cumulative amount of effortful practice that is completed over many hours and years (Ericsson, Krampe and Tesch-Romer, 1993; Sloboda and others, 1996). Based on violinists' retrospective estimates of practice, the former study found that by the age of 21 the best violinists in their sample had accumulated approximately 10,000 hours of practice, more than twice the amount done by a group of violinists at the same institution who were training to be music teachers. Similar results have been obtained in a study comparing expert and amateur pianists (Krampe, 1994). High levels of regular practice from an early age have also featured in the biographical accounts of expert performing musicians (Manturzewska, 1990; Sosniak, 1990). After asking young musicians who displayed wide-ranging levels of musical competence to keep diaries on the amount of time they spent practising over a 42-week period, Sloboda and others (1996) found that the highest-achieving young musicians devoted significantly more time to their practice than the moderate and low achievers; the results also indicated that the highest achievers were more consistent in their practice from week to week and tended to concentrate on their technical practice in the mornings. However, most research in this area provides little information about the quality of practice undertaken and the effectiveness of strategies used by individuals when practising. Notable exceptions include studies by Gruson (1988), Ghent (1989) and Miklaszewski (1989). These studies indicate that, although there are degrees of variability and individual differences in practising behaviour, once musicians attain a certain level of expertise, there are important similarities in their use of strategies. Beginner instrumentalists tend to use fewer and less effective strategies and are less consistent in their practising behaviour than those who are more experienced. In a review of practising research, Hallam (1997) summarizes the following in relation to the practice of novice musicians: (*a*) Novices often appear unaware that they are making errors and have problems in identifying difficult sections. This may be because they do not have appropriate internal aural representations (schemata) against which they can evaluate their performance. (*b*) Novices tend to practise by playing through music rather than focussing on difficult sections. (*c*) When novices begin to identify errors they initially correct them by repetition of the single wrong note. As expertise develops, small sections (half-bar or bar) are repeated when errors are made; error correction gradually changes to a focus on difficult sections which are then worked on as units. Gruson (1988) found that the most reliable predictor of expertise was practice that focussed on repeating sections longer than a bar. (*d*) Novices learning to read music tend to focus first on playing notes at the correct pitch. Attention is then directed to rhythm. This then extends to all technical aspects of playing. Finally, attention becomes focussed on dynamics, interpretation and the expressive aspects of playing. As expertise develops, musicians tend to acquire an overview of the music they are to learn in the early stages of practising a new work, whereby the structure of the music determines how it is divided into sections for practice. (*e*) Changes in practice strategy use seem to be more closely linked to developing expertise than to age.

Although it is widely accepted that the amount of practice undertaken by individuals is an important factor in the acquisition of musical skills, it remains unclear why some individuals but not others persist in the many hours of practice necessary to master a musical instrument. It does not follow from the rejection of innate limits on acquired performance that everyone can easily attain high levels of skill. Contemporary elite performers have overcome a number of constraints. They have obtained early access to instructors, maintained high levels of deliberate practice throughout development, received continued parental and environmental support and avoided disease and injury. When one considers in addition the prerequisite – a level of motivation necessary to lead a child to engage in deliberate practice every day for years and decades, when most children and adolescents of similar ages engage in play and leisure – the real constraints on the acquisition of expert performance skills become apparent (Ericsson, Krampe and Tesch-Romer, 1993, p.400). There is little doubt that motivation to persist in instrumental training is inextricably linked to the social and cultural environment. For example, Sosniak (1985) and Sloboda and Davidson (1996) found that the time a child spent practising was related to the amount of support and encouragement the parents and teachers were willing and able to provide. The nature of this support changes with age, but in the pre-adolescent years it typically included direct parental supervision of practice activities. No amount of social support, however, is likely to make a child without motivation or intrinsic interest in music engage in the long-term effort required to succeed at even modest levels of musical competence.

A review of research into motivation for music is provided by Thomas (1992). Much of this research has been on the relationship between attitudes, self-esteem or self-concept and musical achievement (e.g. Hedden, 1982; Austin, 1991) and the attributions individuals make for success and failure in music (e.g. Asmus, 1989). Junior high school students who attributed the failure of a fictitious music student to insufficient effort or poor learning strategies were more likely to expect improved future performance than students who attributed failure to a lack of ability (Vispoel and Austin, 1993). Before beginning formal instrumental training, children may be divided into two broad groups: those who had a tendency towards adaptive mastery motivational behaviour and those who tended towards maladaptive helpless motivational behaviour (O'Neill, forthcoming). Mastery behaviour is associated with the pursuit of task mastery and high persistence following difficulty or failure; conversely, helpless behaviour is associated with the avoidance of challenge, task choices that emphasize short-term success at the expense of opportunities for future development, and low persistence and performance deterioration in the face of failure (see also Diener and Dweck, 1980; Dweck, 1986). These motivational patterns are especially salient in evaluative achievement contexts and are often quite independent of an individual's actual ability or potential. In other words, helpless and mastery motivational patterns account for the difference between the cognitive skills an individual can use and the skills he or she actually displays under certain conditions. The results of the study showed that children who displayed mastery behaviour made more progress at learning to play an instrument than those who displayed helpless behaviour, while standardized measures of musical aptitude and intelligence did not contribute significantly to the prediction of musical achievement.

During the initial stages of learning to play a musical instrument there are many obstacles to overcome; as a result, individuals experience difficulty and failure very early in their training. In addition, teachers often emphasize the incorrect aspects of performance, which tends to focus attention on an individual's lack of ability rather than encourage the effort and enjoyment associated with spontaneous music-making. Also, unlike academic school subjects where children are rarely given the choice of not pursuing an activity, instrumental training requires a great deal of autonomy on the child's part. For example, it is often up to the child to ensure that practice is done at home or to decide what is practised (i.e. whether new, difficult material is practised or avoided). It is in these circumstances in particular that helpless children may differ from mastery children. For example, helpless children may avoid practising pieces that pose particular difficulties, or give up practising as soon as something becomes difficult, whereas mastery children will seek challenges and persevere until each new skill or technique is fully mastered. Thus it is likely that mastery children will make faster progress in the initial stages of learning a musical instrument than helpless children.

Evaluative achievement contexts are apparent from the earliest stages of instrumental training and feature prominently in any assessment of musical skills (such as competitions, examinations or public performances). In Western cultures in particular, most instrumental training follows a classical conservatory tradition. The characteristics of this cultural tradition include an emphasis on performances which accurately reflect printed music notation, a focus on repertory with a high standard of technical difficulty and an implicit or explicit focus on competitive events and evaluative situations which form an important part in the decision-making process concerning an individual's progression and reward (Sloboda, 1996). However, it is important to recognize that many individuals learn to play instruments using less formal or traditional approaches (including teaching oneself), such as jazz, pop or folk improvisation. These learning approaches have very different characteristics; moreover, motivational patterns may affect achievement in different ways.

Musical ability depends on a complex interaction involving cognitive, motivational, social and cultural factors, and an individual's experience, education, aspirations and attitudes towards music and musical training. Any full account of the development of musical ability must acknowledge the direct or indirect influence that each of these factors has on achievement.

*See also* **PERFORMANCE**.

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## VII. Social psychology

### 1. Introduction.

The social psychology of music attempts to explain how musical behaviour is related to its social and cultural context. Music is an essentially social activity: we create, perform, perceive and evaluate it using knowledge, attitudes and skills that are shared with other people. Music consists of physical sounds whose organization and patterning can be explained in terms of precise structures, but these structures only acquire musical meaning as a result of the social and cultural context in which they exist.

An important early landmark in the field was Farnsworth's *The Social Psychology of Music* (1954, 2/1969). His intention was to re-establish the importance of what he called the cultural determinants of musical behaviour in relation to its biological and physical bases. He felt that the cultural determinants were given insufficient emphasis in research, which was concerned with establishing absolute standards of musical performance and taste. However, a substantial proportion of Farnsworth's book dealt with perceptual issues (scales, intervals, melody) rather than with truly social psychological ones, though his extensive research on historical trends in musical taste and the eminence of composers is a notable exception.

The role of music in everyday life has changed dramatically as a result of recent social and technological developments (see Hargreaves and North, 1997). As far as the listener is concerned, the growth of the mass media, the availability of inexpensive tapes, CDs and videos, advances in miniaturization and portability (e.g. the ‘Walkman’), and the huge potential of the internet mean that the range of music that can be heard by most people, the uses they make of it and the situations in which they hear it are far more extensive than hitherto. As far as musicians are concerned, the development of midi is beginning to revolutionize the ways in which music is created, arranged, recorded, stored and transferred between locations. These changes mean that creating, performing and listening to music are part of the everyday lives of more ordinary people than ever before, and that the nature of musical participation, musicianship and musical literacy needs to be redefined. The boundaries between different styles and genres are becoming increasingly blurred, and the uses to which music is put are ever-increasing. Music might be used in therapeutic settings; to promote non-musical aspects of children's learning; to increase work performance in industry; to create a particular mood or ambience in a commercial setting; to establish a ‘brand image’ in advertising; or to accomplish other aims in medicine, therapy or education.

The interaction between musical behaviour and the social environment can be analysed on three broad levels relating to individuals, social groups and situations, and broader cultural influences.

### 2. Individual differences.

The study of individual differences in musical behaviour, and the ways in which these are influenced by the social environment, has centred largely on three main factors: age, gender and personality.

#### (i) Age.

The influence of the social environment on age-related developmental changes is seen most clearly in musical tastes and preferences. Young children express interest in and liking for a wide range of musical styles and genres. This tolerance declines over the childhood years and reaches its lowest point in early adolescence. It increases again into early and middle adulthood, and then declines once more in later life. These changes almost certainly result from social and cultural influences rather than from any maturational or developmental processes, and these influences can be seen most clearly in adolescence. Many teenagers have extremely strong liking for and affiliation to a relatively small number of popular music styles. The overwhelming importance of pop music in their lives is shown by the massive sales figures of the pop music industry as well as by surveys that show that teenagers spend far more time listening to pop music than they devote to other comparable leisure activities. Research also shows that pop music fulfils many important functions in the lives of teenagers. It can serve as a distraction from the problems of adolescence, and often forms the basis of interpersonal and inter-group relationships. More generally, it has been suggested that music serves as a 'badge' of identity by which adolescents define themselves and others.

### (ii) Gender.

Many gender differences in musical behaviour can be explained in social psychological terms. Men have traditionally dominated the music profession in Western culture. The vast majority of the great composers have been men, and some instruments (e.g. brass, woodwind and percussion) were traditionally regarded as inappropriate for females, although women are increasingly employed as professional players of a variety of instruments. Gender differences in music education, however, run in the opposite direction. In the UK more girls than boys learn musical instruments at school. Almost twice as many girls as boys enter national music examinations, generally gaining higher marks than boys. This apparent paradox suggests that gender differences are the product of social forces and conventions rather than of innate differences in musical ability (see §VI, 5). Many of the effects can be explained in terms of gender stereotyping. A growing body of evidence shows that certain instruments, such as the drums, trombone and trumpet, are widely perceived as 'masculine', whereas the flute, violin and clarinet are regarded as 'feminine'. The power of these stereotypes on teachers, parents and pupils is undeniable, and is probably at the heart of women's underachievement in the music profession.

*See also* **WOMEN IN MUSIC**.

### (iii) Personality.

The third area of individual differences in musical behaviour is the study of personality. It has been shown by psychologists that the acquisition of music knowledge and skills depends to some degree on personality and temperament. Several personality traits are normally considered 'masculine' or 'feminine' in the general population (Saville, 1972; Saville and Blinkhorn, 1976); however, in musicians from mid-adolescence onwards these gender-related differences are greatly reduced and in some cases reversed (Kemp, 1982a, 1985, 1996). Musical performance, in particular, is dependent on a personality profile that in some ways can be perceived as androgynous (Bem, 1974). The principal characteristics of the musician's personality are introversion, independence, sensitivity and anxiety, all of which are influenced by occupational factors.

### (a) Introversion.

Research suggests that musicians at all stages of development reveal tendencies towards introversion, perhaps acquired through years of isolated practice (Kemp, 1981b, 1996). This begins to reveal itself in teenage musicians and becomes more pronounced in those who proceed to higher education and into professional life. Musicians do not generally display the shyness and seriousness normally associated with introversion; its psychological significance in them is more related to a tendency to be self-sufficient and detached, characteristics referred to by Jung as 'living inwards'. Tchaikovsky referred to his compositional process as 'hidden utterances of my inner life' (Vernon, 1970). Musicians develop a rich, symbolic and imaginative inner life in which all valued knowledge and experience are constantly revisited and revised. This internalization of sound permeates the body's nervous system kinaesthetically so that musicians can be said to think with their bodies in the way suggested by Jaques-Dalcroze (Bachmann, 1984). It may well be true that it is this essential capacity that separates the musician from the non-musician.

### (b) Independence.

In general populations independence is invariably linked with extraversion, but in musicians it is associated with introversion (Kemp, 1981b, 1996). The combination of these two personality dimensions causes the musician to emerge in adulthood as a 'bold introvert' (Drevdahl and Cattell, 1958). Other phenomena associated with independence relate to aspects of the cognitive style of creative people who appear to prefer complexity and possess the ability to operate with thoughts, feelings and ideas that may be in conflict. Their independence manifests itself in their need to seek novel experiences (Kemp, 1996). These qualities are less observable in teenage musicians, who tend to be predisposed towards dependency.

### (c) Sensitivity.

Sensitivity is a quality that musicians possess at all stages of development. It is, however, wrong to interpret it purely in terms of aural acuity. Musicians' sensitivity is better interpreted as a proclivity towards 'feelingfulness' in which the lower levels of the brain are mobilized in a type of thinking that might be less exclusively cerebral than found, say, in mathematicians or computer programmers, and more open to insight and intuition (Kemp, 1996). These qualities are especially apparent in musicians' thought processes during performance and composition, as well as in their responses to music generally. Surprisingly, musicians may not be the quickest thinkers – their cognitive style requires them to ruminate at some length and depth, and to incubate solutions to problems (Myers, 1980). It is often thought that decisions in performance need to be carried out cerebrally and taken in split seconds; in fact, it may be more accurate to view them as being kinaesthetically based – a form of body thinking (as described above in connection with introversion; see also §IV, above).

### (d) Anxiety.

The study of anxiety in musicians has generated an extensive literature, much of which relates to performance anxiety and its control; this behavioural research lies outside the scope of this article. Anxiety as a personality trait manifests itself chiefly in adult musicians; the only exception is its appearance in teenagers who attend specialist music schools (Kemp, 1996). While anxiety can be extremely debilitating in the performer, it is wrong to view it as an exclusively negative phenomenon. Its appearance within the personality make-up of performing artists who do not experience performance anxiety suggests that it also has facilitating properties – for example, in ensuring that the performer is 'activated' at an optimum level in order to perform at his or her best (Hamann, 1982; Hamann and Sobaje, 1983). Problems may arise when the individual becomes overactivated and a state of panic can ensue. In other words, although anxiety may be beneficial for motivational purposes, in various circumstances higher levels will cause a disintegration of performance.

### (e) Occupational factors.

The traits described above are found in varying degrees and combinations in performing musicians, composers and teachers. Research over a fairly long period has suggested that there exist significant differences between the personalities of different types of instrumentalists (Martin, 1976; Kemp, 1981a; Bell and Cresswell, 1984; Kemp, 1996). String players have been shown to be the most introverted, brass players (with the possible exception of horn players) the most extraverted. Of the two groups, string players are also the more sensitive. The predominantly male brass players do not conform to the features of androgyny found in other musicians, preferring to maintain a more stereotyped gender identity. It is more difficult to identify a personality pattern common to all woodwind players. There appears to be a tendency for them to be introverted and lacking in anxiety, although the latter may not generally apply to oboe players. Little research has been undertaken with orchestral percussion players. Keyboard players have been found to be comparatively extraverted and adjusted, and somewhat submissive and conscientious in outlook. Singers display a consistent profile of extraversion, independence and sensitivity that may reflect the task of singing in which the singer's personality is itself projected rather than the character of an external instrument (Piers, radio broadcast, BBC, 4 Oct 1978).

Composers display most of the personality traits of the performer at significantly higher levels. Not only are they more introverted, more independent and sensitive, they are radical in a way that most performing musicians are not. They are also less disciplined (Kemp, 1981c), perhaps reflecting a need to be free of externally imposed norms in order to adhere to their own well-internalized rule systems. The finding that composers exhibit less anxiety than performers may be accounted for in psychoanalytical terms: by engaging in creative processes, people bring resolution to tensions within themselves and develop new integrations. By extension, it might be thought that creative activity would attract those with severe mental health problems (Post, 1994; Kemp, 1996); this is perhaps borne out by the biographies of Berlioz, Bruckner, Musorgsky, Puccini, Schumann, Tchaikovsky, Wagner and other composers.

School music teachers, on the other hand, typically show lower levels of the personality traits described above as compared to composers. It seems likely, for example, that the rough-and-tumble of school classrooms requires a resilience that many musicians would not be able to generate given their degree of introversion and sensitivity. Student music teachers tend to be significantly more extraverted, less sensitive and more conservative than music students pursuing performance (Kemp, 1982b). Moreover, the gender differences noted above in connection with performers are reversed in teachers, bringing them more in line with the general population. This research suggests that, in order to be accepted in today's classrooms, music teachers need to be less obviously different from the general population while still retaining some residue of the personality characteristics of the musician. This appears not to apply to the private studio teacher, who may retain much of the musicianship-related profile.

### 3. Social groups and situations.

Social psychologists have established that the judgments of an individual often conform to those of an external social group, even if the latter are clearly erroneous. Thus, some people will choose to listen to music that they do not like if they believe that important external groups do like it. One possible explanation for conformity in musical preference is that prestige effects occur when favourable information attached to a particular piece of music influences the listener's response positively. For example, listeners in experimental studies often report liking a piece supposedly played by a concert pianist but report disliking exactly the same piece when it is supposedly played by a music student. A similar process may explain why music by physically attractive performers is evaluated more favourably than that by unattractive performers, or how listeners' interpretations of music may be influenced by the body language of the performer. It seems that some form of perceptual reorganization may occur under these circumstances, such that the listener actually hears the music differently after exposure to specific information about it.

The social environment may also influence responses to music by affecting the autonomic nervous system. In most situations, people tend to prefer music that moderates extreme levels of environmentally induced arousal. For example, after exercising or being insulted, both of which induce high arousal, people tend to prefer soothing music. While exercising, however, people may deliberately increase their arousal by listening to loud, fast music. In other words, musical preference can be driven by the goals people have in a particular situation. Similarly, people tend to prefer music that is consistent with their expectations of that which is typically heard in a particular setting: the

Wedding March from *Lohengrin* may evoke tears of joy in a church, but tears of boredom elsewhere. Such effects cannot be explained purely in terms of arousal, and psychologists also draw on contemporary models of human cognition which are based upon the networks of associations between different elements of our thinking. Some aspects of situational influences on musical preference can be explained in terms of the differential activation of these networks, raising the possibility of neural linkages between our musical and social worlds (see §VIII).

### 4. Cultural influences.

Musical behaviour is also influenced by the broader culture in which music is produced and listened to; for example, the vast majority of listeners, composers and performers tend to listen to, compose within and perform the musical genres that are prevalent within their culture. Farnsworth was perhaps the first to investigate these specific cultural influences in detail, documenting the waxing and waning in popularity of classical composers using a variety of measures such as radio airplay and the content of orchestral programmes. These patterns mirror those found in pop music sales charts.

More recently, psychologists have begun to employ computerized analyses to investigate historical and cultural trends in musical behaviour. Several interesting trends have emerged. For example, moderately original themes (defined in terms of their statistical infrequency) are more popular at any given time than either highly original or very unoriginal themes. Over time, however, themes increase in originality as each generation of composers seems to employ ever more drastic measures to capture the attention of the public. These analyses also show that a range of other factors influence composers' work: for example, composers working in cities of high compositional activity tend to produce more original work than do composers in areas of less compositional activity; and compositions tend to become more original and disjointed when composers work under stress induced by illness or warfare. Non-Western cultures provide numerous examples of the non-aesthetic functions of music listening and performance such as storytelling, ceremony and the preservation of ethnic identity.

### 5. Applications.

There are three main areas of research on the applications of music in everyday life.

(*a*) Music education research addresses social psychological issues such as the interaction between teacher and pupil, and how trainee music teachers grow into their new role.

(*b*) Research in health psychology deals with the role of music in therapy – in particular, the direct physiological benefits that music can produce, such as pain relief, or weight gain in neonates.

(*c*) Social psychologists are also concerned with the commercial uses of music. The music industry is a major contributor to the gross domestic product of many nations. Moreover, when played in shops, restaurants or bars, music has been shown to influence sales volume, the amount customers are prepared to spend, the image of the place in which it is played, the products customers choose, the amount of time they spend browsing or waiting on-hold, and their perceptions of the amount of time spent in the store (*see also* **ENVIRONMENTAL MUSIC**).

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## VIII. Neuropsychology

The neuropsychology of music attempts to provide an understanding of how our nervous systems enable us to be musical. A fundamental question is whether specialized areas in the brain may exist for music and, if so, where such systems may be located. This question was first investigated through studies on how brain damage may affect musical abilities. A number of descriptions exist of individuals who suffered musical disturbance following brain damage (Marin and Perry, 2/1999). There are also instances of dissociation between music and other abilities, such as the case of the Russian composer Shebalin, whose Fifth Symphony was written after a stroke that abolished his language function (Luria, Tsvetkova and Fuler, 1965). More systematic and controlled studies have demonstrated that damage to portions of the temporal lobe, an area of the brain containing the auditory cortex, results in deficient processing of melodies (Milner, 1962). The impairment is more marked when the damage is on the right, leading to the hypothesis that there might exist a specialization of function for aspects of music that is complementary to the well established left-brain dominance for language skills.

Subsequent work has suggested that music consists of many subfunctions, each of which has its own organization in the brain. Thus brain structures in and around the right primary auditory cortex seem critical for extracting pitch from the overtone structure of complex tone (Zatorre, 1988), while surrounding regions may be involved in computing interval relationships, maintaining pitch information for short periods in memory (Zatorre and Samson, 1991) and encoding information relevant to timbre, such as rise time or harmonic envelope (Samson and Zatorre, 1994). Findings have also emerged indicating that damage to areas of cortex important for perceiving music also disrupts the ability to imagine music, suggesting that the ability to represent musical information in the mind is dependent on the same brain areas as when music is actually heard (Zatorre and Halpern, 1993). Basic auditory discrimination capacity remains largely intact in these patients, leading to the possibility that the cortex might be important for processing patterns of information rather than for the elementary acoustic elements of music.

New scanning and imaging methods have allowed the measurement of brain activity in undamaged humans during normal musical activity. These studies have confirmed the importance of the right temporal cortex to music, since this area is active when listening to melodies. However, complex interactions exist between many brain areas even for the simplest task. For instance, remembering the pitch of a single tone while other tones are sounded requires the coordinated activity of many distinct areas within both cerebral hemispheres (Zatorre, Evans and Meyer, 1994).

Despite evidence of the importance of the right cerebral cortex, normal musical functioning depends on intact processing and communication between both halves of the brain. This is shown in patients with ‘amusia’ (the specific loss of essentially all music processing skills; Peretz and others, 1994). Such individuals are unable to perform many simple musical tasks, such as recognizing a tune familiar since childhood, yet display no trouble with language or other cognitive skills. The best documented of these cases suffer from damage to both hemispheres, indicating the coordinated nature of the underlying processes. Such cases also provide additional evidence for the independence of music from other abilities, and support the notion of specialized neural circuitry for music.

Musical training has been shown to affect brain organization. For example, the region of the brain that controls the fingers of the left hand in players of string instruments has been reported to be more highly developed than for the right-hand fingers, indicating that an expansion of the cortical systems for motor control of the fingers may take place (Ebert and others, 1995). Similarly, other studies suggest that the fibres connecting the two halves of the brain may be more numerous in musicians, perhaps as a result of the fine coordination of the two hands that is necessary for playing many instruments (Schlaug and others, 1995). These and other findings suggest that a great deal of flexibility may exist in the brain, and that experience, particularly early in life, may change its organization; such plasticity may play a major role in developing expertise in music.

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