CHAPTER

10

Auditory Preferences and Aesthetics: Music, Voices, and Everyday Sounds

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INTRODUCTION

Some sounds are preferable to others. We enjoy the hypnotic roar of the ocean, or the voice of a favorite radio host, to the point that they can relax us in the midst of an otherwise stressful day. However, sounds can also drive us crazy, be it a baby crying next to us on a plane or the

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high-pitched whine of a dentist's drill. Hedonic and aversive responses to sound figure prominently in our lives. Unpleasant sounds warn us of air raids, fires, and approaching police cars, and are even used as coercive tools during interrogation procedures. Pleasant sounds are fundamental to music, our main sound-driven form of art, and the pleasantness of voices is important in evaluating members of the opposite sex.

This chapter will present an exploration of sounds that evoke hedonic and aversive responses in humans. Our central interest is in what determines our auditory preferences, and why. *A priori* we can imagine that many different factors might come into play, including acoustic properties, learned associations between sounds and emotional situations, the surrounding context, input from other senses, and the listener's personality and mood. As we shall see, all of these factors can at times be important. We will consider the aesthetic response to isolated sounds, annoying and pleasant, as well as to the complex sound sequences produced by music.

ANNOYING SOUNDS

At their worst, sounds can be flat out cringe-worthy. The most commonly cited example is the sound of fingernails on a chalkboard, the mere thought of which is enough to make many people grimace. What makes such sounds so awful? Apart from their intrinsic interest, much of the motivation for studying annoying sounds comes from industry. Manufacturers have long had an interest in understanding what makes sounds aversive so as to avoid these properties in products that emit noise (electric saws, refrigerators, cars, trains, etc.), and studies on this topic date back many decades.

When people are asked to rate the annoyingness of large sets of real-world sounds, considerable agreement is usually observed across listeners (Cardozo & van Lieshout, 1981; Terhardt & Stoll, 1981), at least within the groups of Westerners typically studied. A fair bit of the variance in pleasantness across sounds can be explained by a few simple acoustic properties.

In addition to overall loudness, two properties that have substantial influence are "sharpness" and "roughness" (Fastl, 1997; Terhardt & Stoll, 1981). Sharpness describes the proportion of energy at high frequencies, with sharper sounds (those with more high-frequency energy) generally found to be less pleasant. Frequencies in the range of 2–4 kHz contribute the most to annoyingness (Kumar, Forster, Bailey & Griffiths, 2008). This range is high in absolute terms, but well below the upper limit of what is audible to a human listener with normal hearing. Screech-like sounds (Figure 10.1), much like fingernails on a blackboard, lose some of their

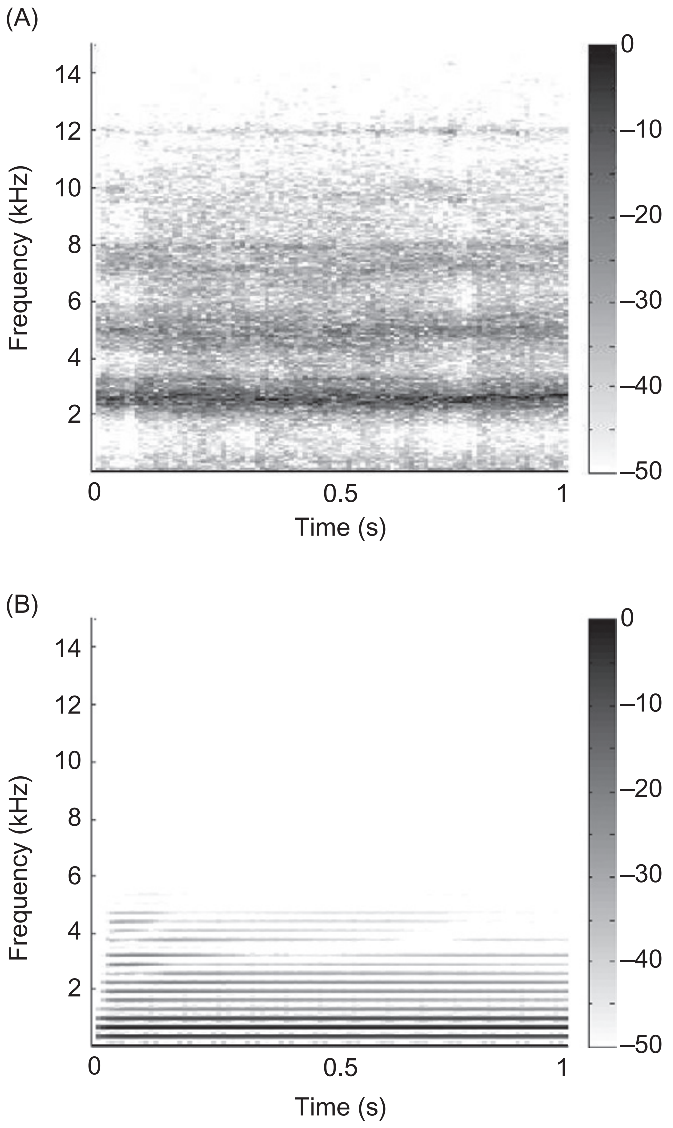

FIGURE 10.1 **Spectrograms of (A) a screech (produced by scraping a metal garden tool down a glass window) and (B) a note played on a saxophone.** Gray level displays sound amplitude in dB. Note that the screech has a concentration of energy between 2–4 kHz. The saxophone, by contrast, has harmonics that are more closely spaced, as it has a lower pitch, with most of the energy concentrated below 2 kHz.

aversiveness when frequencies in the 2–4 kHz range are filtered out, but not when frequencies above this range are removed (Halpern, Blake & Hillenbrand, 1986).

Roughness is the perceptual correlate of fluctuations in energy (intensity) that occur over time, analogous to the fluctuations in surface depth that determine the roughness of an object to the touch. Fluctuations at rates between ~20–200 Hz are those that determine roughness (Terhardt, 1974a); any lower, and the fluctuations can be heard individually rather than contributing to a sound's timbre. In general, the rougher a sound, the less pleasant it tends to be. For instance, studies of automobile interior noise, which manufacturers aim to make as pleasant as possible, indicate that roughness is a major determinant of unpleasantness (Takao, Hashimoto & Hatano, 1993). Roughness is also a characteristic of many scraping and screeching sounds, including that of fingernails on a blackboard. The amplitude fluctuations in these sounds result from an object (e.g. a fingernail) rapidly catching and then releasing on the surface being scraped, producing many brief bursts of sound that cause amplitude fluctuations.

Why are these sound properties unpleasant? The annoying effects of sharpness may be rooted in the frequency sensitivity of the ear, which peaks in the range of 2–4 kHz. The ear canal has a resonance in this range, boosting sound levels of these frequencies by as much as 30 dB (Henoch & Chesky, 1999). Exposure to noise in this frequency range is thus most likely to damage the ear. The aversive response to these frequencies could simply be because they sound the loudest, and are potentially the most dangerous to listen to. Notably, most highly unpleasant sounds are much less aversive at low volume.

It is less clear why roughness is unpleasant, as it does not obviously pose any danger to the auditory system. It is also unclear at present whether the reaction to roughness and other sound properties is universal and obligatory. In Western music, as discussed below, rough sounds are thought to be unpleasant (Helmholtz, 1863; McDermott, Lehr & Oxenham, 2010; Plomp and Levelt, 1965). In some cultures, however, roughness is a staple of musical expression, and its aesthetic interpretation may be different than in the Western world (Vassilakis, 2005). Even in Western music, rough sounds have become common in some subgenres since the introduction of distortion in rock music in the 1950s and 1960s, and in this context are enjoyed by listeners. It thus remains possible that the aversion to roughness is partially context-dependent.

Associations between sounds and the events in the world that cause them also clearly play some role in whether we experience a sound as pleasant or unpleasant. In a large internet-based experiment, the sound rated most awful out of a large set was that of someone vomiting (Cox, 2008a). Though not particularly sharp or rough, the associations most of us have with vomiting no doubt contributed to its status as the most annoying sound. The same study found that seeing the image of fingernails on a chalkboard, or a dentist, while listening to the corresponding sound yielded a worse rating for the sound (Cox, 2008b). Visual input can also render sounds less annoying – white noise is deemed less objectionable when accompanied by a picture of a waterfall that suggests a natural sound source (Abe, Ozawa, Suzuki & Sone, 1999).

PLEASANT ENVIRONMENTAL SOUNDS

Fortunately, not all sounds are annoying. Indeed, many people find natural environmental soundscapes (ocean waves, rainfall, etc.) to be relaxing and pleasant, to the point that recordings of such sounds are marketed to aid sleep and relaxation. Why are these sounds enjoyable? Very little research has addressed the pleasantness of environmental sounds, but emotional associations with relaxing circumstances surely play some role. Such sounds also typically lack the acoustic properties described above that are found in many annoying sounds. The sounds of oceans, rain, wind, etc. usually have more energy at low frequencies than at high (Voss & Clarke, 1975), and feature slow temporal modulations (Attias & Schreiner, 1997; Singh & Theunissen, 2003), rather than prominent modulations in the roughness range. It is also interesting that the perception of many natural sound "textures," such as water sounds, can be explained in relatively simple terms with generic statistics of the early auditory system (McDermott, Oxenham & Simoncelli, 2009; McDermott & Simoncelli, 2011), though a relationship between this sort of simplicity and pleasantness remains conjecture at present.

VOICES

The attractiveness of voices is of particular interest because the voice is believed to provide important signals of the fitness of potential partners. Humans historically tended to engage in sexual activity at night, when little light was available to judge visual characteristics. The voice may thus have been critical for judgments of mate quality, with vocal characteristics that signal fitness coming to be perceived as attractive. Empirically, voices vary significantly in their attractiveness, and listeners largely agree on what sounds attractive (Zuckerman & Driver, 1989).

Consistent with the notion that it functions to signal mate quality, vocal attractiveness co-varies with body symmetry (e.g. between the widths of the two hands), a known marker of fitness (Hughes, Harrison & Gallup, 2002), and co-varies with other sexually dimorphic traits – males with larger shoulder-to-hip ratios, and females with larger hip-to-waist ratios, have more attractive voices (Hughes, Dispenza & Gallup, 2004). Individuals with more attractive voices also have more sexual partners, and become sexually active earlier in life, than those with unattractive voices. In females, voice attractiveness is actually a better predictor of promiscuity than the visual signal provided by hip-to-waist ratio (Hughes, Dispenza & Gallup, 2004), and varies across the menstrual cycle, providing an "honest" signal of fertility (Pipitone & Gallup, 2008). The influence of voice attractiveness in most life situations is at least

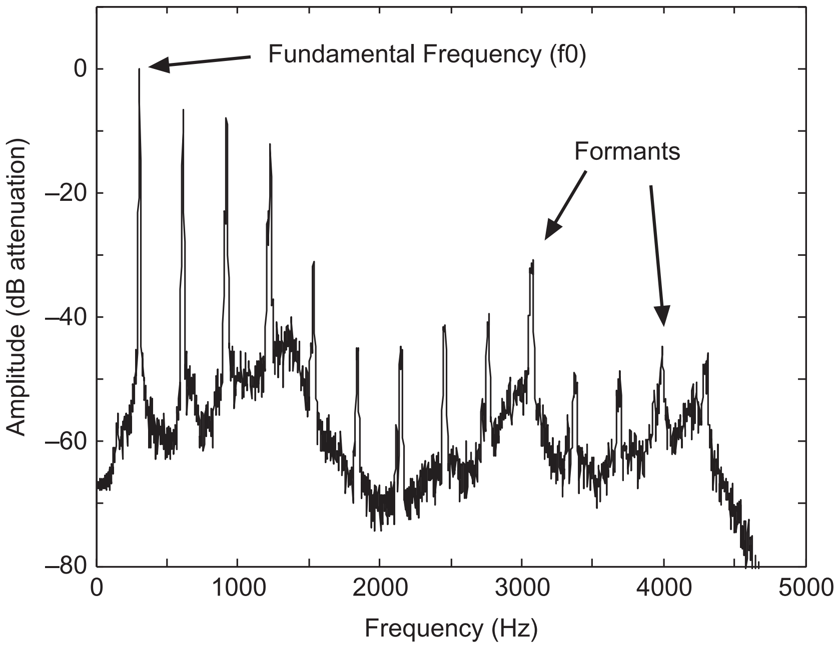

FIGURE 10.2 **Power spectrum of a vowel.** Note that the frequencies in the vowel are integer multiples of the fundamental frequency (harmonics), and are thus equally spaced along the spectrum.

partly confounded with other aspects of attractiveness (which are correlated with attractive voice characteristics), but when provided only with vocal samples, listeners judge themselves more likely to affiliate with people with attractive voices (Miyake & Zuckerman, 1993).

Acoustically, voices are characterized in part by their characteristic pitch and formant frequencies, each of which correspond to a component of the sound production process. The sound signal that leaves a speaker’s mouth can be thought of as sound from a source (the vocal folds) that is then passed through a filter (the vocal tract) that alters its frequency characteristics. Sound is created when the vocal folds open and close as air passes through them. The opening and closing happens at a regular rate and generates a sound waveform that repeats at this rate. The pitch corresponds to the rate of repetition, i.e. the fundamental frequency (f0) of the voice (the other frequencies are integer multiples of the f0, i.e. harmonics of it; Figure 10.2). The f0 can be controlled to some extent by the musculature surrounding the vocal folds, but the central tendency is set by the thickness and size of the folds (Fant, 1960).

Formants, in contrast, are global peaks in the spectrum that result from the filtering effects of the vocal tract, which amplifies some frequencies and dampens others (Figure 10.2). They can also be varied by changing the shape of the throat and mouth, as when articulating different vowels, but their central tendency and spacing are determined by the vocal tract's intrinsic shape, most notably its length. Formants thus provide a cue to vocal tract length, which in turn is tightly linked to body size. In this respect they are distinct from pitch, which depends instead on the size of the vocal folds, a trait that is largely independent of overall body size (Fitch, 1997).

Both pitch and formant frequencies are sexually dimorphic. Testosterone causes the vocal folds to increase in size, lowering voice pitch, as happens in males at puberty. Pitch is high in children and decreases during development in both sexes, but at a faster rate in males, with the decrease accelerated during puberty. The result is that adult male f0s are on average about half that of adult females (Bachorowski and Owren, 1999). Individual variation within each sex is high, however, and likely provides a signal of hormone levels that relate to reproductive potential. Formant frequencies and their spacing similarly differ on average between sexes, but also vary considerably across individuals of a particular sex.

Low voice pitch in men is more attractive to female listeners, who associate it with other attractive male physical features and signals of sexual maturity (Collins, 2000). Moreover, artificially lowering the pitch and formants of a male voice increases its attractiveness to female listeners, an effect that is enhanced during the fertile phase of the menstrual cycle (Feinberg, Jones, Law Smith et al., 2006). Low voice pitch is also predictive of reproductive success in hunter-gatherers, for whom the absence of birth control methods allows this success to be readily measured (Apicella, Feinberg & Marlow, 2007).

In female voices, the reverse trend occurs: they are judged as more attractive by men if they are higher in pitch and have more widely spaced formants (Collins and Missing, 2003), and artificially raising female voice pitch increases attractiveness (Feinberg, DeBruine, Jones & Perrett, 2008). Like male voice pitch, female vocal pitch appears to signal fitness. Women with feminine facial features tend to have high pitched voices (Collins and Missing, 2003), suggesting that both provide cues to femininity and reproductive fitness. Voice pitch in women is also correlated (negatively) with health risk factors like overall weight, body mass index, and body fat percentage (Vukovic, Feinberg, DeBruine et al., 2010), suggesting that it signals properties indirectly related to reproductive success as well. Moreover, when communicating with men that they find attractive, women speak with higher pitch, indicating implicit knowledge of the fitness-related signal provided by the pitch of their voice (Fraccaro, Jones, Vukovic et al., 2011).

In addition to gender-specific effects, there is a general tendency to prefer voices that have clearer (less noisy) pitch. Voice pitch clarity, indicated quantitatively by a high "harmonic-to-noise" ratio, is another signal of fitness – it decreases in the elderly (Ferrand, 2002), and is lower in voices that are hoarse (Yumoto, Gould & Baer, 1982), as when suffering from a cold or other illness. Preferences for clear pitch are evident in recent studies of voice averaging. Averaging recordings of vowels produced by a large set of different speakers (using voice morphing software) tends to yield a voice that is almost as attractive as the most attractive individual voice in the set (Bruckert, Bestelmeyer, Latinus et al., 2010). Some of this effect is due to the smoothing inherent to averaging, which enhances the harmonic frequencies of the pitch and averages out the aperiodic noisy components (imperfections in the pitch), producing a cleaner pitch.

The effect of averaging multiple voices together is similar in some respects to the effect of reverberation, which also tends to make voices sound better, as most of us have experienced when singing in the shower. The hard walls of a shower reflect the sound that comes out of our mouths, such that the ears receive sound indirectly from each of the reflections in addition to the sound that comes directly from the mouth. Because the path from the source to our ears is longer for the reflected versions, they reach our ears a small fraction of a second later than the direct sound. The ear thus receives a sum of many copies of the original sound, each with a different delay, and each filtered to some extent by the reflective surface (which generally absorbs some frequencies more than others). The effect is somewhat like taking an average of different voices in that the noisy components tend to get averaged out, leaving a pitch that sounds more pure than it would without the reverberation. Recording engineers in fact typically incorporate reverberation into the music recording process for its aesthetic effect, either by choosing a room with pleasant reverberation in which to record, or by adding reverberation as a digital effect (Gardner, 1998).

It has also been argued that the effect of voice averaging is not limited to simply smoothing out imperfections, and that voices whose pitch and formants are closer to the average values for that sex are more attractive (Bruckert et al., 2010), as is the case for faces (Langlois & Roggman, 1990) and other stimuli (Halberstadt & Rhodes, 2000). One piece of evidence is that "moving" an individual's voice towards the average, by altering the f0 and formant frequencies in the direction of the average voice, tends to make the voice more attractive (Bruckert et al., 2010). This would seem inconsistent with the many findings, cited earlier, that lowering male pitch, or raising female pitch, increases attractiveness irrespective of where the voice lies relative to the average, but it is possible the effect is driven mainly by the formants rather than the pitch. As with faces (Perrett, May & Yoshikawa, 1994), however, it seems likely that at least some highly attractive voices are non-average (consider the deep baritone of Barry White, or the gravelly character of Louis Armstrong's voice, for instance), though it remains to be tested.

MUSIC

Music is the domain in which our aesthetic response to sound is most obvious and striking. For the typical human listener, music is a highly rewarding stimulus. Listening to our favorite music activates the same reward pathways that are stimulated by good food, cocaine, and sex (Blood & Zatorre, 2001; Menon & Levitin, 2005; Salimpoor, Benovoy, Larcher et al., 2011). The reward of listening to music motivates us to consume a startling amount of it, expending considerable resources as a result. Before the availability of free online music caused the industry to nosedive, music sales were in tens of billions of dollars (Geter and Streisand, 1995), and major record labels were viewed by Wall Street as lucrative investment opportunities (Knopper, 2010). When randomly probed via their cell phones, British adults were recently found to be in the presence of music 39% of the time (North, Hargreaves & Hargreaves, 2004). Music is ubiquitous in restaurants and department stores (Bruner, 1990), and has been shown to improve sales (North, Shilcock & Hargreaves, 2003), presumably because of its positive influence on mood.

There are many open questions concerning the nature of our response to music, including where music is processed in the brain (Peretz & Zatorre, 2003), whether it interacts with other cognitive abilities and resources (Patel, 2008), why we experience emotion when listening to it (Juslin & Sloboda, 2010; Zentner, Grandjean & Scherer, 2008), and why we have it to begin with (Huron, 2001; McDermott, 2008; Wallin, Merker & Brown, 2001). In this chapter our interest is specifically in why people like the music that they do. Ultimately we will discuss the preferences that a listener has for one piece of music over another, but it is first worth considering the aesthetic response to the simpler sound elements that music is made of.

Instrument Sounds

Music often is played on instruments, the sound of which is obviously important to the aesthetic value of the end product. Not every violin, or every guitar, sounds the same. Different instruments are distinguished by having different "timbre" – aspects of their sound that are not captured by pitch or loudness, that vary both across and within an instrument category. Some instrument brands are especially sought-after for their aesthetically pleasing timbre, the most famous example being the Stradivarius violin (Beamen, 2000). However, the sound of the music that enters our ears, and that determines our aesthetic response, is not just determined by the instrument and manner of playing. The experience of live music, for instance, depends crucially on the concert hall, the sound of which is the product of painstakingly adjusted reflection patterns that add reverberation while ensuring that clarity is preserved throughout the listening space (Lokki, Patynen, Tervo et al., 2011). Other factors influence music that is recorded for later mass consumption, including the brand of microphone used to record the instrument, the placement of the microphone(s) around the instrument and room, the room where the instrument is recorded, and the filters and other effects applied post-recording (Milner, 2009). Many music producers and engineers develop an idiosyncratic and elusive mixture of these factors that gives their recordings of drums, horns, etc., a distinctive and characteristic sound.

The sound of a great recording can be remarkably difficult to replicate. One place where this is evident is in the modern-day practice of "sampling", in which a contemporary music maker excerpts a brief segment of another recording (often from an earlier era) to obtain a sound with the desired timbre that would otherwise be difficult to recreate in a modern recording studio. In the golden age of hip-hop, for instance, drum "breaks" were often excerpted from older recordings and looped (often combined with other samples) to create rhythm tracks. Certain drum breaks were used over and over, in some cases on literally hundreds of different recordings, as producers valued particular drum sounds that had been recorded decades earlier (Crate Kings, 2007). Some of these classic samples were bits of records by well-known artists like James Brown or Kool and the Gang, but many were taken from otherwise obscure recordings, by artists such as the Honeydrippers, the Winstons, and the Incredible Bongo Band. They may not have produced hit records at the time, but they achieved a sound that contemporary listeners value even if they are unaware of its origins.

Although instrument sounds matter greatly to music listeners, with much time and effort devoted to achieving the right sound during the recording process, drawing scientific conclusions about why people like particular instrument sounds is a challenge. It is likely that preferences vary across genre and culture, and that individual differences are substantial. Instrument sounds may also matter most in how they combine with other sounds to create a piece of music (Schloss, 2004).

Consonance and Dissonance of Chords

One domain in which preferences have been more rigorously measured and modeled is that of musical chords – combinations of notes played at the same time. It has been known for thousands of years that some combinations of notes are more pleasing than others (to Western listeners, at least). Figure 10.3a shows an example data set of pleasantness ratings given by American undergraduates to various two- and three-note chords (McDermott et al., 2010). It is apparent that some chords are rated higher than others, and that the general pattern is

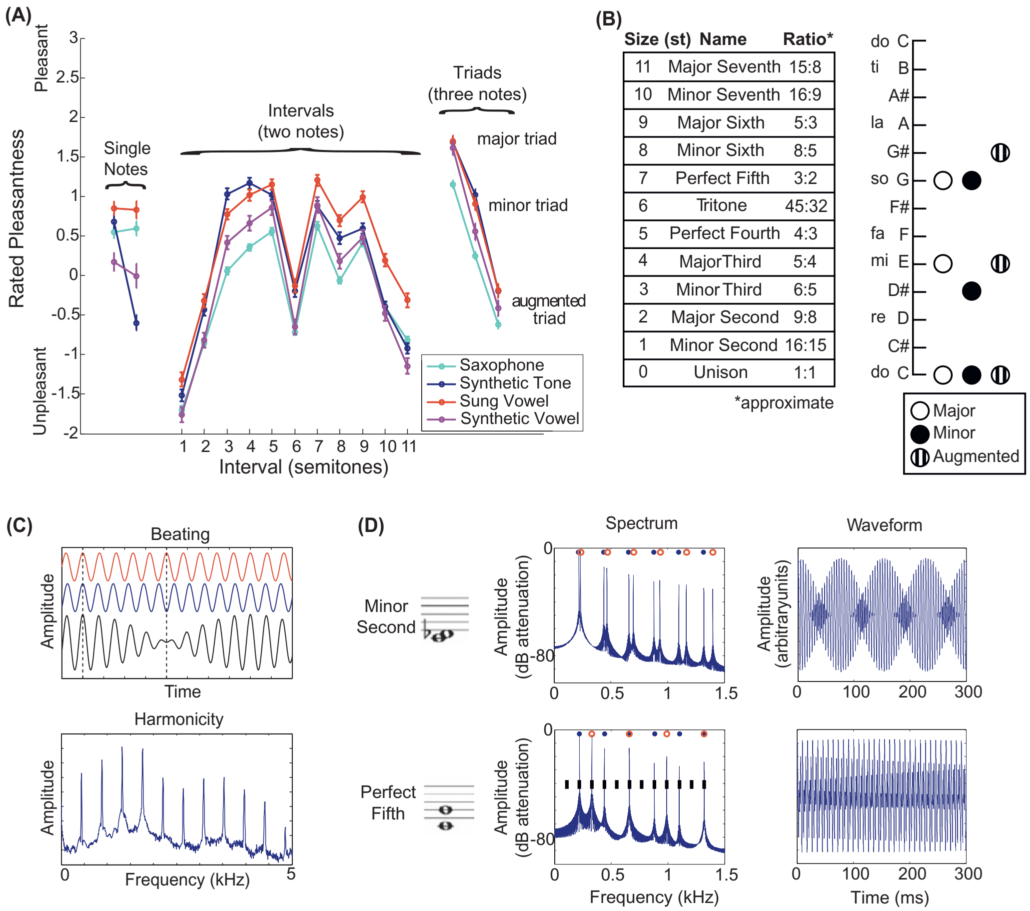

FIGURE 10.3 **Consonance preferences and their possible acoustic basis.** (A) Average pleasantness ratings of individual notes and chords, for a large group of American undergraduates. The two single-note conditions differed in pitch (lower pitch on left). Error bars denote standard errors. (B) Intervals and chords from A, with diatonic scale (on left) as reference. Ratios in stimuli approximated those listed in table, due to use of the equal-tempered scale. (C) Beating and harmonicity. Top – two sinusoids of different frequencies are plotted in red and blue; their superposition (in black) contains amplitude modulation known as "beating." Bottom – amplitude spectrum for the note A440 played on an oboe. The frequencies in the note are all integer multiples of the fundamental frequency of 440 Hz, and as a result are regularly spaced along the frequency axis. (D) Spectra and waveforms for the minor second and perfect fifth, in which beating and harmonicity are apparent. The intervals were generated by combining two synthetic complex tones with different fundamental frequencies. Red (open) and blue (closed) circles denote the frequencies belonging to each note. The frequencies of the fifth are approximately harmonically related (black lines denote harmonic series). Amplitude modulation (from beating) is evident in the waveform of the minor second, but not the fifth (Modified from McDermott et al., 2010).

largely independent of what instrument is used to play the notes. The highly-rated chords are conventionally called consonant, and the low-rated chords are termed dissonant.

The distinction between consonance and dissonance is central to Western music. Computational analysis of scores and scales indicates that many classical composers made choices to maximize consonance in their compositions (Huron, 1991), and that the structure of the Western diatonic scale itself may have resulted from an attempt to maximize the number of possible consonant note combinations (Huron, 1994). However, when dissonance is used, it plays an important role, being routinely employed to create tension in music, as is often apparent in movie or television soundtracks.

Why is it that only some combinations of notes sound consonant? Debates over the basis of consonance date back to the Greeks, who famously believed that aesthetics derived from ratios, and noted that consonant intervals are produced by strings whose lengths form simple integer ratios (Figure 10.3b). Modern-day theories have instead tried to explain consonance in terms of acoustic properties – roughness, mentioned above in the context of aversive noises, or harmonicity, an important property of the frequency spectra of many natural sounds.

The proposal of a role for roughness in consonance is generally credited to Helmholtz, who noticed that dissonant chords tend to have a preponderance of a phenomenon known as beating (Helmholtz, 1863). Beating occurs whenever similar frequencies are present simultaneously (Figure 10.3c, top). Over time, two frequencies shift in and out of phase, causing them to constructively and then destructively interfere. This cyclical pattern results in a sound (shown in black in the figure) that waxes and wanes in amplitude. Beating is one way to produce a sound that is rough, which tends to be heard as unpleasant, as discussed earlier (Terhardt, 1974a). Helmholtz noted that dissonant chords tend to produce many pairs of frequencies that are close but not identical, and that thus beat. One example, the minor second, is shown in Figure 10.3c (middle row, left column). Each pair of nearby frequencies beat, producing a rough waveform (Figure 10.3c, bottom left). Consonant intervals, in contrast (for example, the perfect fifth, shown in Figure 10.3c, middle row, right column), have frequencies that are either identical or widely spaced, and that produce little beating as a result. This difference in roughness has been widely proposed to underlie the differences in pleasantness of different musical chords (Hutchinson & Knopoff, 1978; Kameoka & Kuriyagawa, 1969; Plomp & Levelt, 1965; Sethares, 1999; Vassilakis, 2005).

Although roughness has arguably been the standard explanation of consonance since the 1960s, an alternative explanation in terms of "harmonicity" has also retained proponents. In the earlier section on voice, we discussed how sounds that have a pitch contain frequencies that are harmonically related – the frequencies are integer multiples of a fundamental frequency, producing regular peaks in the spectrum (an example is shown in Figure 10.3c, bottom). Vocal and instrument sounds tend to have a pitch, and to be harmonic, and thus when a chord is played in music, each of the component notes is generally a harmonic tone. However, it turns out that for consonant chords, the combined frequencies of all the notes together are also harmonically related. Every frequency in the spectrum of the perfect fifth, for instance (Figure 10.3c, middle right), corresponds to an element of the harmonic series (indicated by the thick black line segments superimposed on the spectrum), although generally not every harmonic is present. Dissonant chords, in contrast, produce sets of frequencies that are inharmonic. Harmonic frequencies have been supposed to be preferred over inharmonic frequencies due to their resemblance to single tones, thus potentially explaining the preference for consonance over dissonance. The harmonicity theory of consonance has a long history (Bidelman & Krishnan, 2009; Ebeling, 2008; Stumpf, 1890; Terhardt, 1974b; Tramo, Cariani, Delgutte & Braida, 2001), but has in recent decades been disregarded in favor of roughness. The theories proved difficult to definitively distinguish because they make many of the same predictions (Mathews & Pierce, 1980; McDermott & Oxenham, 2008).

In recent work, my colleagues and I were able to disentangle these factors using individual differences (McDermott et al., 2010). The logic of our approach was that the strength of the preference for consonance over dissonance ought to vary somewhat across individuals, as should the aversion to either inharmonicity or beating, the two acoustic factors thought to possibly contribute (negatively) to consonance. If one of the acoustic factors is causally related to preferences for consonance, then the strength of the aversion for that factor ought to correlate with the strength of consonance preferences. We measured the aversions to beating and to inharmonicity in a large set of subjects, then measured preferences for isolated musical chords, and examined correlations between the different preferences. To assess the aversion to the two candidate acoustic factors, we measured the preference for stimuli that lacked beating over stimuli that produced beating, and for harmonic tones over inharmonic tones (in which the frequencies of a harmonic tone were perturbed such that they were no longer multiples of a common fundamental frequency).

The results were surprisingly decisive: only harmonicity preferences correlated significantly with consonance preferences. Our results indicate that roughness (caused by beating in this case) is orthogonal to dissonance rather than covarying with it – rough sounds are clearly unpleasant in many contexts, but the difference between consonant and dissonant chords seems to be due to another acoustic variable, that of harmonicity. This may be because in practice, consonant chords are in fact not consistently rougher than dissonant chords, or because the overall amount of beating varies considerably with instrument timbre, such that it is not diagnostic of the note combinations in a chord. In any case, roughness does not seem to be causally related to consonance. We concluded that much of the pleasantness of musical chords derives from whether their frequencies are harmonically related or not.

Concluding that harmonicity underlies consonance leaves open the question of why we prefer harmonic sounds, and thus consonance. In particular, there is longstanding interest in whether the response to consonance is learned from exposure to music (Cazden, 1945; Lundin, 1947), which tends to have more consonant than dissonant chords. It would be useful to know to what extent consonance preferences are present in foreign cultures, some of which have music that departs considerably from Western music in scales and harmony, but regrettably few such studies have addressed this issue thus far (Butler & Daston, 1968; Fritz, Jentschke, Gosselin et al., 2009). Consonance has been studied more extensively in developmental psychology. Several investigators have found that young infants seem to prefer consonance to dissonance (Trainor & Heinmiller, 1998; Zentner & Kagan, 1998; Trainor, Tsang & Cheung, 2002), suggesting that preferences emerge without much exposure to music. On the other hand, in our individual differences work, we found that preferences for consonance, as well as for harmonicity, were correlated with the number of years undergraduate subjects had spent playing an instrument, suggesting that the preference is at least modified considerably by musical experience (McDermott et al., 2010). Further work is needed to definitively address the universality and/or innate nature of this basic aspect of music perception.

Musical Pieces and Genres

We will now explore the basis of preferences for more complex and extended pieces of music. Everyone has experience listening to music, and many of us have intuitions about why we like what we like. Much of the research in this area has thus far confirmed with controlled experiments phenomena that have a good deal of intuitive plausibility. Many factors come into play. Social influences loom large, as people use music to project an identity (North, Hargreaves & O'Neill, 2000), and are strongly influenced by what others around them listen to when making their own listening choices (Salganik, Dodds & Watts, 2006). There are also factors involving something like intrinsic aesthetic quality, at least within a culture, as well as factors idiosyncratic to particular listeners, such as their past experience and personality.

Exposure and Familiarity

One of the largest influences on music preferences is prior exposure – we are inclined to like things we have heard before, and to dislike those we have not. People tend to prefer to listen to the music of their culture, even as young infants (Soley & Hannon, 2010), and often find the music of foreign cultures to be uninteresting or unpleasant by comparison (Fung, 1993). In modern times, foreign music has in fact been used in warfare and interrogation. During the Iraq War, the BBC reported that uncooperative prisoners were exposed for prolonged periods of time to heavy metal music and American children's songs (e.g. the Sesame Street theme) in order to coerce them into talking to US interrogators, a practice that is apparently standard operating procedure in the US "war on terror" (Cusick, 2008). The stress from exposure to foreign music is evidently considerable. A related much-publicized incident occurred during the US invasion of Panama. Manuel Noriega, the Panamanian dictator, took refuge in the Vatican embassy, which US forces could not enter without violating international law. To induce him to surrender, US troops supposedly set up loudspeakers outside the embassy, from which they played Van Halen, Guns and Roses, and other hard rock music around the clock. Noriega surrendered within a week.

Even within a familiar culture and genre, many people have had the experience of finding a piece of music relatively unrewarding upon first listen, but coming to love it with repeated listens. Any DJ can tell you that the single most important factor predicting whether people will dance to a song is whether or not they are familiar with it; even highly danceable music is unlikely to evoke enthusiasm on the dancefloor the first time it is played. Familiarity effects are also well-documented experimentally. Across genres, familiar musical pieces are generally liked more than unfamiliar pieces (Hargreaves, Messerschmidt & Rubert, 1980; Hargreaves, 1987). This by itself could be explained by the possibly higher quality of familiar pieces (in that better songs would be more likely to become hits). However, repeated exposure also increases liking in unfamiliar music pieces, whether in music from a familiar idiom (Gilliland & Moore, 1924; Ali & Peynircioglu, 2010) or an unfamiliar or foreign style – modern classical (Mull, 1957), or Pakistani music heard by Americans (Heingartner & Hall, 1974). Effects are typically observed over the course of a few exposures. The effect of "mere exposure" is not unique to music. Stimuli across the board are liked more with repeated exposure, at least up to a point (Zajonc, 1968), often plateauing after about 10 exposures (Bornstein, 1989). It often feels subjectively that the effects of repetition on liking are more pronounced for music than for other stimuli, but I know of no empirical evidence to support that notion at present.

Many people also have the sense that there is a special relationship between music and the memories induced by prior exposure. We tend to have a fondness for the music that surrounded us during childhood and adolescence, and often feel we like particular pieces in part because they remind us of good times from the past. However, at least as has been tested thus far, memory for music does not seem to be any more accurate than memory for other kinds of stimuli to which we have comparable exposure. For instance, when recollection of songs from people's high school years were compared to that for faces from their high school yearbooks, no memory advantage was observed (Schulkind, 2009). The sense we have of a privileged link between music and memory may be an illusion like that associated with memory for emotional life events. People often believe that their memories of emotionally traumatic events (e.g. the Kennedy assassination, or the September 11 terrorist attacks) are more accurate than memories of more mundane events, but when tested in the lab, accuracy is in fact no different (Talarico & Rubin, 2003). What *is* different is the sense of vividness with which people recollect emotional events (Talarico & Rubin, 2003), believed to be because the emotion centers of the brain alter the experience of remembering (Sharot, Delgado & Phelps, 2004). Memory for music may involve a similar phenomenon – the emotional content of music may cause the experience of remembering it to be enhanced even if the memory itself is no more precise or robust to decay.

Complexity

The effect of familiarity on our aesthetic response to music is substantial, but it also seems obvious that it cannot be the only factor influencing what we like – some pieces are clearly much easier to like than others. One widely discussed idea in experimental aesthetics is that the aesthetic response is related to complexity. The notion is that stimuli that are too simple or too complex are not aesthetically pleasing, but that somewhere in the middle lies an optimum. Complexity and aesthetic value are thus proposed to be related via an inverted U-shaped function (Berlyne, 1971); Figure 10.4. Exactly how complexity should be measured is unclear. Some authors have argued for information theoretic measures; others define it for music in terms of the degree of conformity to the rules of the dominant musical idiom.

Intuitively, the idea of an inverted U-shaped curve relating complexity and pleasingness is at least partly consistent with what we know from experience: something that is too repetitive is boring, while something that is completely random has no structure, and thus cannot be related to things we've previously heard. The idea is also consistent with observations that the complexity of typical musical melodies is moderate, with note-to-note changes being dominated by small intervals (Voss & Clarke, 1975; Vos & Troost, 1989).

Numerous experimental findings support a role for complexity in musical preferences. Moderately complex pieces tend to be preferred over pieces of lesser or greater complexity, be they piano solos whose complexity is varied by changing the number of chords and degree of

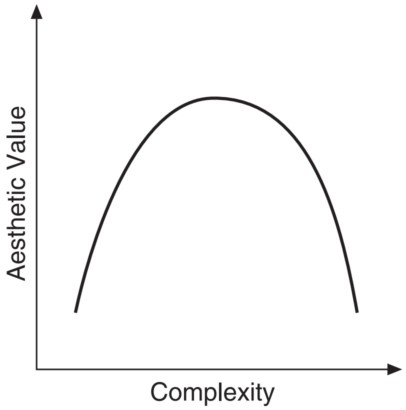

FIGURE 10.4 The inverted U-curve proposed to related subjective complexity to aesthetic value (Berlyne, 1971).

syncopation (Heyduk, 1975), instrumental classical music (Radocy, 1982), random tone sequences whose temporal correlation is varied (Voss & Clarke, 1975), contemporary pop music (North & Hargreaves, 1995), or ambient electronic music (North & Hargreaves, 1996) whose complexity is assessed by listener ratings. One problematic issue is that if the range of complexity that is sampled by an experiment is not centered near the optimal level of complexity, or is not broad enough, one would expect to see either a monotonic dependence of liking on complexity, or none at all, both of which are sometimes reported (Martindale & Moore, 1989; Smith & Melara, 1990; Orr & Ohlsson, 2001). That said, many investigators have found an inverted U-shape.

Importantly, what is purported to matter is subjective rather than objective complexity. This distinction is critical because the subjective complexity of a piece of art or music is thought to decrease with repeated exposure, as the observer internalizes its structure. The preference discussed earlier for the music of one's own culture may derive from this principle. As we develop in a musical culture, we internalize its rules and characteristic forms. We become more adept at encoding idiomatic pitch and rhythm structures, and at recognizing the emotions they represent, relative to those of other cultures (Dalla Bella, Peretz, Rousseau & Gosselin, 2001; Hannon & Trehub, 2005; Lynch, Eilers, Oller & Urbano, 1990; Thompson and Balkwill, 2010; Trehub, Schellenberg & Kamenetsky, 1999). Because our expertise is culture-specific, the subjective complexity of typical foreign music may be prohibitively high, preventing us from enjoying it.

Repeated exposure is expected to shift the location of a particular piece leftwards on the complexity axis of the inverted U-curve, one interesting consequence of which is that the effect of exposure on aesthetic evaluation should depend on the starting location. A piece that initially has a level of complexity that is close to optimal is thus predicted to be liked less with repetition, as it falls off the peak, whereas a piece that is initially too complex is expected to improve with repeated exposure, at least up to a point. These predictions have been confirmed in multiple studies. Smith and Cuddy found that repetition decreased pleasingness for harmonically simple melodies, but increased it for more complex melodies, with the biggest increases occurring for the most complex melodies in the stimulus set (Smith & Cuddy, 1986). Schellenberg and colleagues found that repetition increased the liking of moderately complex piano pieces if listeners were doing another task while listening to the music, but that focused listening caused liking to increase and then decrease with repetition, as though listeners had passed over the peak of the curve (Schellenberg, Peretz & Vieillard, 2008; Szpunar, Schellenberg & Pliner, 2004). Similar results have been obtained by other groups (Tan, Spackman & Peaslee, 2006; Verveer, Barry & Bousfield, 1933).

The proposed interaction of repetition and complexity fits qualitatively with aspects of everyday musical experience. A jazz recording, with chords and scales that are not fully familiar, might initially be too complex to be maximally rewarding to an untrained listener, but with repeated listens becomes increasingly comprehensible until it reaches the peak of the curve. A catchy pop tune, in contrast, may be instantly appealing due to its simple, familiar structure, but with repeated listens becomes annoying rather than enjoyable – it starts out at the peak of the curve, and repetition makes it more predictable than is optimal. An inverted U-shaped trajectory is also consistent with the finite shelf-life of hit songs. We do not listen to the same songs forever, but rather consume them for a time, eventually moving on, at least for the moment.

Introspectively, we know that a song we've tired of can become pleasing again following a delay, and experiments confirm this in some cases (Verveer, Barry & Bousfield, 1933). How this recovery relates to memory remains unclear, as we often have the impression of remembering the piece perfectly even following the delay. It may be that the sensory trace has decayed, rather than the abstract memory of the musical structure, allowing us to enjoy the piece even though we know it by heart. There are also cases in which music may be too complex for an unschooled listener to show much of an improvement in liking with repetition, as with highly avant-garde jazz (Hargreaves, 1984). Much remains to be studied about the representational changes that underlie these effects of exposure on preference.

The effect of complexity on preferences also interacts with the musical expertise of the listener. Experts (e.g. music graduate students) sometimes have a higher optimal complexity than novices (e.g. undergraduate non-music majors), at least when complexity is measured by the degree of deviation from the conventions of a musical idiom (Smith & Melara, 1990). This fits with the expectation that expert listeners have internalized musical conventions to a greater degree, such that the prototypical structure that is optimal for the untrained listener may strike them as overly simplistic. Other evidence indicates that expertise reduces the influence of complexity on preferences (Orr & Ohlsson, 2005), suggesting that other aesthetic factors become more important in people who have engaged in unusual amounts of focused listening and/or production. Such findings may relate to the differences that frequently exist between the music assessments of professional critics and lay listeners (North & Hargreaves, 1998).

Emotion

It has long been acknowledged that the emotional effects of music are central to its aesthetic value. Listeners report that the emotional content of music is one of the main reasons they listen to it, and they can typically identify the emotion that a piece of music was intended to convey (Fritz et al., 2009; Hevner, 1936). However, enjoyment of music is determined not by what emotion people judge it to be conveying, but rather by what they themselves experience when they listen to it. Enjoyment is maximal at moments of peak emotional arousal (Salimpoor, Benovoy, Longo et al., 2009), and listeners prefer pieces that induce emotion over those that do not (Schubert, 2010). Listeners in fact give low liking ratings to musical works when there is a large gap between what they deem it to be intending to convey and what they actually experience emotionally when they listen to it (Schubert, 2007). This likely corresponds to the common experience of hearing a piece of music that seems to be trying too hard to impart a particular feeling, and that comes across as inauthentic or “cheesy” as a result.

People often report enjoying happy music more than sad, other things being equal (Thompson, Schellenberg & Husain, 2001). Happiness in Western music is typically conveyed by fast tempos and major keys, which probably explains the general preference for fast tempos across age groups (LeBlanc, Colman, McCrary et al., 1988). That said, it is well known that people enjoy listening to sad music, especially if it is made familiar through repeated exposure (Ali & Peynircioglu, 2010; Schellenberg et al., 2008). Moreover, peak emotional experiences in music are more often produced by sad music than happy, as discussed below. The enjoyment of sad music is often viewed as paradoxical, though it is perhaps no more so than the fact that people also enjoy sad films.

The emotional effects of music give it important functions in our lives. For instance, listeners frequently report using music for mood regulation (Thayer, Newman & McClain, 1994; Phillips, 1999). In some contexts, listeners who are put in a bad mood beforehand are more prone to listen to energetic and joyful music than listeners who are put in a positive emotional state (Knobloch & Zillman, 2002). However, there is also evidence that people placed in a sad mood (e.g. by watching a documentary about the last letters written home by soldiers killed in battle) are initially drawn to sad music, particularly if they describe themselves as prone to ruminating on negative emotions (Chen, Zhou & Bryant, 2007). It seems likely that mood regulation is a domain with substantial individual differences, reflected in how people interact with music.

One striking feature of popular music is the preponderance of love-related lyrical themes, often of a mournful variety. The intuitive notion that the romantically rejected are drawn to music describing unrequited or lost love is in fact born out experimentally. When people are given the option of freely sampling different pieces of music, those who describe themselves as romantically discontented prefer to listen to mournful, love-lamenting music sung by members of the same gender, whereas people in satisfying relationships prefer to listen to music that celebrates love (Knobloch, Weisbach & Zillman, 2004; Knobloch & Zillman, 2003). This is thus another instance where people seek music that is congruent with their emotional state, rather than using music to alter it.

Personality

Music preferences also depend on and convey personality. Standard personality trait assessments correlate with the music a person likes: people ranking high in "sensation seeking" prefer intense and arousing music (rock, punk, rap, etc.) over less arousing music such as soundtracks (Little & Zuckerman, 1986; McNamara & Ballard, 1999), extroverts prefer music with enhanced bass (McCown, Keiser, Mulhearn, & Williamson, 1997) and that is energetic and rhythmic (Rentfrow & Gosling, 2003), and people who rank high in "openness" tend to like music labeled as reflective and complex (Rentfrow & Gosling, 2003). There are also gender differences: bass enhancement is more popular with men than women (McCown et al., 1997). Stereotypes about what types of people like different types of music thus have some empirical validity (Rentfrow & Gosling, 2007). They also influence our interactions. Undergraduates believe that their music preferences reveal as much about themselves as their hobbies (Rentfrow & Gosling, 2003). They talk about music more than other topics when getting to know another person, and can use a person's music preferences to form accurate impressions of their personality (Rentfrow & Gosling, 2006).

Pleasurable Moments in Music

Even for preferred recordings of music, the pleasure we derive from listening varies considerably over the course of the piece, and can be assessed with continuously obtained ratings during listening. These rating trajectories are highly reliable for individual listeners, with the temporal pattern for a particular piece replicating across multiple presentations (Madsen, Britten & Capperella-Sheldon, 1993). Consistency is sometimes seen across listeners as well, though it is also common for a piece to evoke peak pleasure responses in one listener while not in another. The variations in pleasure appear to be partly due to variations in felt emotion. Although the emotions associated with great pleasure can be muted and relaxed (Gabrielsson, 2001), peak pleasure often occurs at moments of peak emotional arousal (Salimpoor et al., 2009), and these have received the most study thus far.

The moments at which listeners experience a peak aesthetic and emotional response are typically brief, lasting on the order of a few seconds. Many listeners report experiencing "chills" during such moments of pleasure – palpable physical sensations of arousal, such as goose bumps (Goldstein, 1980; Panksepp, 1995; Sloboda, 1991). Although chills evoked in other contexts are not always pleasant (they can be produced by fear, for instance), in musical contexts, the arousal they signal is typically pleasurable. They are not a rare phenomenon, but not everyone experiences them. Studies with random samples of non-musicians indicate that perhaps half of the general population experiences chills (Goldstein, 1980; Grewe, Nagel, Kopiez, & Altenmüller, 2007), with the experience being more common among people closely involved with music, such as music degree students.

Chills have been of particular interest because they provide a timestamp for an emotional and aesthetic crescendo. They also provide an objective measure of the aesthetic experience, because of the associated physiological response – chills co-occur with peaks in measures of physiological arousal, such as galvanic skin response, heart rate, and respiration rate (Grewe, Kopiez & Altenmüller, 2009; Guhn, Hamm & Zentner, 2007; Rickard, 2004; Salimpoor et al., 2009). Consistent with a relation to musical enjoyment, chill-evoking music tends to be rated overall as aesthetically pleasing, and when people listen to such music, their reward pathways are activated (Blood & Zatorre, 2001). The response in the striatum (a key part of this pathway) covaries with the pleasure experienced during listening, and peaks during the experience of a chill, which is specifically accompanied by striatal dopamine release (Salimpoor et al., 2011).

What happens in music to cause these aesthetic peaks? There is consensus that most of the acoustical and musical correlates involve unexpected changes, be they to harmony, texture, pitch range, loudness, or the number of instruments or voices (Grewe et al., 2007; Guhn et al., 2007; Panksepp, 1995; Sloboda, 1991). Some such changes require implicit knowledge of musical "syntax" acquired through enculturation (e.g. to recognize that a chord is unexpected) but others involve basic acoustic variables like overall intensity, that could be detected at the earliest stages of the auditory system. Chills are more commonly evoked by sad or nostalgic music than happy (Panksepp, 1995), and by slow movements than fast, but the moments when they are induced are distinct from those that elicit tears, which are presumably less related to high arousal (Sloboda, 1991).

Although they often occur at moments where something unpredictable happens, the incidence of chills increases with exposure to a piece of music, at least for moderate amounts of exposure, as though learning the musical structure helps the listener recognize the critical chill-evoking deviations (Sloboda, 1991). These findings underscore the importance and paradoxical nature of expectation in our experience of music (Huron, 2006; Meyer, 1961; Narmour, 1990). Our aesthetic response seems to hinge on violations of the expectations induced by our knowledge of musical rules, yet repeated exposure enhances the response. It is as though the aesthetic response is driven by something that lacks direct access to our explicit memory (because the response to the expectation violation is enhanced even though consciously we know in advance what will happen), but that benefits from the enhanced structural representations attained from repeated exposure.

Open Issues in Music Aesthetics

The literature reviewed here reveals that many influences on our musical preferences can be verified and studied scientifically. However, science has yet to broach a number of the most intriguing aspects of musical aesthetics. For instance, we still know little about what sets a great recording apart from one that is merely good or passably competent. Beauty is to some extent in the eye of the beholder, and individuals certainly differ in their tastes. But within a culture and genre, there is often considerable agreement on what is great, embodied in the observation that nearly everyone likes "Kind of Blue," "Abbey Road," or "Songs in the Key of Life." Professional critics are not as correlated in their ratings of music as are individuals rating vocal (Zuckerman & Driver, 1989) or facial (Cunningham, Roberts, Barbee et al., 1995) attractiveness, but the correlations are still substantial (Lundy, 2010): ~0.5 for music versus ~0.9 for faces/voices.

Moreover, although music consumption, and critical assessments, are clearly affected by social influence (observations of what others choose to listen to), they are also constrained by the extremes of musical quality. When download choices in an artificial online music market were monitored in the presence of social influence, the very best songs (as measured via download choices in the absence of social influence) usually did well, and the very worst songs usually did poorly, even though the popularity of most other recordings was unpredictable (due to the instability that seems inherent to complex marketplace interactions) (Salganik, Dodds & Watts, 2006). Quality, at least as reflected in what people like, is thus measurable, and matters.

What, then, underlies the quality of exceptional works of music liked or loved by nearly everyone within a cultural group? Some of the factors reviewed earlier, namely complexity and unpredictability, are surely part of intrinsic aesthetic quality. But can they explain what differentiates Mozart or Bob Dylan from their peers? It is often said that great pieces of music strike a balance between originality and conformity to the rules of a genre, which sounds a lot like the peak of Berlyne's inverted U-shaped curve. But for this to be more than a vague intuition, we have to understand the relevant measure of complexity or predictability, and at present we lack such a formulation for realistic musical structure.

Apart from songwriting and composition, there are elusive variables that determine whether a particular recording of a composition turns out great rather than terrible. To realize how critical such factors can be, one has only to endure Britney Spears' cover of the Rolling Stones "Satisfaction," or to compare Otis Redding's competent but not quite spectacular version of "Respect" to Aretha Franklin's definitive rendition. These recordings are based on the same score, but the choices made in the recording studio, from the instrumental and vocal arrangement to the levels in the mix, make a vast difference in whether we are enchanted or unmoved by the result. Powerful perceptual and cognitive principles are at work, and represent important targets for future research.

CONCLUSIONS

Sounds can make us sigh in contentment, spend our time and money, or cringe in pain. We have reviewed some of the factors that cause us to react to sounds with pleasure or disgust. Some aspects of our auditory preferences can be explained by relatively simple acoustic properties, such as sharpness, roughness, or harmonicity. These preferences in some cases were likely shaped by evolution to help us avoid danger or select quality mates. Others may simply be flukes of the auditory system. Context matters, as does experience – we like things we have heard before. Music preferences additionally involve the interaction of personality traits and emotional content, aesthetic principles such as optimal complexity, and physiologically realized episodes of peak emotional arousal. Important aspects of musical aesthetics remain for the moment impenetrable, but they represent powerful effects that scientists will hopefully attempt to understand as experimental aesthetics proceeds in the coming decades.

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