Music as a transformative technology of the mind

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Introduction: What is the evolutionary status of music?

In the past decade there has been an explosion of research on music and the brain. One consequence has been the renewal of old questions about the evolutionary origins of music. In *The Descent of Man*, Darwin (1871) remarked that since music is ubiquitous in human culture but serves no obvious biological adaptive function "our musical abilities must be ranked among the most mysterious with which [humans are] endowed". In recent years some have argued that musical abilities arose as an evolutionary adaptation for life in our hunter-gatherer past (for example, in promoting social cohesion, Dunbar, 2003; cf. Trehub, 2003). Others disagree, suggesting that music is a fortuitous byproduct of other cognitive skills such as language, and is a pleasurable but biologically superficial aspect of cognition. Pinker (1997) is the best-known modern advocate of this view, referring to music as "auditory cheesecake" and writing that "music could vanish from our species and the rest of our lifestyle would be virtually unchanged."[1]

Hence there is now an active debate over whether or not music represents an evolutionary adaptation (e.g., Wallin et al., 2000; McDermott & Hauser, 2005; Fitch, 2006). Unfortunately, in the popular media (and in some scholarly writing as well) there seems to be an implicit view that one must choose between two opposing ideas: either music is a biological adaptation, or it is a superficial and dispensable part of our existence. I think this view presents a false dichotomy. There is another way to think about music, namely as something we humans invented that transforms human life. That is, music is a "transformative technology" that builds on existing brain systems, but transforms our experience of the world (Patel, 2008).

The remainder of this essay takes three parts. The first part introduces a null hypothesis about the evolution of music and suggests that this hypothesis cannot yet be

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[1] There are of course other positions, including that of Darwin himself, who suggested that music had its origins in a primitive song-like communication system of our primate ancestors (see Fitch 2006 for an overview). According to Darwin (1871), this non-referential but complex acoustic system may have served as a precursor to language, an idea further developed by Brown (2000) and Mithen (2005). Since language and music leave scant traces in the fossil record, we may never know exactly how music began.

rejected. Part two address the question: "if musical abilities are not a product of natural selection, where then do they come from?" I suggest that musical abilities build on mechanisms that evolved to serve other domains, and illustrate this idea by discussing some connections between music and language. Part three offers an answer to the question: "why is music universal?" It is suggested that music is universal because what it does for humans is universally valued, in terms of its ability to transform our emotions and our sense of self.

1. The evolutionary null hypothesis for music

Given the lack of an obvious adaptive function for music, a scientifically conservative hypothesis about its evolutionary status is a null hypothesis, namely, that humans have *not* been specifically shaped by natural selection for music. The pertinent question then becomes "is there enough evidence to seriously challenge the null hypothesis?" For complex cognitive abilities such as music and language, where learning clearly plays a very important role in acquisition, a critical line of evidence for adaptationist arguments comes from development. That is, if human brains can be shown to be specifically predisposed to learn about the structures and behaviors pertinent to an ability, this challenges an evolutionary null hypothesis. In the case of language, several lines of evidence from development do in fact challenge this hypothesis. The current section briefly discusses some of this evidence, and examines music side by side with language. (A fuller treatment, including cited references, can be found in Patel, 2008, Ch. 7.)

1.1 Rate of learning

Human infants are precocious learners of language. For example, they perceptually tune into their native language sound system before 1 year of age, and attain complex speech perception and production skills by the age of 3 or 4. (Consider how well a typical 3-year old can coordinate the complex machinery of speech articulation vs. throw or catch a ball).

What of music? While infants have many abilities *relevant* for music, such as discriminating two melodies with different pitch contours (the patterns of melodic ups and downs), such abilities are unlikely to be *specific* to music (for example, melodic contour processing is important for speech intonation). When we examine music-specific abilities, such as sensitivity to musical scale structure, the ability to sing in tune, or the ability to synchronize movement to a musical beat, such abilities seem to develop relatively slowly. Even 4 or 5-year old children appear to have limited abilities in these respects, suggesting that the acquisition of these abilities is not biologically prepared.

1.2 Critical period effects

Critical periods – time windows when developmental processes are especially sensitive to environmental input – are well known in biology (e.g. from songbirds). Critical periods are often regarded as evidence that natural selection has shaped mechanisms for acquiring an important, species-specific behavior. Critical periods have been demonstrated for language via studies of sign language acquisition. When language input is delayed beyond the first few years of life in deaf individuals with no other language, there is a significant impact on adult grammatical skills. At present there is no compelling evidence for a critical period in the acquisition of musical abilities. In order to study this, one would need to examine children who had no musical input for the first few years of their life, and see how this affected later musical development. In this respect, it may be interesting to study children who for some cultural reason (e.g. certain religious traditions) are not exposed to music in the home prior to going to school.

1.3 Robustness of acquisition

All normal humans develop basic linguistic abilities without formal instruction. Humans without formal music instruction appear far more variable in their basic musical abilities. We all know people who have difficulty singing in tune or clapping in time with music, yet who are otherwise normal. Even if such cases are excluded, it seems that basic musical abilities may be far more variable than basic linguistic abilities, though once again empirical data are called for. It would be particularly interesting to find out if this holds true in cultures where music making is a part of everyday life, unlike in American culture today (For some new tools being used to probe basic musical melodic and rhythmic abilities, see Peretz et al., 2008; Iversen & Patel, in press).

2. Connections between music and language

Part 1 above suggests that music may not be a biological adaptation. Where then do music-processing mechanisms come from? One idea is that they are built on mechanisms that serve other, more obviously adaptive cognitive abilities, such as auditory scene analysis, spatial cognition, or language. Relationships between music and language processing are especially interesting because both involve the interpretation of complex sequences that unfold in time. This section touches on three areas where music and language processing overlap in non-obvious ways, drawing on extended treatments in Patel (2008) [See Chs. 4,5 and 7 for details and references].

2.1 Musical syntactic processing

Most musical sequences are far from random: they observe culture-specific organizational principles, principles to which enculturated listeners (even those with no formal musical training) are sensitive. Music is thus a syntactic system, meaning that it involves perceptually discrete elements (such as notes or chords) combined in principled ways. For example, in Western tonal music, a *musical key* (such as C major or D minor) selects and organizes a set of 7 out of 12 possible pitch classes within the octave, using these to build melodic and harmonic sequences in which one note (the tonic) is the most stable or central note. Harmonic relations provide one basis for perceiving patterns of tension and resolution in music, patterns which appear to be hierarchically organized in the minds of listeners.

Of course, language is also a syntactic system with rich hierarchical structure, and there has long been an interest in whether musical and linguistic syntax have any relationship. Current evidence from neuroscience suggests that while linguistic and musical syntax operate on distinct kinds of representations (e.g., nouns and verbs and their syntactic features, or chords and their harmonic relations), some aspect of syntactic processing is shared between the domains. In particular, it seems that integrating incoming elements into syntactic structures draws on common brain regions and processing resources (including Broca's area, as demonstrated by Stefan Koelsch and colleagues). One recent line of evidence for such overlap comes from studies showing that musical harmonic processing interferes with the processing of linguistic syntactic relations, but not semantic relations. Hence a highly abstract feature of tonal music with no obvious links to verbal cognition (namely, tonal harmony) appears to rely on linguistic processing mechanisms in the brain.

2.2 Musical tone deafness

A small percentage of the population never develops normal basic musical abilities, such as the ability to judge when music goes out of tune, to recognize familiar melodies, or to tell when two melodies are the same or different. This can occur despite normal hearing and exposure to music during development. "Congential amusia" affects 2-4% of the population, has a strong genetic component and subtle neuroanatomical correlates. Early investigations of this disorder suggested it was highly specific for music, not affecting other types of complex auditory processing (e.g, speech). This striking dissociation between music and other abilities raised the possibility of finding genes that are specifically important for music cognition.

More recent work, however, has shown that amusia is not totally independent of language deficits. It appears that at about 30% of amusics have problems with the perception of pitch contours in speech. Specifically, these amusics have problems discriminating a statement from a question when the two sentences are distinguished by a sentence-final pitch rise vs. fall.[2] This points to a problem in pitch direction discrimination. Indeed, amusics are known to have severe problems with pitch direction discrimination in purely psychophysical tasks (with thresholds > 5 times higher than controls). This deficit may have a disproportionate influence on the development of musical (vs. linguistic) abilities because of the relatively greater importance of pitch contours in musical structure. Thus the genes involved in musical tone deafness may not be influencing music perception directly, but indirectly via a brain circuits for pitch direction, circuits shared by speech and music.

2.3 Synchronized movement to a musical beat

One universal of human music perception is the tendency to move in synchrony with a periodic beat (e.g., in dance). This response is not commonly observed in nonhuman animals. Furthermore, it differs from the synchronized displays of nonhuman animals (such as crickets and frogs) in a number of important ways, including its crossmodal nature, whereby an auditory stimulus drives the motor system in periodic behavior that is not necessarily aimed at sound production. There is currently strong interest in whether

[2] 30% may be a conservative estimate because amusics were tested with sentences with large pitch movements. Current work is using sentences with smaller pitch movements to determine whether most amusics have pitch direction deficits in speech, compared to normal listeners.

or not synchronization to a musical beat is a uniquely human ability (e.g., Cross & Woodruff, in press), possibly representing an evolutionary adaptation for music. Hence it is of interest that spontaneous synchronization to music has recently been documented in a Sulphur-crested cockatoo (*Cacatua galerita eleanora*), “Snowball” (see YouTube: “dancing cockatoo”). It appears that this animal shows true entrainment to a musical beat: when his preferred song is presented at different tempi (e.g., original, +/- 2.5%, 10%, etc.), he shows an ability to adjust his dancing tempo to stay synchronized with the music (Patel et al., in press).

From an evolutionary standpoint, it is significant that this behavior is observed in a vocal-learning bird and not in nonhuman primates, because humans closely resemble such birds in one particular trait. This is complex vocal learning (which is unique to humans among all primates). Vocal learning involves learning to produce complex acoustic signals based on auditory input during development and auditory feedback during sound production. Complex vocal learning thus requires a tight auditory-motor interface and has been hypothesized to provide the evolutionary foundation for synchronization to a musical beat (see Patel, 2008:408-411 for further details).

If synchronization to a beat relies on vocal-learning brain circuitry, and if such circuitry emerged in humans due to natural selection for language, then a basic aspect of music processing owes its existence to language, even though synchronizing to a musical beat is an entirely nonlinguistic behavior.

3. Music as a transformative technology

If music is not a biological adaptation, and it builds on processing mechanisms that serve other abilities, does this mean that it is a biologically superficial phenomenon that merely tickles our senses and provides hedonic diversion in our lives? Not at all. Music belongs in neither the adaptation nor frill category. Instead, it can reasonably be considered a “transformative technology” that builds on existing brain systems, but transforms our experience of the world. Music is not unique in this regard. Written language provides another example of a transformative technology. Reading/writing was an invention, not a product of natural selection. Yet it clearly builds on existing brain systems (such as those for spoken language comprehension, visuo-spatial cognition, fine motor skills etc.) and has a profound impact on how individual humans experience the world, by connecting us through space and time to minds far distant from our own.

Reading and music are both transformative technologies, but they differ in one very obvious respect. Music is a human universal and appears to be quite ancient (the oldest musical instrument is about 36,000 years old), whereas literacy is far from being universal, and appears to be comparatively recent (the oldest cuneiform tablets are about 5,000 years old). If music is not innate, why is it so ancient and universal? I suggest it is universal because what it does for humans is universally valued, in terms of its transformative effects on our emotions and on our sense of self.

In speaking of music as “transformative” in this way, it is important to clarify what I mean by “transformation.” There is growing evidence that learning to play a musical instrument changes the structure of the brain, from subcortical circuits that encode sound patterns, to neural fiber tracts that connect the two cerebral hemispheres, to localized patterns of gray matter density in specific regions of the cerebral cortex. While these findings are fascinating and provide rich grounds for the study of neural plasticity, they are not the kinds of transformations I will be exploring here. Here I wish to focus on the power of music to transform our emotions and our sense of self, two kinds of transformations which may not have detectable effects on the structure of the brain.

The emotional power of music is acknowledged in every known culture, and has been written about since the beginnings of philosophy. Yet only very recently have scientists begun to systematically investigate the mechanisms that underlie emotional responses to music. A forthcoming paper by Juslin & Västfjäll (in press) reviews a large body of research and suggests that music elicits emotion via no less than six distinct brain mechanisms. While none of these mechanisms are unique to music, I think music may be unique in the way it activates and coordinates these mechanisms. The result is a complex emotional experience that can differ from our ordinary day-to-day emotions, and which can provide a powerful source of comfort, emotional release, or connectedness to others. In some individuals, hearing music in a particular ritualistic context can generate so strong an emotional response that it shifts consciousness into a state known as trance, as described by Becker (2004) in her cross-cultural research on trance experience.

In terms of the transformative effect of music on the sense of self, social psychologists in the West have documented how listening to music can be an important part of the process of identity formation in adolescence (cf. Patel, 2008:324 for references). That is, music is not just used as a way to regulate one's mood, but is used to construct a sense of self based on the thoughts and feelings expressed by the music (and by the accompanying lyrics). I suspect that this is not a specifically Western phenomenon, though I am not aware of data from other cultures on this issue.

One fascinating consequence of the transformative effect of music is the depth to which music becomes embedded in our nervous system. In his recent book *Musicophilia,* Sacks (2007) writes of numerous cases where the ability to produce or respond to music remains intact despite severe brain disorders. For example, music can make a fragmented mind coherent again for a time, can help a frozen Parkinson's patient to walk, or allow a nonfluent aphasic patient to produce fluent verbal output in the form of song. These remarkable phenomena remind us that music is an invention like no other, one that has become deeply integrated into the very fabric of our being.

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