The McMaster Journal of
Communication

Volume 3, Issue 1
2006
Article 3

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Abstract

Unrau examines notions of "perfect" and "relative" pitch. She establishes which of these two processing methods is more useful across different listening conditions, why relative pitch seems to "win out" for most people as their primary method of processing music, and how the two processes could possibly interact or affect each other.

KEYWORDS: Relative Pitch, Absolute Pitch, Perfect Pitch, Auditory Systems, Tonotopic Map

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When listening to music or other complex acoustic sequences, people can theoretically utilize two strategies for processing information about pitch. The first, called "absolute pitch" processing, involves comparing sounds from the environment with specific memory representations of particular (or "absolute") pitches, independently of their relations to other sounds (Levitin, 2005:414). This strategy is associated with a relatively rare ability called Absolute Pitch or AP, which can be defined as "the ability to identify the pitch of a musical tone without the use of an external reference pitch" (Takeuchi & Hulse, 1993:345). To avoid confusion and to make later arguments more clear, I will distinguish between "AP processing" (which may not involve knowledge of musical note names) and "AP ability" (which by definition, requires this knowledge).

The second available strategy for processing musical pitch is known as "relative pitch" and is used by even the most casual music listeners. Relative pitch, as the name implies, involves interpreting the relations between melodic and harmonic components of music within tonal contexts (Miyazaki, 2002:962); in other words, we select and interpret the invariant aspects of highly variable stimuli (Paavilailen et al., 1999:179). For example, males and females can sing a melody beginning on different pitches, and we will call it the "same song" because of the invariant relationships between the notes of the melody. Relative pitch or RP is the primary musical processing method for most humans, and being able to encode important relational aspects of music is essential in orchestra playing, song-writing, and identification of musical pieces.

At a first glance, AP processing appears to be the more feasible task for our auditory system to undertake. Every level of the human auditory system, from the cochlea of the inner ear to the primary auditory cortex, is organized into one or more tonotopic maps (Yost, 2000:233). In a tonotopic map, low frequencies are represented in one spatial location, and high frequencies at another, so that neighbouring groups of neurons will tend to respond best to similar frequencies in an ordered manner (Yost, 2000:232). Thus, we can safely say that the central auditory nervous system is processing absolute frequency information, even if this ability is not translating to the level of conscious pitch recognition and identification.

Our brains also process perceptually invariant, relative features of speech and music at a pre-conscious level. In an EEG study, participants heard a short melody transposed to a different key on each repetition while watching a silent video. (Trainor, McDonald & Alain, 2002:430). When the interval between the final two notes of the melody was changed (to either stay within the key or go outside the key), the experimenters found an event-related response called Mismatch Negativity, a reliable indication that the participants detected a change from the expected intervals, even without paying attention to the stimuli. There is evidence, then, that humans process – at some level – both AP and RP information for incoming musical stimuli.

In this paper I will investigate which of these two processing methods is more useful across different listening conditions, why relative pitch seems to "win out" for most people as their primary method of processing music, and how the two processes could possibly interact or affect each other. Does everyone process pitch using either AP alone or RP alone, or can some people use both types of information, with different degrees of success? By examining the literature on AP and non-AP performance in various tasks, I will attempt to "de-mystify" common assumptions about AP ability and show that the RP processor (that is, the average person) is able to access some absolute pitch information. Finally, I will consider some newer definitions and views of Absolute Pitch, including a theory supported by Levitin (2005:421) that there are actually two components involved in Absolute Pitch ability: one which is widespread throughout the general population, and one which is more rare and likely depends on early musical experience.

Absolute and Relative Pitch in Development

In order to appreciate the musical value of relative versus absolute pitch, as well as how and why RP becomes so dominant in adult music processing, it is first crucial to understand the roles of both processes in development. Is early musical training sufficient for the development of AP ability, or do certain people simply have a genetic predisposition to process pitches in absolute terms? Do infants begin life processing relative pitch, with a few switching to absolute pitch after specific exposure to sounds and music, or could the reverse be true, with a small minority *retaining* absolute pitch? The answers to these questions are not without controversy (for a review, see Trainor, 2005:268-9) but the evidence does provide some interesting insights into both types of pitch processing.

AP ability in adulthood is strongly associated with musical training before age 6 (Baharloo et al., 1998:755); however, this experience is likely not sufficient or entirely necessary for the development of AP. Most musically trained children still develop as RP processors, even when their training emphasizes absolute pitches (Gregersen et al., 2001:281). It also appears that some nonmusicians use AP processing, but their abilities are never discovered because they cannot name musical notes, and therefore cannot pass most standard tests for AP ability. Indeed, Ross, Olsen and Gore (524) found an individual who, in a task involving memory for pitch after a number of distracting interference tones, performed just as well as the AP participants even though he had no formal musical training or knowledge of musical note names.

Since musical experience cannot entirely explain the presence or absence of AP ability later in life, a genetic predispositions may be necessary for its manifestation. MRI images of AP musicians show a larger leftward asymmetry in the size of the planum temporale, a cortical area associated with auditory processing, when compared with RP musicians and non-musicians (Keenan et al. 2001:1402). Importantly, this brain difference could still be due to early exposure to music, and thus is not conclusive evidence for an exclusively genetic component of AP ability. Chin (2003:164) suggests that those with a particular cognitive style involving narrow attention and a tendency to focus on smaller components of stimuli will be predisposed to processing musical pitches in absolute terms. Most current theories of AP ability and its development indicate a role for both genetics and environment (see Zatorre, 2003:695).

If experience and genetics are both important in the development of AP ability (or in its absence, RP skills), the next question becomes whether infants initially process music using relative or absolute pitch. Saffron and Griepentrog (77,79) reported that 8-month-old infants were more likely to discriminate musical "words" (3-note phrases) based on absolute rather than relative pitch, suggesting a processing switch from absolute to relative pitch as young children learn about the relational, invariant aspects of stimuli in music, speech and other domains. However, other studies have indicated that 6-month-old infants find relative pitch information more salient than the absolute pitches of a given melody (Plantinga and Trainor, 2005:6-7), and 8-month-olds readily use and remember relative pitch when given appropriate stimuli (Saffran et al., 2005:5). Overall, the evidence seems to indicate that most humans, even from early in development, are primarily RP processors who appear to use AP information only in certain circumstances. As we develop, selecting invariant aspects of variable stimuli becomes even more important (in order, for example, to recognize voices across different speech sounds and specific speech sounds across different voices); this is certainly true in musical tasks as well, as will be discussed below.

A Relative View of Absolute Pitch

The common name for Absolute Pitch ability is Perfect Pitch, and with that word "perfect" comes a whole host of assumptions about the properties of AP processing, and about the differences between those with and without AP ability (Levitin and Rogers, 2005:28). Perfect Pitch is often referred to as something to be possessed or obtained (e.g. Takeuchi and Hulse, 1993:358; Baharloo et al. 1998:224), implying that those who process pitch using relations simply *lack* AP ability, but that individuals with Perfect Pitch lack nothing. While AP ability is certainly rare – prevalence in the general population is usually estimated at around to 0.01% (Takeuchi and Hulse, 1993:345) and at around 10-15% for professional musicians (Baharloo et al., 1998:227) – and many RP processors of various ages do attempt to learn AP ability (Ward and Burns, 1982:449), AP processing certainly does not result in flawless or invariable behaviour in music perception tasks. A great deal of research over the last 20 years has focused on determining exactly what those with AP ability can and cannot do, and in which types of musical tasks these individuals may not perform so perfectly. Issues regarding AP individuals' pitch identification and production ability, pitch acuity and "internal scale" reliability are discussed below.

Researchers disagree about whether or not to include ability to produce given pitches as a criterion for defining AP, with most recent research focusing only on pitch identification (see Wynn, 1992:130 "revisited" for use of production only; Miyazaki, 2002:502 "pitch identification" and "Relative Pitch" 963 for use of identification only). The obvious problem with relying solely on pitch production is that not all musicians are singers, and sometimes non-singers cannot match their vocal productions to their mental representations of pitches (Levitin, 1994:419; Takeuchi and Hulse, 1993:348).

Identification of absolute pitches by those with AP ability is not consistent across different types and classes of notes. The timbre of a musical note (roughly, the unique tone quality that distinguishes sounds of the same pitch played by different instruments) can greatly affect AP judgments (Takeuchi and Hulse, 1993:350). Piano tones tend to be judged more accurately than pure tones and other instrument tones; these results could be due to participants' familiarity with piano tones, or because piano timbre varies over the range of the piano (Takeuchi and Hulse, 1993:351). Takeuchi and Hulse (1993:35) also found that participants with AP ability were faster to compare auditory presentations of tones with visual presentations of pitch names if both were "white-key" pitches (pitches which contain no sharp or flat in the name and are represented by white keys on a piano) than if either was a "black-key" pitch. These discrepancies suggest a large role for experience and exposure to music in AP ability, as well as casting doubt on the claim that AP individuals map frequency to pitch in a consistent or flawless manner.

The belief that AP possessors have superior pitch acuity is common (Levitin and Rogers, 2005:28) and not entirely disproved by empirical research. People with AP can typically identify and categorize pitch differences of as little as 20 cents or 0.2 semitones (Miyazaki, 1998:505), but other research shows inconsistent but widespread semitone and octave errors in pitch identification tasks

(Lockhead and Byrd, 1981:388). When naming is not used at all (for example, simple "same-different" judgment tasks), there is no reliable difference between the pitch acuity of AP and non-AP participants (Takeuchi and Hulse, 1993:353). People with AP have reported feeling uncomfortable listening to orchestras which were tuned to a lower standard for A4 (Miyazaki and Rakowski, 2002:1337), indicating that at least some AP possessors have fixed and specific frequency standards for certain pitches, but that these exact standards may depend on other factors, such as the method employed to test their pitch identification skills.

Another set of assumptions about AP possessors is that their "internal pitch" scales are fixed and unchanging, both in the short- and long-term. Contrary to this claim is evidence that AP possessor's production of A4 (440Hz) can actually vary cyclically throughout the day, with a range of up to 0.5 semitones (Wynn, 1992:117). Wynn also found that productions of A4 by his wife and three other female subjects varied according to their menstrual cycles, although the patterns were not reliable from month to month (Wynn, 1992:116).

In Philip Vernon's 1977 case study on himself, he documented that his internal scales showed a more long-term shift with age. His pitch references were originally quite accurate, but by the age of 52 all of his perceptions had shifted up by one semitone, and were sharp by a full tone by age 71 (Vernon, 1977:486-7). Other studies have shown that semitone shifts in judgment associated with aging are relatively common (Wynn, 1992:130). One explanation of this aging-related phenomenon is that changes in the elasticity of the basilar membrane cause slight shifts in frequency representation, which then propagate to the auditory cortex where decisions about pitch identification are made (Vernon, 1977:488).

Overall, it appears as though AP possessors are neither perfectly accurate nor perfectly consistent on tests of their "perfect" pitch processing abilities. As will be shown in the following section, AP subjects also tend to perform poorly in tasks which favour the use of relative pitch strategies.

Absolute Pitch in Different Musical Contexts: Skill or Deficit?

Absolute Pitch ability clearly has practical advantages in certain musical domains. The presence of someone with AP ability is often helpful for choral groups who sing *a capella* (without instrumental accompaniment) or for groups using acoustic instruments in the absence of a tuning fork or digital pitch reference. However, considering the evidence presented earlier indicating that AP possessors may not be the precise tuners we expect them to be, we must search for other advantages. Sight-reading music can be easier for the person with AP ability, as can taking musical dictation or transcribing music from recordings, because referring to his or her internal "template" for pitch never requires an outside source (Miyazaki, 1988:271).

Singers with AP ability can also sing atonal music – which does not rely on a fixed tonal centre, and in which no consonant intervals are emphasized – with considerably more ease than those who rely primarily on pitch relations (Parncutt and Levitin, 2001:37-8). Conversely, musical tasks which emphasize relative pitch, such as interval naming or identifying a transposed melody, could present problems for someone who relies primarily on AP processing. The distinction between AP ability and AP processing becomes important again here: just because a person has AP ability does not necessarily mean that he or she can only process pitch absolutely, nor does it mean that he or she can easily process pitches both ways. Large variation between AP individuals in RP tasks shows that AP ability does not totally replace RP, nor does it appear to be added on to a completely intact representation of RP (Miyazaki and Rakowski, 2002:1344). Performance on tasks which tap into relative pitch processing appears to depend on each AP possessor's ability to "code-switch" between AP and RP, and on his or her *persistence* in using AP encoding for all types of musical tasks.

Kenichi Miyazaki has compared the performance of those with AP and those without AP on tasks including interval naming (Miyazaki, 1988:963-5), recognition of transposed melodies (Mizayaki, 1988:271), and recognition of notated melodies presented at transposed and non-transposed pitch levels (Mizayaki and Rakowski, 2002:1339). When participants were presented with melodic intervals separated by 2-12 semitones with a reference tone (the first tone of the interval) of C4, there were no discernible differences in naming accuracy or response times between AP and non-AP musicians. If the reference was changed to F# or an out of-tune E, however, the AP participants were significantly slower and less accurate at interval naming than their non-AP counterparts, especially for larger intervals (Miyazaki, 1988:966). Some of the AP participants' errors are also interesting to note: 3 out of 11 of Miyazaki's AP subjects frequently misnamed intervals with a non-C reference as though the reference was still C. For example, a participant may have responded "minor 7th" to a major 3rd with an F# reference, simply because the upper note was a minor 7th from C4. These results point out a serious disadvantage for AP possessors, and also highlight the importance some people with AP place on using "middle C" as a reference for calculating and identifying intervals (Miyazaki, 1988:969).

In a test of transposed melody recognition from C major to one of C (non-transposed), out of-tune E (up 3.5 semitones), or F# major (up 6 semitones), results showed a similar pattern (Miyazaki, 1988:274-5). Differences between AP and non-AP listeners only appeared in the transposed conditions, where AP possessors performed significantly worse. To account for the likely possibility that absolute pitches were preserved in working auditory memory for the non-transposed condition, other experiments have tested auditory recognition of *notated* (and thus visually-presented) melodies (e.g. Miyazaki and Rakowski, 2002:1339-40). Perhaps surprisingly, even when the non-AP musicians had much *less* musical training than the AP group, they still performed reliably better in transposition situations (Miyazaki and Rakowski, 2002:1340,1343).

It is possible that if children with AP develop the ability early in life (Costa-Giomi et al., 2001:395), and if these young musicians learn to rely on absolute pitch processing for most musical tasks, they may never fully develop the musically useful relative pitch skills that others take for granted (Miyazaki, 1988:969). Someone with AP ability may be perceiving intervals indirectly, by first identifying each pitch separately and then deciding which interval describes the difference between them (Miyazaki, 1988:968). If they are using this indirect process, it is not surprising that their automatic, pre-attentive AP processing can sometimes cause interference. Although some "skewed" interval naming has been documented for AP possessors when provided with out-of-tune references (Miyazaki, 1988:418), the evidence for categorical perception of intervals is not strong (see Ward and Burns, 1982:448; Levitin and Rogers, 2005:27).

The large variation in performance between AP individuals in relative pitch experiments indicates that different AP subjects may be using different strategies for figuring out pitch relations. In some cases, the better they score on a standard AP test, the worse they perform on the RP tests (Miyazaki and Rakowski, 2002:1343), suggesting that the accurate AP participants never developed adequate RP skills. Perhaps even more interesting is that in one transposed melody test, it was the *inaccurate*-AP participants who performed worst on the transposition test (Miyazaki, 1988:278-9). By asking the AP possessors to describe how they were identifying test stimuli, Miyazaki (1988:281) found that some AP listeners had developed "tricks" (such as pretending the melody was notated in a different musical clef) to avoid being forced to use their less-effective RP skills. These results show that difficulties shifting to conscious RP processing, automatic AP interference, and some subjects' near-refusal to learn or use RP cause AP participants to perform poorly on pitch relationship tasks.

An Absolute Side to Relative Pitch

Relative pitch processing, as discussed earlier, is more fundamental to music (as human societies have constructed it) than absolute pitch. The relations between tones of a melody (in pitch and rhythm) define that melody; its surface characteristics do not (Krumhansl, 2000:166).

Reading written transpositions, playing transposed musical instruments (Such as the French horn, which sounds a perfect 5th below the written note), and even singing with a choir that tends to drift together away from the correct pitch pose no problem to relative pitch musicians (Miyazaki, 2002: 1337; 1988:280). Their abilities appear to strongly contrast with the aforementioned advantages and disadvantages of AP ability in musical tasks: identifying individual pitches is difficult (if not impossible) for the RP musician, but melody recognition across transpositions and identification of perceptually invariant features is much easier, since the absolute pitch changes likely go unnoticed by these people!

Because of the very poor performance of most non-AP participants in pitch identification tasks (Miyazaki, 1988: 502-3) and their reluctance even to participate in such tests (e.g. Keenan et al. 2001:1404), it is often assumed that absolute pitches are simply meaningless for those who are used to relative pitch processing. However, recent research indicates that even the musically untrained may have some potential for absolute pitch memory and recognition.

In 1994, Daniel Levitin tested students' long-term memory for the absolute pitch of familiar songs (1994:416). He allowed each participant to choose a song that he or she claimed to know "very well", and then instructed him to imagine that song playing in his head and to produce part of its melody by singing, humming or whistling. This procedure was repeated twice for each participant, and the participants' productions were compared with the original artists' recordings of the songs. He found that 40% of subjects sang their excerpt at the correct pitch on at least one of two trials, and 81% were within 2 semitones on both trials (Levitin, 1994:416-7). Levitin inferred from these results that many people have "stable, long-term memory representation" for pitch. In similar work, Halpern found that participants were highly consistent in the pitch levels of their song productions of familiar tunes such as "Somewhere Over the Rainbow" and common children's songs within and between sessions (usually within 2 semitones) (1989:575). Mothers also tend to sing songs to their infants at consistent absolute pitch and tempo levels, with average differences of less than a semitone between test sessions (Bergeson and Trehub, 2002:73).

Schellenberg and Trehub (2003:263) tested the accuracy of long-term pitch memory using recognition instead of production, and with familiar television show themes always heard at the same pitch (such as "Friends", "ER" and "The Simpsons") as stimuli. Participants were to judge which of two versions of each theme (one at the original pitch level, one shifted up or down by one or two semitones) was "correct." Recognition was significantly better than chance for both the one- and two-semitone shift conditions, around 70% correct in the latter case (Schellenberg and Trehub, 2003:264). These results have strong implications for the definitions of AP processing, especially when considered alongside AP possessors' frequent semitone errors discussed earlier.

A word of caution should be noted against interpreting these results as conclusive evidence for widespread, long-term absolute pitch memory in the general population. A further look at Levitin's song production results reveals that pitches were rounded to the nearest semitone and octave errors disregarded, so that every error smaller than 2.5 semitones was considered "within 2", and no error could be considered larger than 6 semitones (Levitin, 1994:416).

With these facts in mind, one could state that "56% of participants made errors of 3-6 semitones on at least one of two trials". The TV themes data is also far from perfect: 43% of responses were *incorrect* for "The Simpsons" theme, and 42% of all responses in the one-semitone shift condition were also incorrect – for a two-alternative task (Schellenberg and Trehub, 2003:264). While the results of these studies are still reliably better than chance, performance levels are not very impressive. As well, the production consistency reported in Halpern's, Levitin's, and Trehub's studies could be due to motor memory from past productions of the melody, and not purely auditory memory of the absolute pitches (Halpern, 1989:575). It appears, then, that the average person's AP processing abilities are rather limited. Importantly, though, the more ecologically valid stimuli used in the above studies bring out significantly better performance than traditional AP testing (Levitin and Rogers, 2005:30-1), and thus these newer methods can be extremely useful for exploring previously undiscovered absolute abilities in relative processors.

Newer Approaches to Absolute Pitch

Recent definitions and conceptions of Absolute Pitch ability have begun to acknowledge possible relationships between absolute and relative pitch processing methods across individuals. In the Grove Dictionary for Music and Musicians, Parncutt and Levitin distinguish between what they call "tone-AP" and "piece-AP" (2001:37-38). They define tone-AP as we have defined AP ability thus far, and piece-AP as the ability to identify the absolute tonality of familiar pieces of music, or to produce familiar songs at their absolute pitch levels (Parncutt and Levitin, 2001:38). Piece-AP may not be simply a weak form of tone-AP (Takeuchi and Hulse, 1993:352), and it is certainly more widespread and arguably just as musically useful as tone-AP.

Along with these new definitions comes the much-needed differentiation between traditionally-defined AP ability and the AP *processing* ability that all people may share. Levitin (1994:421) describes two components that he says comprise AP ability: *pitch memory* ("the ability to maintain stable, long-term representations of specific pitches in memory, and to access them when required") and *pitch labeling* ("the ability to attach meaningful labels to these pitches, such as C# or A440"). According to this view, many musicians and non-musicians could have accurate pitch memory without pitch labeling (Levitin, 1994:421), and the relative strength of these components could contribute to individual variation among AP possessors and non-possessors.

Certainly the broad topics of AP and RP processing deserve more attention in future research. Most people continue to see a sharp line separating the few who process music using absolute pitch information from "the rest of us" who use only relative pitch. Perhaps by abandoning our assumption that Absolute Pitch ability is not a graded ability, and focusing more on the interplay between absolute and relative encoding across people with different musical backgrounds and abilites, we can come to a better understanding of pitch processing, the relations between pitch representation and memory, and the supposed conflict between AP and RP processing strategies throughout human development.

Acknowledgements:

I thank Laurel J. Trainor for helpful discussion and comments on an earlier draft.

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