CHAPTER 21

MUSICAL EXPECTANCY AND THRILLS

DAVID HURON AND
ELIZABETH HELLMUTH MARGULIS

21.1 Introduction

In the history of scholarship pertaining to music and emotion, the phenomenon of *expectation* has occupied a central and perhaps privileged position. The traditional emphasis on expectation may be traced in part to some of the unique properties of music compared with other arts. Commentators have suggested that in many arts, emotions are evoked through stylized depictions or representations of common emotional displays (e.g. Aiken, 1998). In arts such as portraiture, sculpture, drama, film, mime, and dance, human body language and facial expressions may evoke, portray, or suggest particular affective states. While music sometimes contains representational elements, philosophers and music commentators have long recognized that music is not a representational art in the way that painting or sculpture can be.

Nevertheless, throughout history, music has frequently been described as the most 'emotional' of the arts. Next to conversation with a close friend, music is the most commonly sought catalyst when people want to change moods (Thayer, 1996). Whether people seek joyful animation or sad nostalgia, music is often the art of choice.

Paradoxically, music achieves its affective power through seemingly abstract tone sequences, largely devoid of representational content. What accounts for music's success in evoking emotions when its capabilities for representing the natural world seem so constrained?

A possible answer to this question begins with the recognition that music consists of a sequence of sound events that unfolds in time.[1] The foremost dimension available to musicians is the temporal dimension. While other elements of music may play important emotional roles, a number of scholars have understood that the psychology of time plays a paramount role in musical experience (Jones, 1976). Temporally rooted phenomena such as anticipation, surprise, and delay underlie important aspects of musically evoked affect.

The idea that time is a central element in emotion contrasts starkly with mainstream research in the psychology of emotion. Until recently, emotion research has been unduly consumed with facial expression. The psychology of emotion's preoccupation with visual stimuli has been accompanied by a corresponding neglect of the role of time. But time permits a listener to engage with a stimulus in an active, predictive way, allowing for dynamic fluctuations in affective responses.

In this chapter, we provide an overview of contemporary and historical research on music and expectation. We describe some of the functional biology involved in prospective cognition, review common experimental methods used in expectation research, summarize some of the pertinent neuroanatomy and physiology, discuss some of the mechanisms by which expectations are thought to be acquired, and identify some of the affective consequences of expectation. In addition, we summarize some of the main theories of musical expectation, including theories by Meyer, Narmour, Margulis, and Huron. The chapter ends with an extended discussion of the phenomenon of music-induced *frisson*—the 'chills' or 'thrills' characterized by a sensation of the hair standing up on the back of one's neck, accompanied by sensations of coldness and pleasure.

21.2 Biological origins

A number of authors (Hawkins & Blakeslee, 2004; Huron, 2006; Raichle et al, 2000; Suddendorf, 2005) have drawn attention to the biological importance of expectation. The ability to foretell the future confers obvious survival benefits even when the predicted future is just seconds away. The mental aptitude to form expectations is widely assumed to be a product of evolution by natural selection. That is, our predictive faculties arose through efforts over millions of years to produce organisms capable of clairvoyance and prophecy.

The adaptive value of accurate expectation is evident in the speed of behavioural responses. Innumerable reaction-time studies have shown that animals respond to stimuli more quickly when the stimulus is more predictable (e.g. Aarden, 2002; Bharucha & Stoeckig, 1986; Bigand & Pineau, 1997; Margulis & Levine, 2006; Tillman, Bigand, & Pineau, 1998). For example, when asked to indicate whether pitches go up or down, listeners are faster to respond when the melodic contours conform to their expectations (Aarden, 2003). In general, anticipating events buys an organism additional time—time to prepare.

21.3 The nature of musical expectations

Prediction is so important for survival that evolution appears to have created more than one predictive mechanism. One way that organisms prepare for the future is by mentally enacting different future scenarios through the process of *imagination* (Wilson & Gilbert, 2005). Imagining future scenarios is not limited to humans. In running a maze, the brain areas associated with different spatial trajectories are activated when the mouse pauses to consider its options (Johnson & Redish, 2007). That is, the neural regions associated with different pathways are replayed, suggesting that the stationary mouse is imagining different routes.

Other predictive mechanisms are more automatic and require no active contemplation. When listening to a familiar playlist of songs, for example, listeners typically anticipate the beginning of the next song in the playlist as the current song ends. This familiar experience occurs even when the relationship between successive songs is entirely arbitrary. That is, listeners can learn to anticipate future sounds, even when there is no musical principle or structural relationship connecting the two events.

21.3.1 Statistical learning

More formal demonstrations of this effect have been made by Jenny Saffran, Richard Aslin, and their collaborators. In a classic experiment, Saffran et al (1999) constructed small musical 'vocabularies' consisting of six three-note 'figures'. Using these figures, they then constructed long tone sequences in which the six figures were played repeated in random order. The tone sequences were constrained so that the same figure was never presented twice in succession. They then exposed eight-month old infants to this isochronous tone sequence for up to 20 minutes. From the infant's perspective, they simply heard a steady stream of pitches with no grouping cues to indicate that the sequences had been constructed out of three-note figures. Following this exposure phase, the infants heard pairs of three-note figures. Using a head-turning paradigm, Saffran and her colleagues demonstrated that the infants had abstracted the three-note figures from the original vocabulary used to construct the tone sequences. Experimental controls allowed Saffran and her colleagues to conclude that the infant responses had nothing to do with the structure of the figures and related only to their familiarity.

Over the past decade, a considerable volume of experimental research has accumulated supporting this phenomenon of 'statistical learning'. Listeners learn to anticipate sequences of sounds merely through exposure; they anticipate most strongly the sound sequences to which they have been most frequently exposed.

These learned expectations are limited to prospective rather than retrospective relationships between stimuli. For example, listening to the beginning of one song does not typically help a listener recall the end of the previous song on a familiar playlist. That is, expectations move forward in time. From a biological perspective, this limitation makes sense, since the goal of expectation is to prepare an organism for the future, not the past.

Statistical learning is evident in many aspects of music listening. In Western music, duple and quadruple meters are more commonplace than triple meters. Consistent with this, Brochard et al (2003) have shown that listeners exhibit a binary meter bias. Similarly, nearly three-quarters of Western music is in the major mode. Consistent with this, Huron (2006) has noted that listeners assume unfamiliar works to be in major keys.

In many ways, the statistical nature of these automatic expectations should not be surprising. When predicting future events, a straightforward strategy is to predict the recurrence of the most common past event, including the most common contingencies (X typically occurs in context Y). Notice that if expectations arise from commonly occurring sound patterns, then the main factor influencing expectation is the listener's sonic environment. Because listeners have different listening backgrounds, predictability must be listener specific. Nevertheless, since listeners in a given culture are exposed to broadly similar acoustical environments, they will probably acquire broadly similar expectations. Since musicians cannot afford to tailor musical works for a specific individual listener, only the culturally shared forms of predictability are available in the musician's psychological tool kit.

21.3.2 Mental representations for expectation

The mental representation for prospective knowledge remains an open area of research. In describing expectation-related knowledge, researchers have appealed to a variety of concepts, including *paradigms*, *scripts*, and *heuristic rules*. Whatever the nature of prospective knowledge, experimental evidence suggests that the knowledge listeners have of future events represents imperfect approximations of objective patterns.

An example of such an imperfect approximation can be found in the phenomenon Leonard Meyer famously referred to as 'gap fill'—what von Hippel referred to as 'post-skip reversal'. Post-skip reversal is the notion that listeners expect a large interval to be followed by a change of direction. This pattern can be observed in music all around the world. The majority of large melodic leaps are indeed followed by a change of direction. However, this pattern is known to be an artefact of a well-known statistical behaviour, *regression to the mean*. If we encounter a tall person on the street, the next person we encounter is likely to be shorter. But the presence of the tall person did not *cause* a shorter person to appear. The operative principle is that most people are of average height. Similarly, high pitches are likely to be followed by pitches closer to the average pitch. Since large melodic intervals will tend to move a melody away from the central pitch region, large melodic intervals will tend to be followed by a change of direction. However, the large interval does not *cause* this reversal. Instead, the operative principle is that most pitches in a melody are of average pitch height. Using large samples of music from five continents and spanning six centuries, Von Hippel and Huron (2000) provided a formal statistical demonstration of regression to the mean in the case of music. There is no objective tendency for large intervals to be followed by a change of direction apart from regression to the mean.

However, subsequent experiments carried out by von Hippel (2002) and by Aarden (2003) showed that Western-enculturated listeners expect post-skip reversal rather than regression to the mean. Listeners do not expect ensuing pitches to be closer to the average pitch. Instead, they expect large leaps to be followed by a change of direction. For this particular pitch pattern, listeners have acquired an expectation that is an imperfect approximation of the pattern evident in real music. Meyer's notion of 'gap fill' is an appropriate description of listener psychology, but an erroneous description of objective musical organization: 'gap fill' exists in listeners' heads, not in musical scores. Other examples of such imperfect heuristic expectations are documented in Huron (2006).

21.3.3 Memory

In recent years, psychologists have become more cognizant of the importance of predictive brain mechanisms. Hawkins and Blakeslee (2004) emphasize that 'prediction is not just one of the things your brain does, it's the primary thing . . . the cortex is an organ of prediction' (p. 89). Suddendorf (2006) characterizes the capacity to anticipate the future as a transformative step in human evolution. Raichle and Gusnard (2005) suggest that anticipation is a primary component of the *default mode*, the pattern of neural activity that occurs when the mind is not engaged in any particular task (Bar et al, 2007).

The concept of the predictive brain has transformed thinking in many areas of psychology, notably core research in memory. For much of the past century, memory has been conceived of as a sort of storage system akin to a library—something like a repository of past experiences. Yet in recent decades, researchers have recognized that the adaptive purpose of memory must be prospective rather than retrospective. From a biological perspective, memory would be useless unless it helped future behaviours to be more adaptive (Huron, 2006).

The role of memory in prospective cognition is evident, for example, in the process of imagination (mentioned earlier). Recent research has shown that memory provides the database for simulating future scenarios. For example, patients suffering from amnesia due to hippocampal damage show specific impairments when imagining scenarios such as a day at the beach or a shopping trip (Hassabis, Kumaran, Vann, & Maguire, 2007). In contemplating the future, remembered events are woven together to create plausible future storylines. Addis, Wong, and Schacter (2007) argue, for example, that 'future thinking' is 'an important, if not the primary, function of episodic memory' (p. 1374).

The idea that the biological function of memory must be prospective rather than retrospective suggests that the classic distinctions between various forms of memory (e.g. semantic memory, episodic memory, working memory, etc.) are better thought of as different forms of expectation. This idea was first advanced for music by Jamshed Bharucha (1994), who distinguished schematic from veridical expectations and linked them to long-term and episodic memory respectively.

Bharucha suggested that knowledge of how a particular musical work goes is a different sort of knowledge from knowledge of how music in general goes. Both types of knowledge are omnipresent in listening. That is, when anticipating the unfolding of events in a musical work, our expectations are informed not just by (possible) familiarity with the work, but by familiarity with a musical language. These independent parallel processes help to explain a classic problem in musical expectation, sometimes referred to as *Wittgenstein's puzzle* (Dowling & Harwood, 1986): How is it possible that a deceptive cadence can continue to sound deceptive even though a listener's familiarity with the work means that the deception is entirely expected? According to Bharucha's view, schematic expectations (reflecting how music in general goes) remain surprised, even though veridical expectations (reflecting how this work goes) remain unsurprised.

Further conceptual developments can be expected as psychologists reinterpret the huge memory literature in light of the prospective functioning of memory. All memory research will need to be reinterpreted in terms of the question 'How does this memory phenomenon assist an organism by creating future adaptive behaviours?'

21.4 Affective consequences of expectation

In tandem with this reconception of memory, there has been a parallel reconception of emotion and motivation systems. In the past, affective neuroscientists focused on the pleasures associated with achieving particular desirable outcomes (such as food, warmth, companionship, etc.). The hormone and neurotransmitter dopamine, for example, has long been viewed as the brain's principal reward system,[2] and until recently was thought to reward particular outcomes. However, researchers now regard the hedonic effects of dopamine as linked to the experience of seeking/expectation rather than to the pleasure of consumption/satiety (e.g. Panksepp, 1998). For example, dopamine is released as the moment approaches when an animal receives a reward (e.g. food, water, sex, play object). But when the reward is received or consumption begins, dopamine levels drop. When the dopamine system is destroyed, an animal may die of hunger, even when food is plentiful, and even though eating the food will be pleasurable—simply because the animal is not motivated to eat (Panksepp, 1998). The dopamine deficiency characteristic of Parkinson's disease robs individuals of their will.

Dopamine appears to reward *wanting* or *expectation*, not consummation. The role of dopamine is apparent in the effects of exogenous drugs (like cocaine) that emulate the effect of endogenous dopamine. These drugs do not simply result in a blissful stupor. Instead, they cause users to feel a strong sense of pleasurable engagement—of energy, focus, purpose, drive, zest, or concentration. The positive feelings evoked by consumption involve different hedonic systems.

Like a driver seeking a filling station, the feeling of wanting must occur well before the fuel is actually needed. (If organisms got hungry only when glucose levels approached 'empty', then more animals would die of hunger.) In short, all feelings of want, desire, anticipation, drive, or interest (such as feelings like hunger or curiosity) are future-oriented affects intended to promote specific future-adapative outcomes. The most important brain rewards are not those that reward the acquisition of particular resources, but those that reward striving for those resources.

21.5 Prediction effect

Another example of reinterpreting the emotional literature in light of prospective brain operations can be found in the so-called 'mere exposure effect' (Moreland & Zajonc, 1977). In 1903, Max Meyer demonstrated that listeners show increased liking for a musical work as they become increasingly familiar with it. Throughout the twentieth century, a large volume of research accrued supporting the preference for familiar stimuli (for a review, see Bornstein, 1989).

However, Huron (2006) argues that the empirical research has been misinterpreted. Huron proposed that accurate prediction is so essential for survival that brains must have special structures that motivate (reward) accurate prediction. Rather than a preference for familiarity, he argues that the experimental evidence is more consistent with a 'prediction effect', where the rewards for accurate prediction are misattributed to expected stimuli. Listeners prefer familiar stimuli not because they are familiar, but because they are predictable. In Huron (2006), this suggestion is used to explain many music-related feelings, such as the increased satisfaction associated with ending on a cadential tonic rather than the leading tone.

21.6 Experimental methods in expectation research

Expectations can take various forms and trigger various consequences. Accordingly, the methodologies used to investigate them vary widely. Broadly speaking, investigators can take an explicit or implicit approach in collecting data. Explicit approaches require the listener to directly report his or her expectations; implicit approaches uncover them more obliquely. Implicit approaches are generally preferred because they minimize demand characteristics—in which the behaviour of experimental participants is influenced by their own hypotheses about the purpose of the experiment (see Chapter 10, this volume).

21.6.1 Explicit approaches

One type of explicit approach involves asking participants to perform continuations after hearing an initial musical fragment or prime. Carlsen (1981) and Lake (1987) asked participants to sing continuations following melodic primes. Schmuckler (1989) asked pianists to perform continuations on a keyboard, and Larson (2002) asked music theorists to notate melodic continuations to a given antecedent. Performed completion tasks rely on musically sophisticated participants, and so the results may not be generalizable to a wider population. Performed completion tasks may also introduce production constraints (such as range limitations in the voice) that are not necessarily related to expectations. However, performed completion tasks have the benefit of allowing participants to respond with indefinitely long continuations. Since many other research methods artificially limit responses to a single consequent tone, performed continuations can provide valuable information about the scope of musical expectations.

Another explicit approach builds on the probe-tone methodology pioneered by Roger Shepard and Carol Krumhansl (1979). In probe-tone experiments, participants hear many repetitions of the same contextual passage, each one followed by a different probe. Listeners rate how well the probe fits the preceding context (e.g. Cuddy & Lunney, 1995; Krumhansl & Kessler, 1982; Schellenberg, 1996; Schmuckler, 1989). An advantage of probe-tone experiments is that they allow investigators to collect data about many potential continuations. However, since the probe-tone methodology involves stopping or interrupting the musical flow, it has been suggested that the responses are confounded with judgements about the suitability of a tone for terminating a phrase.

A third explicit approach, the betting paradigm, was used by von Hippel, Huron, and Harnish (1998). Participants heard antecedent passages and were invited to bet on the likeliest continuations. This methodology allows the subjective probabilities for different continuations to be assessed, but proceeds slowly (on average participants took three minutes to place their bets for each melodic note) and thus places high demands on the attention and stamina of participants.

21.6.2 Implicit approaches

An early implicit approach involved participants listening to tones presented alongside a continuous loud noise, and indicating whether or not they heard a tone (Greenberg

& Larkin, 1968). Listeners were better able to detect a tone if it was expected. A series of subsequent studies used reaction time to illuminate expectations inaccessible to explicit report; listeners respond faster to expected continuations. Bharucha and Stoeckig (1986), Bigand and Pineau (1997), and Tillman, Bigand, and Pineau (1998) show this effect for harmonic sequences, and Aarden (2002) and Margulis and Levine (2006) adapt this approach to the study of melodies.

Perhaps the most commonly used implicit approach for the study of expectation involves event-related potentials (ERPs). ERPs entail measurement of electromagnetic activity produced by large collections of neurons, as measured on the scalp (for a review, see Besson, 1997). Different ERP features are known to be associated with various behavioural outcomes. For example, surprising events such as a musically incongruous out-of-key ending evoke distinctive ERPs (Besson & Macar, 1987; Verleger, 1990). These responses differ depending on the extent of a listener's prior musical training (Besson & Faïta, 1995; Koelsch, Schmidt, & Kansok, 2002). Useful ERP data can be collected even when listeners ignore the music and concentrate on another task (Koelsch, Schroger, & Gunter, 2002). Schön and Besson (2005) used ERPs to provide important evidence for the potential modularity of some aspects of music processing. They examined ERPs in musicians as they listened to music while viewing the score. Incongruous events elicited a late positive component (LPC) even when they were notated in the score, and thus known in advance to the listener. This finding supports the idea that musical processing is characterized by some degree of informational encapsulation—the ear does not always know what the eye sees.

Other implicit methods include metabolic measurements, such as heart rate and skin conductance. Steinbeis, Koelsch, and Sloboda (2006), for example, found electrodermal activity and heart rate changes at moments that were harmonically unexpected. Additionally, head-turning paradigms have been used to study expectations in infants and non-human animals (cf. Weiss, Zelazo & Swain, 1988).

21.7 Theoretical approaches to expectation in music

The subject of musical expectation has attracted sustained interest from both experimental psychologists and music theorists. Nearly all psychologists working in the field of music cognition have carried out experiments that bear directly on the issue of expectation. This includes work by Mireille Besson, Jamshed Bharucha, Emmanuel Bigand, Lola Cuddy, Irène Deliège, Peter Desain, Diana Deutsch, Jay Dowling, Alf Gabrielsson, Andrew Gregory, Mari Reiss Jones, Patrik Juslin, Carol Krumhansl, Dirk-Jan Povel, Glenn Schellenberg, Mark Schmuckler, John Sloboda, Johan Sundberg, Barbara Tillmann, among others. A smattering of physiologically oriented research has also been carried out, most notably studies by Petr Janata and Jaak Panksepp.

Similarly, many music scholars have addressed issues of expectation, including Bret Aarden, Zohar Eitan, Robert Gjerdingen, Paul von Hippel, Henkjan Honing, Steve Larson, Fred Lerdahl, Justin London, Elizabeth West Marvin, Dirk Moelants, Yuet-Hon Ng, Bob Snyder, and David Temperley. However, the most comprehensive theoretical attempts to account for the role of expectation in musical experience are found in the work of Leonard Meyer (1956), Eugene Narmour (1990, 1992), Elizabeth Margulis (2005; 2007), and David Huron (2006), to which we now turn.

21.7.1 Meyer's emotion and meaning

Leonard B. Meyer ignited contemporary interest in expectation as a core component of musically evoked emotion. In *Emotion and meaning in music* (1956), Meyer looked to John Dewey's (1894) 'conflict theory of emotions' (as modified by MacCurdy, 1925), which suggested that affect arises from the inhibition of tendency. As an example of this effect, Meyer contrasted the relatively unemotional scenario of a person searching for and finding a cigarette in his pocket, compared with the relatively emotion-laden scenario of a person searching for and failing to find the same cigarette.

Although many mid-century music theorists were interested in the psychology of the listener, few scholars dared to embrace a psychological approach to analysis. In order to analyse music from the perspective of the listener, a scholar would have to wrestle with the variability of human responses, and the whole enterprise seemed destined to collapse in the chaos of multiple meanings. Since musical scores rarely change, the study of musical scores held a much stronger allure.

By focusing narrowly on expectation, and by positing an idealized competent listener, Meyer was able to avoid many of the difficulties raised by psychologically inspired analysis. Moreover, in Dewey's theory, Meyer found a way to analyse listener responses in a systematic way: 'granted listeners who have developed reaction patterns appropriate to the work in question, the structure of the affective response to a piece of music can be studied by examining the music itself . . . the study of the affective content of a particular work . . . can be made without continual and explicit reference to the responses of the listener or critic. That is, subjective content can be discussed objectively' (1956, p. 32).

Given norms that listeners had abstracted from prior exposure to the relevant style or genre, certain musical events could be understood to imply other ones, or to produce a tendency to continue to them. When that tendency was inhibited, affect could arise. This view allowed musical affect, a notoriously subjective phenomenon, to be investigated in relation to musical structure, rather than in relation to the idiosyncratic propensities of individual listeners.

A classic example is found in the *deceptive cadence*, a harmonic progression in which the normal dominant-to-tonic resolution is replaced by a dominant-to-submediant progression. (The tonic and submediant chords share two pitches in common, so the difference between the two progressions involves a seemingly modest change of shifting one tone by one step.) In the deceptive cadence, the 'felt urgency' (Meyer, 1956, p. 61) for resolution to the tonic is denied with dramatic psychological results. Another classic example appears in rondos at points where thematic return is expected; considerable tension can arise simply by delaying the theme's reoccurrence.

Throughout analytic discourse, expectations are most often mentioned when they are violated (Margulis, 2007). But in addition to the affect triggered by violations, Meyer postulates a different type of response—'apprehension and anxiety' (1956, p. 26)—that is thought to arise out of uncertainty. Uncertainty can be understood as the absence of clear expectations (most commonly experienced when listening to music in an unfamiliar style or genre), or the stimulation of multiple, mutually exclusive expectations (for example, an event that hovers ambiguously between several possible interpretations). Thus, expectations can contribute to affect both in the case that they are denied, and in the case that they fail to be clearly established. The default, unvalenced scenario, then, would be one in which expectations are clearly established and fulfilled. According to Meyer's conception, such banal music would be rare, since composers are typically interested in moving listeners. Most works would entail a mixed choreography of expectations fulfilled and expectations thwarted.

Meyer's work coincided with the introduction of a new mathematical tool, *information theory*. Devised at the Bell Telephone Laboratories by Claude Shannon, information theory provides a generalized method for characterizing the quantity of information in any message. It does so by measuring the predictability of successive symbols. When a symbol (such as a musical note) is virtually certain, it carries little information. Conversely, high uncertainty is associated with high information. Shannon himself recognized the applicability of his theory to music, and Meyer (1957) saw the link between Shannon's theory and his own ideas about musical implications.

Beginning in the late 1950s, a number of music scholars further explored the applicability of information theory to music (cf. Youngblood, 1958; Krahenbuehl & Coons, 1959; for more recent accounts, see Knopoff & Hutchinson 1981; and Snyder, 1990), often using the theory to understand characteristics of musical styles. The psychoaesthetics movement in the 1970s (Berlyne, 1971; see also Chapter 19, this volume) sought to connect information theory to musical experience in the tradition of Meyer, and several recent studies have pursued this line of inquiry, looking at how information theory and other probabilistic approaches to music might underlie cognitive and affective processing (Huron, 2006; Margulis & Beatty, 2008; Temperley, 2007).

In assessing Meyer's contribution, it is appropriate to emphasize the novel and pioneering spirit of his work. Although ordinary listeners were captivated by possible relationships between music and emotion, the intellectual milieu of mid-century American scholarship was remarkably hostile to the study of musical emotion. On the one hand, American psychology was dominated by a severe form of behaviourism that regarded emotions as occult qualities beyond the realm of legitimate psychological research. On the other hand, American musicology was dominated by a reaction against the excesses of nineteenth-century (romantic) scholarly writing in which authors indulged in effusive emotional descriptions whose introspective flights of fancy tainted the entire subject of musical emotion.

From our current vantage point, Meyer might be faulted for having relied too heavily on Gestalt principles, whose woolly formulations have received sustained criticism by perceptual psychologists. However, Meyer was far ahead of his time in integrating cognitive and affective aspects of mental functioning. In drawing attention to the importance of expectation, Meyer anticipated the conclusions of cognitive neuroscience by half a century. Meyer was a lone voice, largely out of step with mainstream currents in both musicology and psychology, whose work was nevertheless philosophically erudite and musically sophisticated. He single-handedly carved out an important area of scholarship. His legacy—usefully dubbed the 'Penn School' by David Butler—has included such psychologically informed theorists as Robert Gjerdingen, Eugene Narmour, and Justin London.

21.7.2 Narmour's Implication-Realization theory

In some ways, Eugene Narmour's Implication-Realization theory might be regarded as a generalization and deep explication of Meyer's notion of 'gap fill'. However, Narmour's monumental work (1990, 1992) goes beyond Meyer's nascent ideas to build a more embracing theory of the cognition of melody. Unfortunately, limitations of space permit only a bare outline of the theory.

The Implication-Realization theory is based on two overarching principles: that similarity implies further similarity, and differentiation implies further differentiation. Narmour regards these principles as applicable in all musical parameters, including pitch intervals, melodic contour, dynamics, rhythm, and (forthcoming) harmony. Applying the principles to *intervallic motion* (the size of successive melodic intervals) and *registral direction* (the contour—up, down, or lateral—of these intervals), Narmour creates a taxonomy of melodic figures, each with its own implicative content. For example, process (P) signifies a small melodic interval followed by another small melodic interval in the same direction; the similarity in both domains (small interval to small interval, the preservation of direction) yields an implication for further similarity: continuation to another small interval in the same direction. Reversal (R), however, signifies a large melodic interval followed by a small interval in the opposite direction. It represents differentiation in both domains (large interval to small interval, a change of direction). In addition, the reversal creates closure—a point after the fulfilment of strong implications at which further implications are suppressed. Both bottom-up perceptual principles and top-down stylistic constraints play roles in the theory.

Narmour's theory attempts to characterize the fluctuating sense of goal-directedness in melodies, explaining where melodies seem strongly implicative, and where they seem less so. The theory emphasizes note-to-note connections over more background, hierarchic ones. Margulis (2005), building on Narmour's theory, has used Lerdahl and Jackendoff's (1983) time-span reduction to add a hierarchic account. Narmour hypothesizes a variety of possible affective responses to implication, including *cognitive exhilaration* when subconscious inferences are validated, *cognitive irony* when they are proved only partly right, and *cognitive shock* when the inferences prove incorrect (where the qualifier 'cognitive' is meant to distinguish these aesthetically induced states from their everyday counterparts).

Of the many contributions made by Narmour, it is important to draw attention to his revolutionary attitude toward empirical testing. In the past, music theorists typically offered interpretations of musical phenomena with little interest in testing their ideas. If a particular theory was inherently unfalsifiable, music theorists tended to view this as a strength of the theory rather than a weakness. Following a trend begun by Lerdahl, Narmour has been a strong advocate for holding up theoretical claims to the light of empirical tests. Although not himself an experimentalist, his books typically end with a litany of empirically testable claims that derive from his theorizing, and an invitation to experimental psychologists to separate the defensible from the indefensible. The happy consequence of this attitude has been an explosion in experimentation, with a predictable mix of success and failure (Cuddy & Lunney, 1995; Krumhansl, 1995; Schellenberg, 1996; Schellenberg, 1997). In promoting empirical engagement, Narmour has raised the bar for music theorizing.

21.7.3 Margulis's theory

Margulis (2005), building on Lerdahl's notions about the relationship between attraction and tension (Lerdahl, 2001; Lerdahl & Jackendoff, 1983; Lerdahl & Krumhansl, 2007), proposes three types of musical tension that arise from specific circumstances within a model of deeply schematic melodic expectations—expectations that influence listeners' experience, but are not themselves directly accessible. The model produces quantitative predictions about the expectedness of notes within melodies, and proposes a relationship between these predictions and experiences of musical tension. The model assumes that tension is not a unitary, all-or-nothing phenomenon, but rather a differentiated one, admitting of multiple distinctive types. Surprise-tension is thought to arise when events occur that were not predictable beforehand, and registers phenomenologically as an experience of intensity and dynamism, motivating closer attention from the listener. Denial-tension is thought to occur when an unexpected event occurs in place of an alternative, highly expected event, and registers phenomenologically as an impression of intentionality or will in the music. Expectancy-tension is thought to occur when an event generates a particularly strong expectation for a subsequent one, and registers phenomenologically as an impression of forward-directedness in the melody. All of these impressions are fleeting, subtle, distinctly musical, and, this model argues, consequences of expectations formed dynamically as music transpires. Margulis's model builds on the work of Lerdahl and Narmour, adds a hierarchic component, forms quantitative predictions, and makes explicit a proposed relationship between expectation and tension.

21.7.4 Huron's ITPRA theory

Compared with other theories of expectation, Huron's (2006) account places greater emphasis on biology and enculturation. He emphasizes the adaptive advantage of forming accurate expectations, and suggests that expectation-related emotions are intended to 'reinforce accurate prediction, promote appropriate event-readiness, and increase the likelihood of future positive outcomes' (p. 4). At the same time, Huron's theory emphasizes the role of cultural environment and statistical learning as the source of listener expectancies.

The core of Huron's theory is an analysis of the timecourse of expected/unexpected events (see Figure 21.1). Huron proposes that responses to future events can be usefully divided into five components dubbed *Imagination*, *Tension*, *Prediction*, *Reaction*, and *Appraisal* (ITPRA for short). The five components can be grouped into *pre-outcome* and *post-outcome* phases. In the *pre-outcome* phase, an individual might consciously *imagine* different possible outcomes and vicariously experience some of the feelings that would be expected for each outcome. For example, the act of imagining being reunited with a loved one may evoke anticipatory feelings that act as the motivation to embark on a long journey. Independent of the emotions evoked by imagining outcomes, the pre-outcome phase also entails a tension component: As an anticipated event approaches, arousal and attention states are fine tuned so that ensuing behaviours are optimized. Expecting to catch a ball requires a different mental and corporal state from expecting a phone call, or expecting a sought word to come to mind. These preparations are accompanied by distinctive feelings, associated with muscle tone, respiration, rumination, etc.

After an event has occurred (*post-outcome* phase), three distinct processes are initiated. The accuracy of an individual's prediction is assessed (*prediction response*). Positive feelings are evoked when the outcome is expected, and negative feelings are evoked when the outcome is surprising. The purpose of the prediction response is to

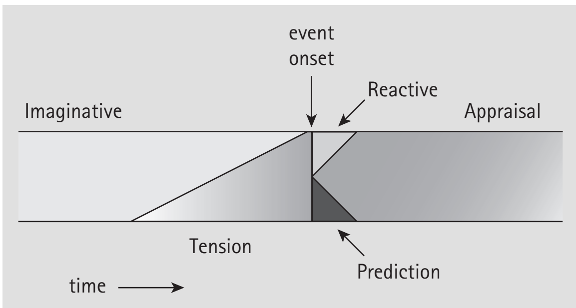

Fig. 21.1 Illustration of the time course for Huron's ITPRA theory of expectation. Feeling states are first activated by imagining different outcomes (I). As an anticipated event approaches, physiological arousal typically increases, often leading to a feeling of increasing tension (T). Once the event has happened, some feelings are immediately evoked related to whether one's predictions were borne out (P). In addition, a fast reaction response is activated based on a very cursory and conservative assessment of the situation (R). Finally, feeling states are evoked that represent a less hasty appraisal of the outcome (A) (from Huron, 2006).

reinforce accurate prediction. At the same time, a 'quick and dirty' *reaction response* is generated. Reaction responses (such as the startle reflex) are defensive in function. These short-lived responses tend to assume a worst-case scenario, and so most of these responses prove to be overreactions that are quickly extinguished. Finally, the *appraisal response* represents a more leisurely assessment of the situation that takes into account complex social and situational factors. Appraisal responses (which originate in the cortex but are not necessarily conscious) commonly inhibit reaction responses (which originate in subcortical structures). Because *reaction* responses involve fewer synaptic connections, they are considerably faster than *appraisal* responses. These fast and slow responses reflect the neurological embodiment of two usually contradictory goals: (1) the need to respond as *quickly* as possible to dangerous circumstances, and (2) the need to judge as *accurately* as possible the value of some event or situation.

Huron suggests that for a given sound event (like the onset of a chord), the listener's overall feeling state is a dynamic mixture of the feelings generated by the *imagination*, *tension*, *prediction*, *reaction*, and *appraisal* responses. These responses may all be positively valenced, or they may all be negatively valenced. But most experiences involve a complex mix of positively and negatively valenced responses.

21.8 Musical examples

Scholars have suggested that many psychological effects arise from the phenomenon of expectation, including delay, anticipatory tension, premonition, deception, humor, garden-path phenomena, and others (e.g. Huron, 2006; Margulis, 2005; Meyer, 1956; Narmour, 1990, 1992; Temperley, 2007). The analytic literature provides many musical examples of these purported effects. However, limited space precludes illustrating all of the suggested effects. Here we briefly describe two examples of musical surprise.

Figure 21.2 shows the well-known opening to Sergey Prokofiev's *Peter and the Wolf*. The upbeat tempo, wide leaps, dotted rhythms, major-key harmony, and use of staccato all contribute to a happy, carefree feeling. At the third measure, however, Prokofiev abruptly shifts to a lowered submediant harmony. This harmonic surprise is accompanied by an unorthodox melody that oscillates between E flat and B natural—a rare use of the augmented fifth interval. The B natural clashes with the C of the accompanying harmony. Above the melody, some of the transitional probabilities for successive scale tones are shown (expressed in bits). For major key melodies, typical transitional probabilities lie in the range of three to five bits (Huron, 2006). In this context, the E flat/B natural alternation jumps out. The probability of the seventh scale tone being followed by the lowered third scale tone is just.00004. Compared with the melodic intervals in the first two measures, the intervals of the third measure are strikingly improbable. For many listeners, the pitches sound 'wrong', as though Prokofiev had mistakenly written B4 rather than C5. In fact, music theorists refer to such transgressions as 'wrong-note' harmonies or 'wrong-note' melodies (Rifkin, 2000).

Fig. 21.2 The opening to Sergey Prokofiev's *Peter and the Wolf*.

Prokofiev's 'wrong notes' display a number of characteristic properties. The notes typically involve semitone displacements from tonally appropriate notes. Often the pitches are flat by a half step. The 'wrong notes' are commonly approached and left by melodic leaps. As in the above example, Prokofiev tends to immediately repeat the wrong-note sequence—as if to say 'Yes, I really intended that pitch.'

Prokofiev's 'wrong notes' are probably not unrelated to his penchant for neo-classical writing. In choosing to write music with conventional tonal and phrase structures, Prokofiev makes his 'wrong notes' more obvious to listeners accustomed to the musical language of the classical period. Prokofiev's conventional classical style provides the schematic backdrop for his 'wrong notes'. The psychological effect of Prokofiev's music has been variously described as 'quirky', 'weird', and 'impertinent'. By repeating these improbable patterns, Prokofiev assures listeners that the notes are clearly intentional. It is not inappropriate for listeners to interpret 'intended wrongness' as a symptom of 'impertinence'.

Recall earlier, Bharucha's distinction between generalized (schematic) expectations and work-specific (veridical) expectations. Like the deceptive cadence, frequent exposure to Prokofiev's music will significantly attenuate the sense of surprise, although veridical familiarity will fail to extinguish the schematic surprises. Familiarity will lessen, but not eliminate, the sense of oddity.

If Bharucha's schematic/veridical distinction holds merit, then we ought to be able to observe musical passages that exhibit the reverse scenario—a veridical surprise accompanied by a schematic non-surprise. Figure 21.3 shows such a passage (discussed in Huron, 2006). The passage is from the Adagio movement of Peter Schickele's *Quodlibet for Small Orchestra* (1959). Schickele is a musical humorist, better known as PDQ Bach. In the live Vanguard recording of this work, the passage evokes sustained and appreciative laughter.

The passage is a modified quotation from the second movement of Beethoven's Fifth Symphony (also shown in Figure 21.3). The two passages are identical until the beginning of the fourth measure: Where Beethoven follows the B flat with an E natural, Schickele follows the B flat with an A flat (see marked intervals). In the original, Beethoven's theme branches into a new key area, but Schickele simply brings the phrase to a stereotypic close. Schickele's version is surprising only to listeners familiar with the original Beethoven, and this familiarity is essential to the musical humour.

Fig. 21.3 Passage from the Adagio movement of Peter Schickele's *Quodlibet for Small Orchestra* (A), which is a modified quotation from the second movement of Beethoven's fifth symphony (B).

In fact, Schickele's version is much more consistent with the norms of Western classical music. In most musical humour, gags involve doing something absurdly improbable. But in this situation, Schickele achieves a humorous effect by substituting a musically banal passage for a musically adventurous one. Schematic and veridical expectations can be surprised independently.

In the two examples described above, we have seen how surprise might lead to feelings such as oddity or levity. But these examples only hint at the range of psychological effects evoked by choreographing listener expectations.

21.9 Frisson—thrills from chills

A musically induced affect that shows close links to musical surprise is the phenomenon of frisson (e.g. Sloboda, 1991; Gabrielsson & Lindström, 1993, 2003). Frisson can be described as a pleasant tingling feeling associated with the flexing of hair follicles, resulting in gooseflesh (technically called piloerection) accompanied by a cold sensation, and sometimes producing a shiver. Dimpled skin is evident in the region of the back of the neck and upper spine, often including the shoulders, scalp and cheeks, and sometimes extending to the entire back, belly, groin, arms, chest, or legs (Panksepp, 1995). The experience may last from less than a second to more than ten seconds. Longer responses usually involve one or more 'waves' of spreading gooseflesh. Grewe, Nagel, Kopiez, and Altenmüller (2007) note that the occurrence of such 'shivers' is significantly correlated with judgements of the pleasantness of music works. Some reports mention that the response may be accompanied by smiling, laughing, weeping, lump-in-throat, sighing, breath-holding, or heart palpitation. For the purposes of this chapter, we will focus exclusively on the prototypical response involving topical (skin-related) sensations.

Researchers have proposed a number of different labels for this response, including *thrills* (e.g. Goldstein, 1980, Konečni et al, 2007), *chills* (e.g. Grewe et al, 2007, Guhn et al, 2007), and *frisson* (Sloboda, 1991; Huron, 2006). Bernatzky has suggested the term *skin orgasm* (see also Panksepp, 1995); however, this term has gained few adherents. In the interests of precision, we will follow Sloboda's suggestion and use the term *frisson*. Listeners can find music 'thrilling' without necessarily experiencing gooseflesh. The term 'chills' is best reserved for the phenomenological feeling of coldness, which, like piloerection, may be considered a characteristic symptom of the frisson response.

Apart from music, gooseflesh (piloerection) can be evoked in many other situations. Gooseflesh can occur when experiencing fear (such as hearing an unknown sound while walking alone in a dark alley), when viewing disgusting photographs, during orgasm, or in response to fingernails scratching a blackboard (Halpern et al, 1986). Of course, gooseflesh is a common response when we are cold, but paradoxically, it can also arise when immersing ourselves in a hot bath. Gooseflesh can also be evoked by physical contact with another person, when experiencing a sudden insight (such as an unexpected solution to a problem), while observing an inspiring moment in a competitive sport, or when experiencing great natural beauty, such as viewing a large canyon (Goldstein, 1980). Notice that the experience of gooseflesh can be either pleasant or unpleasant. The term 'frisson', however, applies only to the pleasure-inducing form. Simply put, frisson might be defined as 'pleasurable piloerection' or 'enjoyable gooseflesh'.

21.9.1 Individual differences

Not everyone experiences music-induced frisson. Goldstein (1980) carried out a survey of employees in a business unconnected to music, in which he achieved a 100 per cent return rate. Of these, 47 per cent reported never having experienced a music-induced 'thrill'. Similarly, Grewe et al (2007) found only 55 per cent of participants reported music-induced 'chills'. Konečni et al (2007) were able to induce 'thrills' in only 35 per cent of participants. By contrast, 90 per cent of the music students included in Goldstein's (1980) study reported having experienced music-induced 'thrills'. It appears that only about half of the general population may be familiar with the experience. The capacity to experience music-induced frisson may encourage certain people to pursue a career in music.

Panksepp (1995) and others have observed that music-induced frisson is more likely to be reported by female listeners than by male listeners. In addition to gender differences, personality differences have been observed by Grewe et al (2007). As measured using the Sensation Seeking Scale (Litle & Zuckerman, 1986), 'chill responders' are less adventurous or thrill seeking. That is, reactive listeners are less likely to enjoy physical risk taking, such as skydiving or riding rollercoasters. One might say these listeners are 'more sensitive' or 'thin-skinned'. Grewe and his colleagues also found that the more reactive listeners have greater familiarity with classical music, identify more with the music they prefer, and are more likely to listen to music in concentrated (rather than background) situations. In short, susceptibility to music-induced frisson is correlated with musical interest.

Listeners who experience music-induced frisson are typically able to point to particular moments in a work when the frisson is evoked (Sloboda, 1991). This specificity has encouraged researchers to search for musical features that might be responsible for the frisson. These efforts have been confounded, however, by poor inter-listener consistency (e.g. Blood & Zatorre, 2001). Early on, investigators discovered that musical works that evoke frisson for the experimenter commonly fail to evoke frisson in other listeners. Asking participants to bring their own frisson-inducing music reinforced this discovery: when participant-selected music is employed as stimuli, listeners inevitably experience more frisson in response to their own music than to music brought by other participants (e.g. Konečni et al, 2007). Moreover, when different listeners experienced frisson in the same work, the points of frisson can differ.

This effect led some researchers to conclude that familiarity may be a key to music-induced frisson. However, this observation is confounded by the reliance on participant-selected music: if asked to bring a piece of music 'that causes you to shiver', participants are likely to choose pieces that they particularly love, and well-loved pieces are apt to be highly familiar. Consider a gustatory parallel. If asked to bring a dish of your favourite food to a pot-luck dinner, what is the likelihood that you will find a dish that you like even better than your own favourite but brought by someone else? If people attending a pot-luck dinner tended to prefer their own culinary offering to those of others, one would not be justified in claiming that familiarity is the most important aspect of taste.

Guhn, Hamm, and Zentner (2007) addressed this possible confound by measuring the familiarity of different works *not* selected by the participants. They found a correlation of zero between the frequency of frisson responses and familiarity. This suggests that listeners become familiar with works that a priori cause them to experience frisson, not that frisson arises due to increasing familiarity.

21.9.2 Causes of frisson

In light of the high proportion of non-responders, and given the high individual variability between responders, the best efforts to identify potential causes of frisson have involved careful pre-selection of experimental participants. When participants were selected according to high self-reports for musical sensitivity, Guhn et al (2007) were able to show a high degree of inter-subjective consistency in the location of frisson responses as determined by self-report and skin conductance measures. In addition, Guhn et al found that heart rate responses are also highly correlated between such participants. Even when a participant doesn't exhibit a frisson response, heart rates are still highest at moments when frisson responses are evoked for other participants. This suggests that sympathetic arousal may be a necessary, though not sufficient, component of frisson.

Among researchers, there is considerable agreement about acoustical and musical correlates of frisson (Blood & Zatorre, 2001; Craig, 2005; Grewe, et al 2007; Guhn, et al 2007; Panksepp, 1995, 1998; Rickard, 2004; Sloboda, 1991). The most important acoustic correlate is a rapid large change of loudness, especially a large increase in loudness (subito forte). A less robust acoustic correlate appears to be the broadening of the frequency range (i.e. the addition of low bass and/or high treble). Musical correlates include the entry of one or more instruments or voices; the return of a melody, theme, or motive; an abrupt change of tempo or rhythm; a new or unprepared harmony; abrupt modulation; or a sudden change of texture. Music deemed 'sad' (e.g. slow tempo, quiet dynamic, minor key) is roughly twice as likely to evoke frisson as 'happy' music (Panksepp, 1995).

Notice that two common elements can be found in this list of features. First, adjectives such as abrupt, rapid, sudden, new, and unprepared suggest that the precipitating musical events may be surprising or unexpected. A second common theme is high energy, such as increased loudness or the addition of sound sources. Notice also that slow, quiet passages (such as are commonly found in sad music) provide an especially contrasting background against which unexpectedly energetic events may be highlighted.

21.9.3 Examples

Figures 21.4 and 21.5 illustrate some of these frisson-inducing properties. Figure 21.4 shows a passage from Pink Floyd's 'The Final Cut' that, as reported by Panksepp (1995), displayed a high probability of evoking frisson responses. The most obvious feature of this passage is the dramatic increase in loudness. The initial phrase is sung in nearly a whispered voice, whereas the subsequent phrase is sung in a shouting voice.

Figure 21.5 shows a more complicated frisson-inducing passage identified by one of the respondents to Sloboda's (1991) survey. The passage, from Schoenberg's *Verklärte Nacht*, exhibits a subito forte dynamic contrast. In addition, harmonic and rhythmic surprises coincide with the onset of the D-major chord at the beginning of measure 229. In the key of G minor, the D-major chord is the dominant; a progression from E-flat major (VI) to V would be a relatively common progression. However, in approaching this passage, there is no hint of G minor, and the E-flat chord is minor rather than major. Consequently, for Western-enculturated listeners, the D-major chord would

Fig. 21.4 Vocal melody from Pink Floyd's 'The Final Cut'. One of the frisson-inducing passages reported in Panksepp (1995).

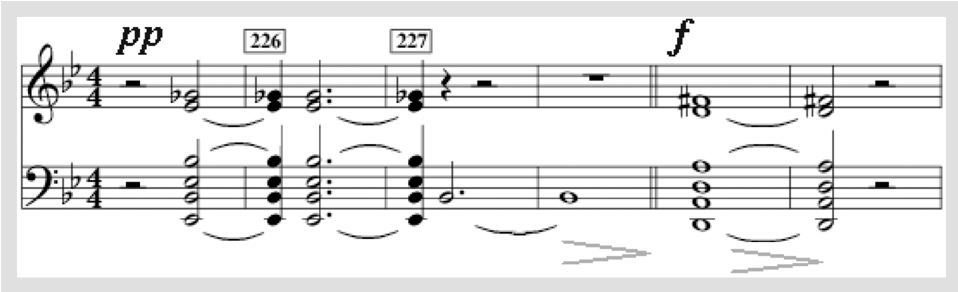

Fig. 21.5 Piano reduction of bars 225–230 from Schoenberg's *Verklärte Nacht*, a passage identified by one of Sloboda's (1991) respondents as reliably evoking a frisson response.

be harmonically unexpected. The advent of this chord also involves an element of temporal surprise. Prior to measure 229, chord onsets systematically avoid the downbeat, so the sense of meter is significantly eroded. Although the D-major chord occurs on the downbeat, this moment is no longer expected for most listeners. In short, the frisson-inducing moment coincides with a combination of temporal surprise, harmonic surprise, and abrupt increase in loudness.

21.9.4 Physiological correlates

Apart from behavioural studies, the frisson response has also attracted physiological studies, including observations of skin conductance, heart rate, neurochemical changes, and hemodynamic changes. Gooseflesh or piloerection is positively correlated with heart rate, although peak heart rate is not a good predictor of frisson responses (Guhn et al, 2007). Frisson is more strongly correlated with increases in skin conductance response (Craig, 2005; Guhn et al, 2007; Rickard, 2004; see also Chapter 11, this volume).

Neurochemical changes associated with frisson were investigated by Goldstein (1980). Goldstein administered naloxone, an opiate receptor antagonist, to healthy volunteers. Naloxone is able to block or significantly attenuate the positive feelings that normally accompany the release of endogeneousopioids such as endorphins. Goldstein used a double-blind protocol in which members of a control group were injected with an inert saline solution. Of the 10 volunteers who received naloxone, three reported a significant reduction in music-induced 'thrills' to participant-selected music. Goldstein's study implies two conclusions. First, the results are consistent with the view that music-induced frisson can lead to the release of endogenous opiates (such as endorphins), commonly associated with the experience of pleasure. At the same time, the results seem equivocal: only three of ten volunteers showed any effect. Since only about half of the population experience music-induced frisson, the mixed results might be attributable to the considerable individual variation in frisson responsiveness.

Neurohemodynamic changes associated with frisson have been investigated by Blood and Zatorre (2001), who carried out PET scans of volunteers listening to participant-selected music. They found that frisson responses coincided with increased blood flow in the nucleus accumbens, the left ventral tegmental area, the dorsomedial midbrain, the insula, thalamus, anterior cingulate, the supplementary motor area and bilateral cerebellum. Decreased blood flow was observed in the amygdala, left hippocampus, and the posterior cortex. This hemodynamic pattern has been found by other researchers to be characteristic of euphoric or pleasurable experiences (Breiter et al, 1997; see also Chapter 12, this volume). In addition, increased activity in the thalamus and anterior cingulate are associated with increased attention.

21.9.5 Theories of music-induced frisson

Two theories have been proposed that attempt to account for the origin of music-induced frisson: Panksepp's *Separation Distress* theory and Huron's *Contrastive Valence* theory. Both theories rely on evolutionary arguments linking affective experience to physiological changes.

Panksepp's Separation Distress theory

Panksepp (1995, 1998) has proposed a theory of music-induced frisson whose foundation is the reactiveness of caregivers to the distress calls of offspring. Few experiences are more traumatic than the separation of mother and child, ewe and lamb, or hen and chick. When visual contact fails, offspring typically rely on distress calls as a way of signalling their location. In order for the distress call to be effective, caregivers must be responsive. Given the biological importance of nurturing and protecting offspring, one would expect distress calls to have a powerful motivating (i.e. emotional) effect on caregivers.

While providing food and protection are the foremost tasks of any parent, the most common behaviour simply involves reassuring offspring of the parent's presence. For most animals, physical contact (so-called 'comfort touch') provides such reassurance. The contact between caregiver and offspring typically results in a mutual increase in skin temperature. In human language, social comfort is often described using thermal metaphors, such as 'warm personality' or 'cold shoulder'. When a caregiver perceives a distress call, Panksepp suggests that feelings of coldness or chill may provide increased motivation for social reunion. Panksepp and Bernatzky (2002) have suggested that frisson-inducing musical passages exhibit acoustic properties similar to the separation calls of young animals.

Inspired by Panksepp's theory, Beeman (2005) has assembled various analyses related to the acoustics of human infant cries. Note that human hearing is not equally sensitive at all frequencies. Due to resonances in the pinna and ear canal, the threshold of hearing is much more sensitive in the region 1–6 kHz. Within this region, sensitivity is most acute in a narrow region between 3 and 4 Hz (Fletcher & Munson, 1933). Beeman notes that human infant cries show an energy peak in this region. Other research has established that the sound of a crying baby is highly distressing for adult listeners (Drummond et al, 1999; Lester, 1978; Lester et al, 1992). Apart from the presumed cognitive motivations, there are straightforward sensory reasons why a crying baby attracts our attention.

Infant cries are not the only sounds that show a high energy peak in the ear's most sensitive region. The adult human scream also displays a disproportionate amount of energy in the broad 1–6 kHz region where human hearing is best. This is true of screams produced by both males and females. A human scream is the sound humans can hear at the greatest distance. Beeman (2005) also notes that this auditory sensitivity is exploited by professional singers. Sundberg (1972, 1987) discovered that operatic singers are able to concentrate acoustic energy in the so-called *singer's formant*. In one study, for example, Sundberg measured the spectral resonances in recordings by the famous Swedish tenor, Jussi Björling, and found an especially strong resonance in the region around 3 kHz (Sundberg, 1972, 1977). Similarly, Johnstone and Scherer (1995) measured the spectral resonances in recordings of the Slovakian soprano, Edita Gruberová, and found high energy peaks between 2.9 and 4.1 kHz. The singer's formant is variously described by vocal teachers as 'acoustic ping' or *squillo*. As pointed out by Beeman (2005), production of the singer's formant is one of the principal aims of professional operatic training.

Of course, many listeners report that they dislike the sound of the Western operatic voice. People who hate opera often say that the singers sound 'hysterical' or overwrought. Professional writers tend to be reserved when criticizing opera, but amateurs writing on the web are more frank. In the words of one web writer: 'I don't like opera because people scream all the time' (www.pencollectors.com/projects.htm, 2007/12/16). For these listeners, it is possible that the acoustic similarity between operatic *squillo* and screaming is just too close.

Panksepp notes that not everyone is equally responsive to distress calls. A crying baby may evoke strong nurturing instincts in its parents, but strangers are more likely to find the sound annoying. The strongest nurturing emotions are evoked when an adult has *bonded* with its offspring. A key factor in bonding is familiarity, and Panksepp suggests that familiarity with a given musical work has an effect similar to parental bonding. As a result, he suggests that music-induced frisson is more likely to arise with familiar music (1995, p. 202).

By way of summary, Panksepp's theory suggests that the emotional power of the frisson response lies in the receptiveness and sensitivity of the auditory system to infant distress calls. Since the principal caregivers in most species are mothers, females would be expected to be more attentive to separation distress calls, and so would be expected to be more reactive to music-induced frisson.

Huron's Contrastive Valence theory

Although Panksepp's separation distress theory appears to provide a good account of music-induced frisson, difficulties arise in trying to extend the theory to other forms of frisson. Apart from music, pleasant piloerection can arise when immersing ourselves in a hot bath, when a potential lover first touches our hand, when experiencing a sudden insight, or when riding a rollercoaster. Unpleasant piloerection can arise when experiencing fear or when we are cold. When exposed to disgusting photographs, the ensuing piloerection may be described by viewers as 'making my skin crawl'. Huron's (2006) theory of expectation attempts to place music-induced frisson within a larger account of pleasant and unpleasant piloerection.

Gooseflesh is a thermoregulatory response: raised hair provides a good insulator—although the response is less effective in relatively hairless humans. Piloerection is also used in aggression displays and as a response, when afraid, to discourage attack by others. Throughout the animal kingdom, a common response to fear is to attempt to appear larger. When threatened, for example, a cat will arch its back and make its hair stand on end. Although principally intended to regulate temperature, fear-induced piloerection appears to be an *exaptation*—a pre-existing physiological response that is 'borrowed' for other purposes.

In the ITPRA theory, a distinction is made between the *reaction* and *appraisal* post-outcome responses. The fast reactive response is restricted to the brain stem, whereas the slow appraisal response also involves the neocortex (LeDoux, 1996). Because brainstem pathways involve fewer synaptic connections, they respond much faster than cortical pathways. This neuroanatomical difference is reflected functionally in the two responses. Reaction responses (such as the startle reflex) are defensive in function; these fast-onset responses tend to assume a worst-case scenario, and so most of these responses prove to be overreactions. The appraisal response represents a more leisurely (and accurate) assessment of situations. Reaction responses are especially sensitive to cues suggesting danger. Appropriate acoustic cues include loud sounds (indicating high energy), and sounds that resemble human alarm signals (such as screams). As noted earlier, another potent fear-inducing situation arises from surprise. Although it is possible to be 'pleasantly surprised' (see below), the failure to anticipate an outcome means that the individual is not prepared for the future.

A classic illustration of the effect can be observed in a surprise party. When a person is unexpectedly surprised by her friends, the first response is one of terror: the eyelids are retracted and the jaw drops, resulting in a classic 'terror' expression. But within half a second, fear is replaced by happy celebration as the individual recognizes her friends and the positive social meaning of the event. A quick defensive reaction response is followed by a slower (inhibitory) cognitive appraisal.

Feeling states appear to be strongly influenced by contrast. If we initially feel bad and then feel good, the good feeling tends to be stronger than if the good experience occurred without the preceding bad feeling. Conversely, if we initially feel good and then feel bad, the bad feeling tends to feel worse (e.g. McGraw, 1999). This 'contrastive valence' may account for the difference between pleasant and unpleasant piloerection. When we feel cold, the experience is simply unpleasant, so the resulting shivers are felt as bad. However, when descending into a warm bath, the quick negative reaction to the rapid change of skin temperature is dismissed by the slower appraisal that judges the temperature to be welcome. When we are unexpectedly touched by a stranger, our reaction is wholly negative. But when the unexpected touch comes from a prospective lover, the initial shock of surprise is quickly displaced by a highly positive appraisal with a memorably large contrast in feelings from bad to good. Wrestling with a difficult problem, an unexpected moment of insight replaces a period of stressful rumination with a sudden feeling of achievement. The terror of riding a rollercoaster is held at bay by the cortical conviction that 'I'm not going to die'. Hearing a loud, scream-like, or unexpected, sound, sets off reactive alarm bells. But a cortical appraisal inevitably concludes that 'it's just music'. According to Huron (2006), frisson arises when an initial negative response is superseded by a neutral or positive appraisal. Fear, panic, or anger may all lead to piloerection. But the ensuing cortical processes form their own judgements about the situation. When the appraisal response concurs with the reaction response, the sense of fear, panic, or anger is amplified. But when the appraisal response contradicts the reaction response, the cortex belatedly inhibits the fast subcortical responses and contrastive valence transforms the negative feelings into something positive.

Notice that the evoking of frisson depends on the individual's susceptibility to experiencing fear. 'Thick-skinned' individuals who are less responsive to fear would be less likely to experience fear-induced piloerection, and so less likely to experience frisson. Since males commonly score higher on measures of sensation-seeking, they are less susceptible to fear, and so may be less likely to experience frisson than females.

An important question raised by this theory is how frisson might be reliably evoked when a given listener hears a passage repeatedly. If piloerection is a response to fear or panic, won't musical familiarity ultimately dull the response? Although repeated stimulation normally leads to 'habituation', an exception occurs in the case of defensive responses, such as pain. Because the function of fast responses is primarily defensive, these responses must always be ready, even in a world full of false alarms. In order for defensive responses to remain effective, they must be resistant to habituation or unlearning. The principal way that biology deals with false alarms is not by desensitizing defensive reflexes, but by adding inhibitory circuits that suppress inappropriate defensive behaviours after they have already begun. While slower than the reaction responses, appraisal circuits often begin the process of inhibition within about 500 milliseconds. As a result, fast reaction responses are typically short lived and rarely reach conscious awareness. Our brains and bodies engage in frequent skirmishes with ghostly dangers while we remain blissfully unaware. It is this resistance to habituation and unlearning that allows the music to retain its hair-raising power.

Neurological tests of this theory are scant. Consistent with the theory, Blood and Zatorre (2001) observed a marked decrease in amygdala activity in response to musically induced frisson. However, due to the poor temporal resolution of PET, the conjecture that decreased amygdala activity is preceded by a short burst of activity remains untested.

This summary provides a cursory introduction to Huron (2006), whose theory includes two other strong affective states: laughter and awe. While large violations of expectation may produce pleasurable gooseflesh (frisson), they can also lead to outbursts of laughter, or to the expansive breath-holding characteristic of awe. In Huron's theory, all three originate as negatively valenced affects that are transformed through contrastive valence into positive experiences.

21.10 Conclusion

The feeling of shivers running up and down one's spine is widely reported as one of the most memorable and pleasurable experiences induced by music. Not all listeners experience musical frisson, however. Its rarity notwithstanding, frisson is readily observed. Craig (2005) has noted that gooseflesh can be directly observed on the forearm of listeners. Consequently, frisson provides an especially fruitful phenomenon for the study of music and emotion. We anticipate that frisson will continue to be an attractive topic of research in the field of music and emotion.

Since Meyer's (1956) pioneering work in the 1950s, considerable progress has been made in understanding the psychology of expectation. The theoretical literature is rich with speculations concerning plausible expectation-related affects, including different forms of tension, surprise, deception, premonition, anticipation, relief, humour, and other phenomena. In this chapter, we have addressed in detail only the phenomenon of frisson. As the empirical research continues to progress, we anticipate that detailed theories will emerge concerning the role expectation plays in auditory experience, including many aspects of musical emotions.

Notes

1. These issues have been explored in relation to other temporal art forms, such as film. See, for example, Aumont et al (2002).
2. An alternative theory attributes dopamine release to increases in arousal and motivation (see Horvitz, 2000).

Recommended further reading

1. Huron, D. (2006). Sweet anticipation: Music and the psychology of expectation. Cambridge, MA: MIT Press.
2. Meyer, L. B. (1956). Emotion and meaning in music. Chicago, IL: Chicago University Press.

References

Aarden, B. (2003). *Dynamic melodic expectancy*. Ph.D. dissertation, School of Music, Ohio State University, USA.

Aarden, B. (2002). Expectancy vs. retrospective perception: Reconsidering the effects of schema and continuation judgments on measures of melodic expectancy. In C. Stevens, D. Burnham, G. McPherson, E. Schuberg, & J. Renwick (eds), *Proceedings of the 7th International Conference on Music Perception and Cognition* (pp. 469–472). Adelaide, Australia: Causal Productions.

Addis, D. R., Wong, A. T., & Schacter, D. L. (2007). Remembering the past and imagining the future: Common and distinct neural substrates during event construction and elaboration. *Neuropsychologia*, *45*, 1363–77.

Aiken, N. E. (1998). *The biological origins of art*. Westport, CT: Praeger.

Aumont, J., Bergala, A., Marie, M., & Vernet, M. (2002). *Aesthetics of film* (trans. R. Neupert). Austin, TX: University of Texas Press.

Bar, M., Aminoff, E., Mason, M., & Fenske, M. (2007). The units of thought. *Hippocampus*, *17*, 420–8.

Beeman, W. O. (2005). Making grown men weep. In A. Hobart & B. Kapferer (eds), *Aesthetics and performance*: *The art of rite* (pp. 23–42). New York: Berghahn Books.

Berlyne, D. E. (1971). *Aesthetics and psychobiology*. New York: Appleton-Century-Crofts.

Besson, M. (1997). Eletrophysicological studies of music processing. In I. Deliège & J. A. Sloboda (eds), *Perception and cognition of music* (pp. 217–50). Hove, UK: Psychology Press.

Besson, M., & Faïta, F. (1995). An event-related potential (ERP) study of musical expectancy: Comparison of musicians with nonmusicians. *Journal of Experimental Psychology*: *Human Perception and Performance*, *21*, 1278–96.

Besson, M., & Macar, F. (1987). An event-related potential analysis of incongruity in music and other non-linguistic contexts.*Psychophysiology*, *24*, 14–25.

Bharucha, J. (1994). Tonality and expectation. In R. Aiello (ed.), *Musical perceptions* (pp. 213–239). Oxford: Oxford University Press.

Bharucha, J., & Stoeckig, K. (1986). Reaction time and musical expectancy: priming of chords. *Journal of Experimental Psychology*: *Human Perception and Performance*, *12*, 403–10.

Bigand, E., & Pineau, M. (1997). Global context effects on musical expectancy. *Perception & Psychophysics*, *59*, 1098–1107.

Blood, A. J., & Zatorre, R. J. (2001). Intensely pleasurable responses to music correlate with activity in brain regions implicated in reward and emotion. *Proceedings of the National Academy of Sciences*, *98*, 11818–23.

Bornstein, R. F. (1989). Exposure and affect: Overview and meta-analysis of research, 1968–87. *Psychological Bulletin*, *106*, 265–89.

Breiter, H. C., Gollub, R. L., Weisskoff, R. M., Kennedy, D. N.,Makris, N., Berke, J. D., Goodman, J. M., Kantor, H. L.,Gastfriend, D. R., Riorden, J. P., Mathew, R. T., Rosen, B. R., & Hyman, S. E. (1997). Acute effects of cocaine on human brain activity and emotion. *Neuron*, *19*, 591–611.

Brochard, R., Abecasis, D., Potter, D., Ragot, R., & Drake, C. (2003). The 'tick tock' of our internal clock: Direct brain evidence of subjective accents in isochronous sequences. *Psychological Science*, *14*, 362–6.

Carlsen, J. C. (1981). Some factors which influence melodic expectancy. *Psychomusicology*, *1*, 12–29.

Cloninger, R. C., Przybeck, T. R., Svrakic, D. M., & Wetzel, R. D. (1999). *Das Temperament-und Charakter-Inventar*. *[The temperament and character inventory]* (trans. J. E. Richter, M. Eisemann, G. Richter, R. C. Cloninger). Frankfurt, Germany: Swets & Zeitlinger. (Originally published 1994)

Craig, D. G. (2005). An exploratory study of physiological changes during 'chills' induced by music. *Musicae Scientiae*, *9*, 273–87.

Cuddy, L. L., & Lunney, C. A. (1995). Expectancies generated by melodic intervals: Perceptual judgments of melodic continuity. *Perception & Psychophysics*, *57*, 451–62.

Dewey, J. (1894). The theory of emotion. *Psychological Review*, *1*, 553–69.

Dowling, W. J., & Harwood, D. L. (1986). *Music cognition*. San Diego, CA: Academic Press.

Drummond, J., Letourneau, N., Neufeld, S., Harvey, H., Elliott, R., & Reilly, S. (1999). Infant crying and parent-infant interaction: Theory and measurement. *Infant Mental Health Journal*, *20*, 452–65.

Fletcher, H., & Munson, W. A. (1933). Loudness, its definition, measurement, and calculation. *Journal of the Acoustical Society of America*, *5*, 82–108.

Gabrielsson, A., & Lindström Wik, S. (2003). Strong experiences related to music: A descriptive system. *Musicae Scientiae*, *7*, 157–217.

Gabrielsson, A., & Lindström, S. (1993). On strong experiences of music. *Musikpsychologie*: *Jahrbuch der Deutschen Gesellschaft für Musikpsychologie*, *10*, 118–39.

Greenberg, G. Z., & Larkin, W. D. (1968). Frequency-response characteristic of auditory observers detecting signals of a single frequency in noise: The probe-signal method. *Journal of the Acoustical Society of America*, *44*, 1513–23.

Grewe, O., Nagel, F., Kopiez, R., & Altenmüller, E. (2007). Listening to music as a re-creative process: Physiological, psychological, and psychoacoustical correlates of chills and strong emotions. *Music Perception*, *24*, 297–314.

Guhn, M., Hamm, A., & Zentner, M. R. (2007). Physiological and musico-acoustic correlates of the chill response. *Music Perception*, *24*, 473–83.

Halpern, D. L., Blake, R., & Hillenbrand, J. (1986). Psychoacoustics of a chilling sound. *Perceptual Psychophysics*, *39*, 77–80.

Hassabis D., Kumaran, D., Vann, S. D., & Maguire, E. A. (2007). Patients with hippocampal amnesia cannot imagine new experiences. *Proceedings of the National Academy of Sciences*, *104*, 1726–31.

Hawkins, J., & Blakeslee, S. (2004). *On intelligence*. New York: Times Books.

Horvitz, J. C. (2000). Mesolimbocortical and nigrostriatal dopamine responsesto salient non-reward events. *Neuroscience*, *96*, 651–6.

Huron, D. (2006). *Sweet anticipation*: *Music and the psychology of expectation*. Cambridge, MA: MIT Press.

Johnson, A., & Redish, A. D. (2007). Neural ensembles in CA3 transiently encode paths forward of the animal at a decision point. *Journal of Neuroscience*, *27*, 12176–89.

Johnstone, I. T., & Scherer, K. R. (1995). Spectral measurement of voice quality in opera singers: The case of Gruberova. *Proceedings of the XIIIth International Congress of Phonetic Sciences*, *1*, 218–21.

Jones, M. R. (1976). Time, our lost dimension: Toward a new theory of perception, attention, and memory. *Psychological Review*, *83*, 323–55.

Koelsch, S., Schroger, E., & Gunter, T. C. (2002). Music matters: Preattentive musicality of the human brain. *Psychophysiology*, *39*, 38–48.

Koelsch, S., Schmidt, B.-H., & Kansok, J. (2002). Effects of musical expertise on the early right anterior negativity: An event-related brain potential study. *Psychophysiology*, *39*, 657–63.

Konečni, V. J., Wanic, R. A., & Brown, A. (2007). Emotional and aesthetic antecedents and consequences of music-induced thrills. *American Journal of Psychology*, *120*, 619–43.

Knopoff, L., & Hutchinson, W. (1981). Information theory for musical continua. *Journal of Music Theory*, *25*, 17–44.

Krahenbuehl, D., & Coons, E. (1959). Information as a measure of experience in music. *Journal of Aesthetics and Art Criticism*, *17*, 510–22.

Krumhansl, C. L., & Shepard, R. N. (1979). Quantification of the hierarchy of tonal functions within a diatonic context. *Journal of Experimental Psychology: Human Perception and Performance*, *5*, 579–94.

Lake, W. (1987). *Melodic perception and cognition: The influence of tonality*. Unpublished doctoral dissertation, University of Michigan, Ann Arbor, USA.

Larson, S. (2002). Musical forces, melodic expectation, and jazz melody. *Music Perception*, *19*, 351–85.

LeDoux, J. (1996). *The emotional brain*. New York: Simon & Schuster.

Lerdahl, F. (2001). *Tonal pitch space*. Oxford: Oxford University Press.

Lerdahl, F., & Krumhansl, C. L. (2007). Modeling tonal tension. *Music Perception*, *24*, 329–66.

Lerdahl, F., & Jackendoff, R. (1983). *A generative theory of tonal music*. Cambridge, MA: MIT Press.

Lester, B. M. (1978). The organization of crying in the neonate. *Journal of Pediatric Psychology*, *3*, 122–30.

Lester, B. M., Boukydis, C. F. Z., Garcia-Coll, C. T., Hole, W., & Peucker, M. (1992). Infantile colic: Acoustic cry characteristics, maternal perception of cry, and temperament. *Infant Behavior and Development*, *15*, 15–26.

Litle, P., & Zuckerman, M. (1986). Sensation seeking and music preferences. *Personality and Individual Differences*, *7*, 575–7.

MacCurdy, J. T. (1925). *The psychology of emotion*. New York: Harcourt Brace.

Margulis, E. H. (2007). Surprise and listening ahead: Analytic engagements with musical tendencies. *Music Theory Spectrum*, *29*, 197–218.

Margulis, E. H. (2005). A model of melodic expectation. *Music Perception*, *22*, 663–714.

Margulis, E. H., & Beatty, A. P. (2008). Musical style, psychoaesthetics, and prospects for entropy as an analytic tool. *Computer Music Journal*, *32*, 64–78.

Margulis, E. H., & Levine, W. H. (2006). Timbre priming effects and expectation in melody. *Journal of New Music Research*, *35*, 175–82.

McGraw, A. P. (1999). *Expectations and emotions in sports*. Master's thesis. Ohio State University, USA.

Meyer, L. B. (1957). Meaning in music and information theory. *Journal of Aesthetics and Art Criticism*, *15*, 412–24.

Meyer, L. B. (1956). *Emotion and meaning in music*. Chicago, IL: Chicago University Press.

Meyer, M. (1903). Experimental studies in the psychology of music. *American Journal of Psychology*, *14*, 456–75.

Moreland, R. L., & Zajonc, R. B. (1977). Is stimulus recognition a necessary condition for the occurrence of exposure effects? *Journal of Personality and Social Psychology*, *35*, 191–9.

Narmour, E. (1992). *The analysis and cognition of melodic complexity*. Chicago, IL: University of Chicago Press

Narmour, E. (1990). *The analysis and cognition of basic melodic structures*. Chicago, IL: University of Chicago Press.

Panksepp, J. (1998). *Affective neuroscience: The foundations of human and animal emotions*. Oxford: Oxford University Press.

Panksepp, J. (1995). The emotional sources of 'chills' induced by music. *Music Perception*, *13*, 171–207.

Panksepp, J., & Bernatzky, G. (2002). Emotional sounds and the brain: The neuro-affective foundations of musical appreciation. *Behavioral Processes*, *60*, 133–55.

Raichle, M. E., & Gusnard, D. A. (2005). Intrinsic brain activity sets the stage for expression of motivated behavior. *Journal of Comparative Neurology*, *493*, 167–76.

Raichle, M. E., MacLeod, A. M., Snyder, A. E., Powers, W. J., Gusnard, D. A., & Shulman, G. L. (2001). A default mode of brain function. *Proceedings of the National Academy of Sciences*, *98*, 676–82.

Rickard, N. S. (2004). Intense emotional responses to music: A test of the physiological arousal hypothesis. *Psychology of Music*, *32*, 371–88.

Rifkin, D. (2000). *Tonal coherence in Prokofiev's music*: *A study of the interrelationships of structure*, *motives*, *and design*. Ph.D. Dissertation, Eastman School of Music, USA.

Saffran, J. R., Johnson, E. K., Aslin, R. N., & Newport, E. L. (1999). Statistical learning of tone sequences by human infants and adults. *Cognition*, *70*, 27–52.

Schellenberg, E.G. (1996). Expectancy in melody: Tests of the implication-realization model. *Cognition*, *58*, 75–125.

Schmuckler, M. (1989). Expectation in music: Investigation of melodic and harmonic processes. *Music Perception*, *7*, 109–50.

Schön D., & Besson M. (2005). Visually induced auditory expectancy in music reading: a behavioural and electrophysicological study. *Journal of Cognitive Neuroscience*, *17*, 693–704.

Shannon, C. E. (1948). A mathematical theory of communication. *Bell Systems Technical Journal*, *27*, 379–423.

Sloboda, J. A. (1991). Music structure and emotional response: Some empirical findings. *Psychology of Music*, *19*, 110–20.

Snyder, J. L. (1990). Entropy as a measure of musical style: The influence of a priori assumptions. *Music Theory Spectrum*, *12*, 121–60.

Steinbeis, N., Koelsch, S., & Sloboda, J. A. (2006). The role of harmonic expectancy violations in musical emotions: evidence from subjective, physiological and neural responses. *Journal of Cognitive Neuroscience*, *18*, 1380–93.

Suddendorf, T. (2006). Foresight and evolution of the human mind. *Science*, *312*, 1006–7.

Sundberg, J. (1972). An articulatory interpretation of the 'singing formant'. *Speech Transmission Laboratory/Quarterly Progress Status Report*, *Stockholm*, *1*, 45–53.

Sundberg, J. (1977). The acoustics of the singing voice. *Scientific American*, *236*, 82–91.

Sundberg, J. (1987). *The science of the singing voice*. DeKalb, IL: Northern Illinois University Press.

Temperley, D. (2007). *Music and probability*. Cambridge, MA: MIT Press.

Thayer, R. E. (1996). *The origin of everyday moods*: *Managing energy*, *tension*, *and stress*. Oxford: Oxford University Press.

Tillmann, B., Bigand, E., & Pineau, M. (1998). Effects of global and local contexts on harmonic expectancy. *Music Perception*, *16*, 99–118.

Verleger, R. (1990). P3-evoking wrong notes: Unexpected, awaited, or arousing? *International Journal of Neuroscience*, *55*, 171–9.

von Hippel, P. (2002). Melodic-expectation rules as learned heuristics. In C. Stevens, D. Burnham, G. McPherson, E. Schubert, & J. Renwick (eds), *Proceedings of the 7th International Conference on Music Perception and Cognition* (pp. 315–317). Adelaide, Australia: Causal Productions.

von Hippel, P., & Huron, D. (2000). Why do skips precede reversals? The effect of tessitura on melodic structure.*Music Perception*, *18*, 59–85.

von Hippel, P., Huron, D., & Harnish, D. (1998). *Melodic expectation for a Balinese melody*: *A comparison of Balinese and American musicians*. Unpublished manuscript.

Weiss, M. J., Zelazo, P. R., & Swain, I. U. (1988). Newborn response to auditory stimulus discrepancy. *Child Development*, *59*, 530–41.

Wilson, T. D., & Gilbert, D. T. (2005). Affective forecasting: Knowing what to want. *Current Directions in Psychological Science*, *14*, 131–4.

Youngblood, J. E. (1958). Style as information. *Journal of Music Theory*, *2*, 24–35.