Chapter 16

Effects of expertise on the cognitive and neural processes involved in musical appreciation

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16.1 Introduction

There is relatively little empirical research that specifically addresses the question of expertise effects on musical appreciation but an anecdote will serve to make the importance of the issue clear. Recently, I attended a concert with a friend and, afterwards, discussing the performance, mentioned that I had found the timing a little erratic. My companion replied, “Well, I’m no expert but I enjoyed the concert!” Is musical training or expertise important for the appreciation of music? Or can anyone appreciate music? Does it depend on the type of music? If training is important, which aspects are crucial? Which components of aesthetic experience do those aspects of training affect? These questions have deep implications for the importance of musical training and experience in education and development of artistic appreciation. The goal of this chapter is to establish a framework for generating and testing hypotheses about the effects of musical expertise on the appreciation of music.

Before we embark, it’s worth pausing to consider a few important methodological points (see Schellenberg 2006). The vast majority of psychological and neuroscientific research on the effects of musical training has taken a cross-sectional approach by comparing musicians and non-musicians on some particular measure. However, this does not demonstrate a *causal* effect of musical training since it cannot be known whether the measure in question differed between the groups before commencement of musical training (it may even have influenced the initiation and maintenance of musical training leading to expertise). Second, it is difficult to know how specific the effect is to musical training per se unless a control group of experts in another domain are also studied (e.g. Dick et al. 2011; Schellenberg 2004), which is rare in the literature. Third, there are many demographic factors (e.g. socio-economic status) that ~~are~~ correlate~~d~~ with musical education, so it is difficult to isolate any effects ~~to~~ musical training unless control groups matched for these factors are included (usually they are not). With those caveats in mind, we begin our enquiry by locating music and musical expertise in more precise terms.

16.2 What is music?

Music is a complex phenomenon that belies definition, leading Edgard Varèse to describe his own compositions very generally as *organized sound* (Varèse and Wen-chung 1966). Virtually omnipresent across cultures, music consists of patterns of human-initiated sound[1] extended in time, sometimes associated with visual displays, and used in a bewildering variety of contexts for an enormous range of purposes.

We might have more success if we follow a cognitive-scientific approach and attempt to pin down the ways in which a musical object may be instantiated in different kinds of representation. Music can be represented in at least three ways (see Babbitt 1965):

1 physically, as an acoustic phenomenon (traditionally resulting from human movement);
2 in symbolic encodings usually designed for recording compositions and giving directions for their performance (e.g. scores, vocal representations, piano-roll representations in sequencers and other software);
3 in various kinds of cognitive and neural representation (e.g. procedural memory, perceptual, and cognitive representations).

Representations of music may vary across multiple dimensions: pitch, timbre, timing, duration, loudness, spatial location, and other more complex characteristics relating to harmonic movement, metrical structure, and overall form. In trying to identify "objective" properties of musical sounds, one quickly finds oneself moving from the acoustic domain, represented by the first category above, into the psychological domain, represented by the third category.[2] Meter, for example, has no well-defined interpretation as an objective property of sounds, without a (cognitive) model to interpret metrical structure from those sounds.

Nonetheless, this characterization of music is useful for our present purposes since it allows us to identify different kinds of expertise afforded by the phenomenon of music. A given individual might not have expertise in all three domains: a piano tuner, for example, is an expert primarily in the acoustic domain while a medieval scribe would have been an expert in the symbolic domain of music notation. However, it is difficult to distinguish music from non-music unless one considers the psychological domain, which is the proper place to start investigating musical appreciation. In fact, both the piano tuner and the scribe, as listeners, also have a psychological experience of sound and surely draw on that experience in plying their different trades. Later, we will be interested in the relationship between sound as an acoustic phenomenon and music as a psychological phenomenon experienced by a listener. As a psychological phenomenon, music involves a communicative process in which an audience receives, cognitively/neurally represents, and processes sensory input (whether from acoustic or visual input or both) and appreciates it *as music*. We might argue that organized sound only becomes music when it is psychologically represented as such by a listener.

Musical communication typically involves a composer, a performer, and a listener (Kendall and Carterette 1990), who may be different individuals or groups depending on the

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situation (e.g. in improvisation the distinction between the composer and performer is blurred; a performer can be his or her own audience). Individuals may develop expertise in any or all of these areas: one may be an expert in composition, improvisation, conducting, performance, listening (e.g. as a critic, analyst, theorist, producer, DJ), among other things. Within each of these areas expertise may relate to different compositional tools, instruments, musical genres, symbolic encodings, and so on.

16.3 Frameworks for understanding expertise~~?~~

If music itself is a slippery concept to define, then *musical expertise* is even more so.

A long tradition of research in cognitive science and artificial intelligence focuses on the study of *experts* in various domains (e.g. board games, science, medicine, the arts, sport) (Ericsson 2006). This research has tended to characterize expertise as unusually high performance in specialized skills, acquired over many years of focused training and deliberate practice. Feltovich, Prietula, and Ericsson (2006) identify the following generalizable characteristics of expertise:

(1) limited in scope and non-transferable;
(2) comprises a large amount of knowledge;
(3) features larger and more integrated cognitive units;
(4) exhibits functional, abstracted representations of presented information;
(5) automation of basic strokes or movements;
(6) shows selective access to relevant information;
(7) includes an ability to reflect consciously on the expert domain;
(8) comprises efficient and effective adaptation to the task;
(9) requires more than simple experience for its development.

Many of these can be found in musical experts (Lehmann and Gruber 2006). One prediction that can be made is that the effects of musical expertise should be limited in scope and non-transferable to other domains and items 5–9 are likely to be characteristic of expertise in music performance. However, items 3 and 4 are especially relevant to perception and appreciation, since they concern cognitive representations rather than the generation of expert performance. On this basis, we might hypothesize that musical experts re-present music to themselves:

(1) in larger chunks or longer-lasting excerpts, both in short-term memory, but also to facilitate efficient retrieval from long-term memory;
(2) as deep, abstract, generalized structures, suited to functional transfer across musical situations, rather than surface characteristics of the music.

These hypotheses are partially congruent with research on *perceptual expertise* (either pre-existing or trained), primarily using visual discrimination paradigms (Bukach et al. 2006). First, experts show *holistic processing* of visual images; for example, *the* *inversion effect* describes the observation that experts show impaired recognition of vertical inversions of objects taken from the expert domain (Rossion and Curran 2010). Second, experts have stronger *relational processing* in which spatial relations between the component parts are encoded to a greater extent than non-experts (Gauthier and Tarr 2002; Gauthier et al. 1998). These imply a global kind of *configural* processing, which is compatible with larger chunk sizes of information and abstract representations. However, this research also finds evidence for more detailed representation of the stimulus. For example, *the entry-level shift*, where expertise leads to faster discrimination responses to differences at specific levels of detail than more general levels of detail. According to the expertise hypothesis, general-purpose brain regions become specialized for objects of expertise indexed by neural responses such as the N170 (Hole 1994) and blood oxygen-level-dependent (BOLD) responses in the inferior temporal cortex (Gauthier et al. 2000). It is worth noting that there is considerable controversy about this hypothesis (Robbins and McKone 2007).

Can these approaches be generalized to musical expertise? If so, we might look for the following attributes in musicians:

(1) musical representations present in larger chunks than in non-experts;

(2) abstract, generalized representations (holistic processing);

(3) greater sensitivity to relations between musical structures;

(4) greater sensitivity to more specific levels of detail in musical structure.

The last item might seem paradoxical in combination with the first three items. However, if we allow for multiple levels of cognitive representation (Marr 1982; McClamrock 1991) there is no reason why expertise should not lead to both more abstract and more detailed representations. We return to these hypothesized effects below.

16.4 Musical expertise

It is important to distinguish musical *training* from musical *expertise*, since one can exist without the other. Musical training, like any form of training, does not always lead to expertise. Less obviously, expertise can sometimes be attained without explicit, formal training (Sloboda 1991). Musical training might refer to a number of different things depending on the kind of expertise targeted and reflecting the fact that, as we have seen, musical practice involves a diverse range of skills, each of which might be emphasized to different degrees in any one programme of training. However, in contemporary Western cultures, the primary goal of musical training is usually to attain a high level of performance in playing a musical instrument, which may be the voice itself. In some cases, this is combined with training in other art forms such as dance, theater, and so on. Because training is easier to quantify than expertise, in much of the research performed to date, questions about the effects of expertise in musicianship are often reduced to questions about the effects of musical training. Furthermore, training is often quantified in terms of number of years of formal lessons but this may not be a good proxy for the extent of actual practice. Even when hours of practice are assessed, the effects of practice on expertise may vary depending on the individual concerned and the nature of the practice.

It is remarkable how much implicit understanding of music can be acquired merely through exposure without the need for explicit musical training. Indeed, research has shown non-musicians to possess sophistication in such a wide range of abilities related to musical perception that they have been characterized as "musically experienced listeners" (Bigand and Poulin-Charronnat 2006). Sloboda (1991) goes further, characterizing musical expertise itself as an emotional sensitivity to the music of a given culture possessed by many (or perhaps, most) individuals within a culture. According to Sloboda, this sensitivity depends on:

(1) the existence in a culture of forms that have perceptible structures of certain kinds;

(2) frequent informal exposure to examples of these forms over a lifetime;

(3) the existence of a normal range of human emotional responses;

(4) the opportunity to experience those emotions mediated through perceived musical structures, which itself requires

(5) the opportunity to experience music in contexts free of externally imposed constraints or negative reinforcements.

We might start our enquiry, therefore, by investigating whether musical training has any effect at all on the different components of this conception of musical expertise as emotional sensitivity. Taking a slightly broader perspective than Sloboda (1991) (and combining the related points 4 and 5 above), this entails asking the following four questions:

(1) Are there effects of musical training on the perception and cognition of musical structure, separable from mere exposure?

(2) Are there effects of musical training on the frequency of informal exposure to music?

(3) Are there effects of musical training on the experience of human emotion?

(4) Are there effects of musical training on the emotional and aesthetic experience of music?

These questions will be addressed in the following sections.

16.5 Expertise effects on perception and cognition of musical structure

The most striking features of musical expertise are the perceptual motor skills necessary to physically perform highly complex sequences of actions on a musical instrument. For example, in highly trained musicians, we ~~see observable effects on~~ the anatomical regions of motor cortex responsible for controlling the relevant effectors (e.g. the left hand for violinists, Amunts et al. 1997; Bangert and Schlaug 2006). Furthermore, there is some evidence that a sensitive period exists, prior to the age of seven, during which musical training has particularly marked effects on behavioral and neural markers of auditory and motor development (Penhune 2011).

What about perceptual skills? Based on the literature on expertise, we might predict that musical training would lead to more abstract representation of music, with larger chunks of musical material held in memory and greater integration between the component parts. To address this question, researchers have studied the aesthetic judgment of musicians and non-musicians for pieces of music in which the large-scale tonal form has been disrupted by rearranging or rewriting certain parts. The results consistently suggest that musicians are no more affected than non-musicians by these disruptions (Cook 1987; Karno and Konecni 1992; Marvin and Brinkman 1999), suggesting that both rely more on local representation than on high-level, integrated representations of large-scale tonal closure.

At the other end of the scale, it seems likely that extensive periods of time spent in focused listening to music would sharpen auditory perception. There is evidence suggesting that this is the case. Professional musicians show smaller pitch discrimination thresholds for pure and complex tones than non-musicians (Micheyl et al. 2006). These effects may increase with number of years of musical training (Kishon-Rabin et al. 2001) and there is some evidence that pitch discrimination is better in musicians who habitually tune their instruments (Micheyl et al. 2006). Musicians are also better than non-musicians at discriminating temporal intervals (Banai et al. 2012) as well as a range of other auditory temporal tasks (Rammsayer and Altenmüller 2006).

These effects suggest that musical training has a positive influence on the efficiency with which sounds are encoded: musicians show optimized perception and discrimination of pitch and timbre, in some cases related specifically to their particular instrument. How do these effects of musical training on low-level auditory processing influence the higher-level cognitive processing of music? In processing rhythm and meter, for example, there is evidence that musicians represent deeper metrical hierarchies than non-musicians (Palmer and Krumhansl 1990). Musicians are sensitive to a greater range of features (e.g. slurs, rests, articulation, and timbre) in identifying grouping boundaries in music (Delige 1987). This presumably allows musicians to make finer-grained distinctions in their interpretations of metrical and grouping structure, facilitating temporal prediction of events. More predictable music in turn is better remembered (Agres et al. 2013; Schmuckler 1997), and evidence suggests that, musicians show better recognition memory for melodies than non-musicians (Dowling and Bartlett 1981; Dowling 1978; Orsmond and Miller 1999), perhaps because they have more accurate predictive models.

Research directly examining predictive processing of music is relevant here. General theories of sensory processing in cognitive science and cognitive neuroscience include top-down prediction as a central component in constructing coherent representations of incoming sensory input (Barlow 1959; Dayan et al. 1995; Friston 2005; Gregory 1980; Helmholtz 1866). Recent incarnations of this approach take a probabilistic approach in a hierarchical framework where information is processed over successively larger time windows at higher scales in the hierarchy (Friston 2005; Friston and Kiebel 2009). According to this theory of perception, learning is driven by *prediction errors*, occurring when bottom-up sensory input conflicts with top-down prediction. Therefore, violations of expectation are of central importance in understanding how the brain constructs optimized models of sensory input through experience. If musical training optimizes those top-down predictive models, then we should observe differences between experts and non-experts in terms of prediction error.

Recent research suggests that expectations in music are acquired through a process of statistical learning in which listeners construct implicit probabilistic models of the next element in a musical sequence given the preceding context both at the psychological (Huron 2006; Meyer 1957; Oram and Cuddy 1995; Pearce and Wiggins 2006; Tillmann et al. 2000) and neural levels (Kim et al. 2011; Loui et al. 2009; Pearce et al. 2010). The majority of behavioral research on expectation in music perception has found that the expectations of non-musicians look very similar to those of musicians (Bigand et al. 2003; Schellenberg 1996), although some research has identified differences (Pearce et al. 2010). However, neuroscientific studies on musical expectations, using electroencephalography (EEG) and ~~magnetencephalophraphy~~ (MEG), have revealed differences in neural responses of experts and non-experts to violations of musical expectation (i.e. prediction errors).

Research introducing low-probability auditory events in simple melodic tone sequences has found larger event-related potentials (ERPs) in auditory cortical regions for musicians compared to non-musicians. In an MEG study, for example, Fujioka, Trainor, Ross, Kakigi, and Pantev (2004) examined neural responses to notes forming deviant contours or intervals in short five-note melodies, finding that the mismatch negativity (MMN) response was significantly larger in musicians than non-musicians for both interval and contour deviants, while no difference was observed for a pitch-deviant control condition. There is also evidence that instrument-specific musical training affects sensitivity to timbre. Pantev, Roberts, Schulz, Engelien, and Ross (2001) presented trumpeters and violinists with oddball sequences reproduced on the trumpet or the violin during EEG recording. The results indicated a larger N1 response to the oddball presented in the timbre of their own instrument. In addition to instrument-specific differences in neural processing of prediction errors, additional research has shown style-specific differences between jazz, classical, or pop musicians processing deviants in terms of pitch mistuning, intensity, timbre, sound-source location, rhythm, and pitch slide (Vuust et al. 2012).

Effects of musical training are also observed for violations of temporal expectations. In an MEG study, jazz musicians showed a left-lateralized MMN to violations of metrical expectation, while in non-musicians the response was right-lateralized (Vuust et al. 2005). Using elegantly manipulated drum patterns, Geiser, Sandmann, Jäncke, and Meyer (2010) examined the MMN to meter-congruent and meter-incongruent deviants. Trained percussionists showed a greater difference in MMN amplitude between these conditions than non-musicians, suggesting a greater sensitivity to violations of metrical structure.

Related effects of musical training have been found in neural processing of harmonic movement. Stylistically unexpected chords generate characteristic neural responses, including an early right anterior negativity (ERAN) peaking at around 180 ms post-stimulus (Koelsch et al. 2000). Furthermore, the ERAN has been observed both in artificial grammars (Loui et al. 2009) and in real musical examples (Koelsch et al. 2008; Steinbeis et al.

2006). Although the ERAN is present in non-musicians, it has a greater amplitude in trained musicians (Koelsch et al. 2002).

It seems, then, that musicians show larger neural prediction errors to violations of musical syntax. One plausible explanation is that musical training produces more specific, and more accurate, expectations for forthcoming musical structures, resulting from an optimized predictive model. Recent research has examined this question using a probabilistic cognitive model of auditory expectation which acquires pitch expectations through statistical learning of sequential dependencies in music (Pearce 2005). The trained model generates a probability distribution, whose *entropy* reflects how uncertain the model is about the continuation of the current context, and whose components reflect the likelihood of each possible continuation, given the preceding context, in terms of *information content* (MacKay 2003). Using this model to select melodic contexts that differ systematically in entropy, Hansen and Pearce (2014) found that musicians showed lower levels of uncertainty overall but also were better able to distinguish high- and low-entropy contexts than non-musicians. In particular, the musicians were able to make better use of the predictive cues in low-entropy contexts to generate more accurate expectations and showed greater prediction errors to low-probability continuations in those contexts. Furthermore, the degree to which listeners' expectations matched those of the probabilistic model increased linearly with extent of musical training.

These results suggest that musical training can lead to optimized predictive models of musical structure. However, the question arises of whether the crucial factor is musical training per se, or style-specific training and experience. In a follow-up study, Hansen et al. (2013) examined predictive uncertainty for contexts taken from solos by Charlie Parker in professional jazz and classical musicians as well as non-musicians. The results suggest that the predictive advantage in low-entropy contexts, shown by greater prediction errors to low-probability continuations, is greater for jazz musicians than classical musicians, although both groups outperform non-musicians. While style-specific training and experience appears to be important, the question of whether these effects are driven by experience or training remains unanswered.

16.6 Expertise effects on frequency of exposure to music

As in other domains, expertise in music requires enormous amounts of time spent in deliberate practice. In fact, hours of deliberate practice is a significant predictor of level of expertise attained (Sloboda et al. 1996). However, it is highly likely that musicians listen to more music throughout their lives than non-musicians, through individual practice, group practice, critical listening to music, concert attendance, and other activities. Perhaps more importantly, they experience music in more focused and, crucially, more emotionally charged situations than non-musicians. Might this more focused and emotionally engaged exposure, rather than explicit training per se, have any effect on musical appreciation?

We know that exposure to music (as with other sensory stimuli) has a strong influence on its perception and appreciation. For example, passive exposure to music appears to be fundamental in the development of metrical perception (Hannon and Trehub 2005; Hannon et al. 2012) and increasing exposure to and familiarity with a stimulus (e.g. a musical style) increases subjective preference for it (Bornstein and D'Agostino 1992). The effect of mere exposure on aesthetic experience may, according to one theory (Huron 2006; Reber et al. 1998), be directly related to the predictive processing discussed in the previous section if pleasure results from the perceptual fluency (facilitated processing and reduced cognitive load) associated with more accurate predictive models (acquired through exposure and familiarity). As noted earlier, there is a thorny methodological problem in distinguishing the effects of explicit musical training from the effects of increased exposure, since musicians are likely to spend more time listening to music than non-musicians. Furthermore, musicians are more likely to engage in focused listening to music and we know that the efficiency of statistical learning is affected by attentional mechanisms (Toro et al. 2005).

At this stage, therefore, it is at least plausible that the greater amount of time musicians spend in focused listening to music, in combination with the effects of musical training per se, leads to more accurate predictive models which, in turn, may impact on aesthetic experience through increased perceptual fluency (we return to this point later).

16.7 Expertise effects on emotional experience

Our third question is whether musical training affects the general experience of emotion. In a study of schoolchildren, Schellenberg (2004) found that 36 weeks of weekly music lessons increased ability in full-scale IQ and its index scores (Verbal comprehension, Perceptual organization, Freedom from distractability, Processing speed) more than did taking equivalent lessons in drama. However, subsequent studies have shown that musical training does not affect emotional intelligence in adults (Schellenberg 2011) or emotion comprehension in children (Schellenberg and Mankarious 2012).

There is evidence that musicians and 7-year-old children randomly assigned to one year of musical training show better emotion recognition for speech prosody (Thompson et al. 2004) and that this persists even when groups are matched for cognitive ability (Lima and Castro 2011). However, it is important to distinguish between the experience of emotion and the perception or recognition of emotion in a stimulus such as language or music (Juslin and Västfjäll 2008). These findings do not necessarily indicate a difference in the experience of emotion itself, only a better ability to recognize emotion in speech prosody. Therefore, there is no evidence to suggest that musicians differ from non-musicians in terms of their experience of emotion as a result of their musical training (although this does have other effects on general cognitive abilities).

16.8 Expertise effects on emotional and aesthetic experience of music

If emotional experiences of music depend on understanding of high-level musical structure, then we would expect any effects of musical training on musical perception and cognition to have concomitant effects on the emotional experience of music. Again, it is important here to distinguish the recognition of emotion *in* music from the induction of emotion *by* music (Juslin and Västfjäll 2008). Regarding the effects of musical training, the majority of research has addressed emotion recognition in Western instrumental music. In general, the evidence suggests that musical training has very little effect on the perception of emotion in music in adults (Bigand et al. 2005; Edmonston 1966; Hevner 1935; Robazza et al. 1994; Waterman 1996) or children (Robazza et al. 1994; Terwogt and Van Grinsven 1991). Even the training-related differences in the perception of emotion in speech prosody discussed earlier are weaker or absent when tone sequences mimicking speech prosody are used (Thompson et al. 2004; Trimmer and Cuddy 2008).

There is, however, evidence to suggest that musicians may make less use of emotion in making aesthetic judgments of music. In an ERP study of responses to chord sequences in which the final chord varied in terms of its harmonic congruency with the context, Müller, Höfel, Brattico, and Jacobsen (2010) found enhanced emotion-related neural processing (the late positive potential (LPP); Hajcak et al. 2006) for beauty judgments compared with judgments about how correct each chord sequence sounded in non-musicians but not in musicians. It is possible that musicians make less use of emotion and rely on other factors in making aesthetic judgments of music.

What might these factors be? Scientific theories of aesthetic experience emphasize a number of different cognitive components involved (Brattico and Pearce 2013; Leder et al. 2004; Leder 2013) in addition to emotional experience. These range from basic perceptual processing, through effects of attention, memory, knowledge, and judgment. Perhaps the most studied of these are aesthetic judgments for liking, pleasantness, or preference. Here we examine two potential factors affecting aesthetic judgment: musical complexity and dissonance.

16.9 Complexity

Wilhelm Wundt, a founder of experimental psychology and one-time assistant of Hermann Helmholtz in Heidelberg, demonstrated that physiological arousal is related to stimulus complexity and argued that aesthetic pleasure is maximal at intermediate degrees of complexity (Wundt 1874). In his new experimental aesthetics, Berlyne (1974) developed this idea further, positing an inverted U-shaped function (sometimes called the Wundt curve) linking the "arousal potential" of a stimulus with its "hedonic value." Berlyne's research attempted to identify how stimulus properties (such as complexity, familiarity, novelty, uncertainty) influence aspects of the aesthetic experience such as arousal, pleasure, and level of interest.

Support for a U-shaped relationship between complexity and liking has been found in artificial auditory stimuli (Crozier 1974; Heyduk 1975; ~~Vit~~ 1966) and in musical styles ranging from baroque, romantic, and serial (Burke and Gridley 1990), jazz (Gordon and Gridley 2013), bluegrass (Orr and Ohlsson 2001), and pop (North and Hargreaves 1995). If musical expertise facilitates more sophisticated cognitive representations of music, then we would predict that musical training would shift the U-shaped function towards optimal preference for greater degrees of objective stimulus complexity. Importantly, this prediction hinges on an objective definition of complexity. With changes of expertise or familiarity, we would expect the relationship between objective and subjective complexity to change, while the relationship between subjective complexity and liking remains constant (with moderate degrees of subjective complexity producing optimal liking; see Orr and Ohlsson 2005).

There is some evidence that this effect of expertise on the relationship between objective complexity and aesthetic experience does, in fact, hold. Rubin-Rabson (1940) reported a positive correlation between degree of musical training and liking for "modern" music. In an investigation of preferences for world music, Fung (1996) found that musicians preferred excerpts with very complex texture, whereas non-musicians preferred moderately complex textures. Burke and Gridley (1990) showed that musically trained individuals exhibit greater relative preference for complex musical works (by Debussy and Boulez) over less complex compositions (by Bach, Grieg) than non-musicians. In a verbal association task, Istok and colleagues (2009) found that musicians used more adjectives related to originality and variety, and fewer terms related to mood or mood induction, than non-musicians, to describe the aesthetic value of music. These results are somewhat difficult to interpret since the verbal responses may reflect cultural or professional norms related to expertise rather than psychological experience per se.

Other research has empirically tested the effects of expertise on the inverted-U shaped relationship in music more directly. North and Hargreaves (1995), for example, examined excerpts of popular music, finding that the inverted-U relationship between liking and subjective complexity peaked at a slightly lower complexity level for non-musicians than for individuals with intermediate or high levels of musical training. The relationship between complexity, preference, and expertise may even reflect more specific effects of stylistic musical training. Using a paradigm developed in research on music education, Coggiola (2004) examined preferences for four jazz tunes varying in complexity (as defined by the experimenter) by jazz musicians studying at university. The ratings of the two groups differed only for the most complex music, for which the jazz musicians reported stronger aesthetic experience than non-jazz musicians.

Other results apparently contradict this overall picture. Using specially composed jazz and bluegrass improvisations, Orr and Ohlsson (2001) found an inverted-U shaped relationship between subjective complexity and liking in non-musicians for bluegrass but weaker support for the jazz excerpts. In a subsequent study, Orr and Ohlsson (2005) asked professional jazz and bluegrass musicians to rate their liking for short jazz and bluegrass compositions. Comparing the responses of the musicians with non-musicians from an earlier study (Orr and Ohlsson 2001), the results suggested that musical training dissolves the U-shaped relationship between complexity and liking. This may be because experts focus on different aspects of musical structure, such as harmony (Conley 1981), when making complexity judgments. It is also likely that other factors besides complexity, such as expressive performance (Clarke 1993; Repp 1992) play a greater role in experts' aesthetic experience of music.

Running through this work is the problem of obtaining a broad enough range of objective complexity to observe the complete inverted-U shaped function. In most of these studies, complexity is defined subjectively, either by the experimenter or by the participants in the studies. Therefore, we lack insight into which aspects of musical structure contribute to the perception of complexity and, therefore, liking. One way of avoiding this problem is to bypass the complexities of real music and isolate the structures of interest with objective measures of complexity. A successful approach has been to create stimuli that systematically vary in information content (an objective information-theoretic measure of complexity). Research on the pleasantness of artificial tone sequences (Crozier 1974; Vitz 1966) and piano themes (Simon and Wohlwill 1968) suggests that individuals with musical training show greater preferences for more complex stimuli than non-musicians. Smith and Melara (1990) assessed aesthetic responses to harmonic progressions (sequences of chords) varying in degree of syntactic prototypicality to test the hypothesis that unpredictable musical events are experienced as pleasant. The results indicated that all subjects (even novices) found atypical progressions more interesting/complex but non-musicians and undergraduate musicians preferred harmonic prototypes, while only music graduate students preferred atypical progressions.

16.10 Dissonance

Another aspect of the acoustic structure of music that contributes to aesthetic experience (Brattico and Pearce 2013) is dissonance. Here, however, the evidence suggests that expertise sharpens the perception of dissonance and accentuates its negative effect on liking. For example, Bigand, Parncutt, and Lerdahl (1996) found the greater tension-inducing effect of dissonant chords over consonant chords was more pronounced in musicians than in non-musicians. Other research has examined the pleasantness of melodic and harmonic intervals varying in dissonance, finding that musicians distinguish perfect consonance, imperfect consonance, and dissonance to a greater extent than non-musicians who tend to classify all intervals as moderately pleasant (Schön et al. 2005). Similarly, dissonant chords are experienced as more unpleasant and minor chords as more sad by musicians than by non-musicians (Pallesen et al. 2005), although fMRI showed no group differences in neural processing.

Effects of musical expertise on responses to dissonance have also been found in physiological data. Dellacherie, Roy, Hugueville, Peretz, and Samson (2011) found that dissonant piano music induces more unpleasant feelings (valence) and stronger physiological responses (skin conductance responses (SCR) and zygomatic EMG) in musicians than in non-musicians, while musical training was a good predictor of valence. The conclusion that musical training reinforces the aversion to dissonance is supported by EEG and MEG research. Brattico and colleagues (2009) report that the MMN response to dissonant and mistuned chords presented in the context of major chords is stronger for musicians than non-musicians (and this varies as a function of degree of musical training), while no difference is observed in the response to minor chords in the same context. Schön and colleagues (2005) also report qualitative differences between musicians and non-musicians in terms of neural processing of harmonic intervals varying in dissonance.

These studies have focused on musical dissonances rather than sensory dissonance per se. Because musically dissonant intervals are used (less frequently than consonant intervals) in the music that people listen to, these studies cannot discount the possibility that the effects are related to top-down cognitively-driven expectations rather than bottom-up sensory dissonance. However, this is unlikely to be the case for the mistuned chords used by Brattico and ~~his~~ research team (2009). Furthermore, at least one study has found that the effects of chord dissonance (an augmented triad) on ERPs is clearly distinguished from the top-down cognitive effects of harmonic function discussed above (Regnault et al. 2001).

16.11 Conclusion

Drawing inspiration from Sloboda's (1991) definition of musical expertise as an emotional sensitivity to the music of a given culture, we have examined whether musical training affects aesthetic sensitivity to music. Contrary to predictions from the general literature on expertise, there is little evidence that musicians have more abstract representations of music, storing larger, more integrated chunks of music in memory, than non-musicians. There is also little evidence for any effects of musical training on emotional experience in general or on emotion recognition in music per se. However, there is evidence that musical training leads to sharpened perceptual representation and processing and, in particular, the optimization of predictive models of musical structure. Importantly, much of the evidence for more accurate predictive models of musical structure in musicians comes from EEG and MEG studies, whose temporal precision allows detailed analysis of responses to individual musical events. Given that musicians are likely to spend significantly more time in focused listening to music than non-musicians, it is unclear whether this is an effect of music training per se or simply increased musical exposure.

What appears to be clear, however, is that musicians do tend to find pleasure in more complex music than non-musicians (at least in some circumstances), consistent with a Wundt curve shifted to greater levels of objective complexity. It is noteworthy that this effect of expertise on aesthetic experience occurs without any changes to emotional experience of music. It is tempting to associate this preference for increased complexity with the findings of more accurate predictive models, although robust, empirical evidence has yet to be developed. Somewhat paradoxically, it seems that musicians show greater sensitivity to dissonance in their aesthetic judgments than non-musicians. This enhanced sensitivity to perceptual qualities runs counter to a suggestion that experts might make greater use of knowledge-based criteria and less use of perceptual criteria than non-experts in their aesthetic judgments (Juslin 2013). It is, however, somewhat reminiscent of research in which visual experts show both greater configural processing and sensitivity to finer levels of detail than non-experts.

One potential solution to this apparent paradox might be to suggest that dissonance introduces uncertainty that cannot be resolved through greater experience and training while other aspects of objective complexity (e.g. harmonic syntax, metrical sophistication) can be rendered more certain with more accurate predictive models derived through experience and training. However, this would not explain why non-musicians appear to be less sensitive to dissonance than musicians. Another possibility, therefore, is that musicians have more accurate predictive models of musical consonance and dissonance and, as a result, generate greater prediction errors to dissonant tones and intervals. This would be consistent with their preference for greater complexity resulting from more accurate predictive models.

There is clearly much work to be done. It is fundamental to link the development of accurate predictive models during musical training specifically to changes in aesthetic experience of music. Do differences in predictive uncertainty underlie the differential effects of training on different aspects of complexity (e.g. dissonance versus melodic complexity)? How can we develop more general predictive computational models of musical structure that integrate melodic, harmonic, rhythmic, and timbral structure? It is puzzling that musicians fail to show greater sensitivity to high-level tonal form, but perhaps we are asking the question in the wrong way; it is possible that neurophysiological recording might prove more suitable to the task. Finally, the framework predicts that effects of training on predictive coding and aesthetic experience should be experience-specific, therefore we predict limited transfer between areas of musical expertise and to other domains. As already noted, this is consistent with general findings in expertise research (Feltovich et al. 2006).

We have developed a framework for understanding the effects of expertise on aesthetic appreciation of music, facilitating hypothesis generation. Testing these hypotheses is likely to require a sophisticated combination of psychological study, computational modeling, and neuroimaging in which great care is taken to distinguish the causes and effects of musical training and distinguish these from general training effects and other factors that covary with musical training.

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Notes

1 Or, *pace* John Cage, in at least one case, it is absence, although notice here that the absence is still human-produced and extended for a prescribed period of time.

2 Note that Babbit (1965) uses different terms to describe the three kinds of representation.

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Chapter 16

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