decision making, preparation for group action, social bonding, and conflict resolution. Music's role in ritual is quite unique: music is a generalized *emotive manipulator* that acts to reinforce and give emotional meaning to those things with which it is associated (Brown, in press). Music is an enhancer of cultural objects, especially in the context of ritual events. Music's capacity to serve as an enhancer permits it to act as a potent device for persuasion, and this capacity is put to use as readily in television commercials and political propaganda as it is in religious rituals. Music's ability to enhance, persuade, transform, motivate and move can be used for both socially-positive and socially-negative ends. It can support hate as much as tolerance, destruction as much as healing. The important social consequence of this is that music is one of the most politically controlled features of any society, and this has been well documented by the onslaught of musical propaganda and musical censorship in the 20th century and today.

One way to understand music's role in ritual is by analogy to a similar mechanism at the individual level: music is a type of *reward system*. In the same way that neuroscientists talk about neural reward systems reinforcing individual behavior – for example those that underlie feeding, sex, drug addiction and the like – we can think about music as type of *social* reward system that makes group-ritual behaviors into individual necessities. This is consistent not only with the ubiquitous association of music to ritual activities in all human cultures but to the pleasurable and rewarding feelings that music evokes when people engage in such activities. Seeing music in this way forces to rethink the evolution of human ritual, which has been traditionally explained with reference to the emergence of language. Music has clearly played an essential role in this evolution, as it performs a function that language does only inefficiently: group-level emotive manipulator and reward system.

Conclusion: Music Evolved as Ritual's Reward System

In discussing these three biological paradoxes about music, a rather unified view of music evolution emerges, a view that revolves around group function. Music's individual fitness costs are offset by group benefits, and there is little conflict between self-interest and music making, especially where there are strict social norms regarding musical participation – such as in all tribal cultures. During the course of expansion of the hominid brain, new areas evolved to mediate this human-specific function of music, and most especially its unique design features of harmony and meter, features that foster group participation and interpersonal synchronization. But music is a hedonic function as well, one which evolved as a type of collective reward system, making the execution of group actions into a cultural imperative. If I were to summarize this overall view of music, I would say it as follows: *music evolved as ritual's reward system*, a type of social neuromodulatory system and group-level adaptation (Brown, 2000a).

Such novel insights into music's cultural functions come about only through a biological view of music. Biomusicology is poised to shed new light on human social behavior, from its collective nature to its emotive foundations.

Dedication: Shortly after this article was completed, Nils Wallin died. Nils was one of my greatest inspirations. I dedicate this article to his memory.

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Précis to an integrated Absolute pitch: Review

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Absolute Pitch (AP) is generally defined as the ability either to *identify* the chroma (pitch class) of an isolated tone, using labels such as C, 261 Hz, or Do, or to *reproduce* a specified tone, e.g. by singing, or adjusting the frequency of a variable tone generator, and to do so without reference to an external standard (Bachem, 1937; Baggaley, 1974; Ward, 1999). When someone with AP hears a car horn, they might say "That's E-flat!" In contrast, if you play a tone from the piano and ask people what you played, most cannot tell you (unless they watched your hand). People with AP can reliably tell you, "That was a D-sharp," and some can even do the reverse. Ask them to produce a middle C (the center key on a piano keyboard), and they will sing or hum or whistle the pitch for you. Those with AP have memory for the actual pitches in songs, not just the pitches in relation to one another. In fact, when most of them hear a song in a different key (and therefore with different pitches), it sounds wrong to them.

Identifying a tone in such a way can be thought of as *passive* AP, and reproducing the specified tone can be thought of as *active* AP. Whether or not they possess AP, some individuals are able to recognize whether a familiar piece is played in the correct key, and/or can sing a familiar song in the correct key. Note the parallel here between the active- and passive-AP described first: recognizing the key of a musical piece is passive, and reproducing a musical piece in the correct key is active. Because some people display these abilities only with respect to musical pieces and not individual tones, it is useful to distinguish between *piece-AP* and *tone-AP* (Parncutt and Levitin, 2000).

There exist some confusions and misconceptions in the literature that absolute pitch involves more highly developed *perceptual* mechanisms, whereas the preponderance of evidence is that absolute pitch ability is an ability of *long term memory* and *linguistic coding* (Deutsch, 2002; Levitin, 1996). Further, the term *perfect pitch* has also been used somewhat interchangeably with the term *absolute pitch* in the literature whereas in fact, absolute pitch possessors do not perceive pitch any better than non-absolute pitch possessors (Bachem, 1954; Burns & Campbell, 1994; Levitin, 1996). AP possessors can typically tune pitches to within 20-60 cents of target frequencies (Rakowski & Morawska-Büngeler, 1987). In passive tasks, they regularly make semitone errors (Lockhead & Byrd, 1981; Miyazaki, 1988), and are not necessarily better than other musicians at identifying octave register (Miyazaki, 1988; Rakowski & Morawska-Büngeler, 1987). Clearly, there is nothing "perfect" about AP, it is simply the ability to place or produce tones within nominal categories.

The ability to recognize and identify absolute pitch presents the research scientist with two opposing puzzles. First, why are some people able to do this? Since melodies are defined by relative pitches, why do some people have the ability to track the absolute pitches – information that has no apparent value? Understanding speech virtually requires that we ignore absolute pitch information; if we did not, we would not be able to understand children, who speak an octave or two higher than do adults.

A contradictory puzzle arises when we consider that the auditory system, from the cochlea in the ear up to the cortex of the brain, contains neurons that respond only to specific frequencies. Our ears and our brains are indeed registering absolute pitch information at every stage. The second question then becomes not "Why do some people have absolute pitch?" but rather "Why doesn't everyone?" After all, as the late psychologist Dixon Ward was fond of pointing out, we do not have to run to a picture of a rainbow to say that a rooster's comb is red, or run to a bottle of camphor to identify the odor of a skunk (Ward, 1999). Why, then, if someone plays us a note, do most of us have to run to the piano to figure out what note it is?

Some progress has been made on these questions. An emerging body of research suggests that both tone- and piece-AP involve two separate cognitive subskills: long-term pitch memory, and an appropriate form of linguistic coding for attaching labels to stimuli (Levitin, 1994). "True" tone-AP requires individual internal pitch standards for all 12 chroma. This template can shift with age by as much as two semitones (Vernon, 1977; Wynn, 1992) and shifts can also be induced neurochemically (Chaloupka, Mitchell, & Muirhead, 1994). A musician with good relative pitch who has internalized several, but not all of the pitches of the chromatic scale can often label pitches as *accurately* as one with true AP, but not as *rapidly;* such individuals said to have *pseudo-AP* (Bachem, 1937, 1954; Cuddy 1970). The labels used in tone-AP are musical note names; in piece-AP, names of pieces, and texts of songs. It has also been argued that the use of non-musical, informal names (such as "that's the first note in the song 'Hotel California'") should also be accepted as evidence of a form of implicit or latent tone-absolute pitch (Deutsch, 2002; Levitin, 1994; 1996; 2000).

Absolute Pitch (AP) should not be confused with Relative Pitch (RP), an ability that nearly every musician learns. Relative pitch refers to the ability to identify or produce musical *intervals*, while AP refers to the ability to identify or produce individual musical pitches. To illustrate, if we present an RP possessor with the tones *A* and *C*, she can identify the musical interval as a minor third, or 300 cents. If we additionally tell her that the name of the first tone was *A*, her knowledge of interval and scale relations will allow her to identify the second tone as *C*. On the other hand, if we had told the subject that the name of the first tone was *D*, she would have no reason to disbelieve us, and would happily identify the second tone as *F* - the tone that is a minor third above *D* - and not know that we had fooled her. This is because RP possessors, by definition, do not have an internal template or reference system for pitch as AP possessors do (Ward, 1999). In contrast, if we played an *A* for an AP possessor and told him that it was a *D* he would know this was not correct. Most AP possessors actually have difficulty with RP tasks in that they don't identify musical intervals directly by their sound, but instead use their knowledge of scale relations to deduce the name of an interval from their ability to identify its component tones. Note that this is the opposite strategy of RP possessors given a reference tone, and who deduce the tone names from their ability to identify the interval they define.

Interestingly, AP does not appear to be correlated with other musical skills. Composers with tone-AP (e.g., Mozart, Berlioz, Scriabin, Messiaen, Boulez) did not necessarily write better or worse music than composers without it (e.g., Berlioz, Wagner, Tchaikovsky, Ravel, Stravinsky; cf. Slonimsky, 1988). While tone-AP is sometimes an advantage (helping horn players to imagine tones before playing them, singers to perform atonal music, and theorists to follow large-scale tonal structures by ear), it can also be a hindrance to certain tasks (e.g., when playing, singing, or listening to music in a key other than written). Regarding *relative* pitch, APers can be *less* skilled than other musicians, calculating intervals and chords from note names rather than hearing them directly (Miyazaki, 1992, 1993). Their constant awareness of musical pitch labels can detract from their enjoyment of music – as more than one tone-APer has complained: "I don't hear melodies, I hear pitch names passing by."

The relative frequency of absolute pitch in the general population has never been established. An oft-cited estimate of 1 in 10,000 (Profita & Bidder, 1988) was not based on scientific study, and reliable estimates are further confounded by two problems: (1) AP tests as typically administered can be completed only by musicians who have familiarity with tone names, and (2) AP is not an all-or-none ability, and thus one needs to decide non-arbitrarily on the threshold that qualifies one as a true possessor. Thus the distinction between possessors and non-possessors is not clear-cut, and it is best to think of AP ability as falling along a continuum. APers can usually label 70-100% of randomly selected, middle-range piano tones (Miyazaki, 1988), while even musicians not claiming AP identify tones above chance levels (1/12 = 8.3%) with rates up to 40% (Lockhead & Byrd, 1981; Miyazaki, 1988). This latter result is not surprising given that neurological information on absolute pitch is available at all levels of the auditory system (Moore, 1997). Even songbirds (Hulse, Cynx, & Humpal, 1984), canines (Tooze, Harington, & Fentress, 1990) and monkeys (D'Amato, 1988) demonstrate absolute pitch memory.

Deutsch was the first to recognize the continuous nature of AP abilities. Deutsch investigated two aspects of music cognition, invariance of tonal relations under transposition, and the dimensionality of internal pitch representations (Deutsch, 1991, 1992; Deutsch, Kuyper & Fisher, 1987). In these studies, subjects were asked to judge the height of octave-complex, pitch-ambiguous tones, known as Shepard tones (Shepard, 1964). A pair of such tones, with their focal frequency a tritone apart, form a sort of auditory Necker cube and are ambiguous as to whether the second tone is higher or lower than the first. Subjects' directional judgments were found to be dependent on pitch class, leading Deutsch to conclude that, although her subjects were not able to label the tones, they were nevertheless using AP indirectly. Deutsch further speculated that absolute pitch "is a complex faculty which may frequently be present in partial form" (Deutsch, Moore and Dolson, 1986, p. 1351.) More recently, Deutsch has provided evidence that speakers of tonal languages, such as Mandarin, are using absolute pitch information all the time in daily conversation (Deutsch, Henthorn & Dolson, 1999; Glanz, 1999). In addition, Saffran and Griepentrog (2001) demonstrated implicit absolute pitch abilities in infants as young as 8 months.

Although in the popular media (BBC, 2001), there are some who claim that AP is "completely inborn" and that young children are "born with the knowledge of note names" this clearly cannot be true; tone names must be acquired along with other linguistic terms during language acquisition. The real mystery is why it is that some children develop AP and others do not (Deutsch, 2002; Levitin, 1999; Ward & Burns, 1978). It has been established that musicians who start musical training early are more likely to acquire tone-AP than those who start late (Sergent, 1969; Wellek, 1938). Tone-AP can be acquired in later life, but only with considerable motivation, time, and effort (Brady, 1970; Cuddy, 1968, 1970; Meyer, 1899). Late tone-AP acquirers are generally less spontaneous and accurate in their identification of pitches; they tend not to develop a complete internal chroma template, filling the gaps by means of relative pitch. Younger children acquire piece-AP more easily than older children (shown by singing a song in its regular key: Sergeant & Roche, 1973). Many in the field now believe there exists a critical period for the acquisition of true AP, and that specific training to associate tone names with their sound is required. Indeed, in regions of Japan where the Suzuki method is prevalent and this type of training is conducted, AP rates can soar as high as 50%.

The search for an AP gene (Baharloo, et al., 1998; Profita & Bidder, 1988) may be in vain, given that, in a learned skill, "nature" and "nurture" cannot easily be separated (Jeffress, 1962), and that AP involves several neurally distinct subprocesses (pitch perception, classification, labeling, storage in long-term memory, retrieval from memory; Levitin, 2000; Zatorre, Perry, Becket, Westbury & Evans, 1998). Recent evidence from brain imaging studies has suggested that the neural correlates of AP may involve the planum temporale (Schlaug, Jäncke, Huang, & Steinmetz, 1995) and areas of the left posterior dorso-lateral frontal cortex (lpDLFC), an area associated with labeling in conditional associative learning (Zatorre, et al., 1998). In this latter study, lpDLFC was shown to be active in *both* interval naming and absolute pitch naming tasks, providing neuroanatomical confirmation that it is merely *labeling* ability that distinguishes AP possessors from non-possessors. The reason why some children acquire this ability and others do not may be simply be because they were taught it and made an effort to learn it. This is not inconsistent with the notion that there may indeed by *some* genetic contribution in the way of a cluster of genes providing a genetic predisposition toward AP. But if this is the case, it is unlikely that these genes encode protein synthesis for AP per se, but rather, they may encode proteins that contribute to *component* abilities that are required for the development of AP, specifically such subskills as auditory memory, auditory attention, conditional associative learning, categorical perception, and perhaps even a predisposition toward absolute versus relative features of certain perceptual stimuli.

New studies underway in several laboratories are bringing converging techniques and evidence to a more thorough understanding of AP, and these include new studies of infant and child development, functional neuroanatomy, neuropsychological case studies, genetics, psychophysiology (including evoked response potentials), and traditional behavioral studies. Understanding both the nature of absolute pitch, and why it favors some individuals over others, can tell us something about how the human brain processes melodies and pitch, and ultimately, can inform broader theories of cognition, perception, and the interaction between the two.

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CANADA

Absolute pitch – a connection between music and speech?

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Absolute pitch, which is defined as the ability to name or produce a note of a given pitch in the absence of a reference note, is very rare in our culture. It is often regarded as a mysterious and extraordinary gift – one that perhaps takes some exceptional musical ability to acquire. This impression is reinforced by the fact that most of the best-known composers and performers of classical music – such as Bach, Beethoven, Handel, Mozart, Toscanini, Heifetz, and Menuhin – were known to possess this faculty. Indeed, one of the achievements of the young Mozart that so impressed his contemporaries was his ability to name a pitch 'out of the blue'. As described in an anonymous letter that was written about the 7 year old Mozart:

> 'I saw and heard how, when he was made to listen in another room, they would give him notes, now high, now low, not only on the pianoforte but on every other imaginable instrument as well, and he came out with the letter of the name of the note in an instant. Indeed, on hearing a bell toll or a clock, even a pocket-watch, strike, he was able at the same moment to name the note of the bell or time piece (Augsburgische Intelligenz-Zettel, 1763, reprinted in Deutsch, 1990).

This description accurately portrays the capacities of an individual with a very good sense of absolute pitch. The process of naming a pitch is effortless and immediate, and doesn't depend on the timbre of the musical instrument – or other object – that produced it. The faculty typically arises very early in life, and people with absolute pitch often mention the great surprise with which they realized, at a young age, that other people were unable to name notes that were presented in isolation. This was my experience, and to this day I remain puzzled by the rarity of absolute pitch in our culture. After all, we have no difficulty naming colors or smells; neither do we have trouble naming vowel sounds, or identifying the sound of a violin or trumpet, or a human voice, or a barking dog. So the real puzzle concerning absolute pitch is not why some people possess it, but rather why it is so rare.

The mystery deepens when we consider the evidence that most people show an implicit form of absolute pitch, even though they are unable to attach verbal labels to notes that are presented in isolation – or to produce a note of particular name in the absence of a reference note. This evidence is reviewed in Levitin (this issue), so I'll just summarize it briefly. One body of evidence concerns the tritone paradox (Deutsch, 1986, 1991, 1992). To generate this musical illusion, two tones which are related by a half-octave are presented in succession. For example, C might be presented followed by F#, or G# fol-