

Absolute pitch: perception, coding, and controversies

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Recent findings in cognitive neuroscience and cognitive psychology are converging to shed light on the nature of processing, categorization and memory for pitch in humans and animals. Although most people are unable to name or place pitch values in consistent, well-defined categories, as they do for color, stable long-term memory for pitch has been shown in certain animal species, in infants, and in both adult musicians and non-musicians. 'Absolute pitch', the rare ability to label pitches without external reference, appears to require acquisition early in life, and involves specialized brain mechanisms, now partially identified. Research on pitch coding strategies informs wider theories in cognitive science of semantic memory, and the nature of perceptual categories.

Introduction

The study of the memory codes used for musical pitch is one of the oldest in experimental psychology, beginning with Helmholtz, Fechner, Stumpf and Wundt. Indeed, the Gestalt psychology movement was launched with the following question: how is it that a melody composed of specific musical pitches retains its identity despite transposition and when none of the original pitches are present? A related question is that of why some people are able to label all the notes of the musical scale as effortlessly as most of us label colors – a phenomenon known as absolute pitch (AP). Recent findings from neuroimaging, psychophysics, developmental psychology and cognitive science are converging to create a critical mass of knowledge on which to build new theories and experiments.

Research on absolute pitch has grown exponentially over the past 120 years. Defined as the ability either to *identify* the chroma (pitch class) of a tone presented in isolation or to *produce* a specified pitch without external reference [1–3], AP occurs in 1 in 10 000 people [2]. People with AP presumably possess an internal template to map musical tones to linguistic labels. Sometimes regarded as a mark of musicianship, AP is in fact largely irrelevant to most musical tasks. Being unable to turn it off, many possessors of AP perform dramatically poorer at judging whether a melody and its transposed counterpart

are the same, a task that non-AP musicians accomplish with ease [4,5].

Comparisons are often made between color labelling in most humans and pitch labelling in AP possessors [2], because AP possessors categorize and label pitches quite effortlessly and automatically. However, the human visual system is constructed in such a way as to allow discrete categories to emerge readily: information about color is separated into three (or sometimes four) streams by cones in the retina [6], and remains separated up to the cortex. By contrast, information from the cochlea and peripheral auditory system is much more continuous and lacks the one-to-one mapping between excitation patterns and percepts [7]. Accordingly, pitch and color perception are phenomenologically different: colors are experienced as belonging to categories; pitches are experienced (by most of us) as continuous. The fact that some individuals place pitches into categories requires an explanation of what is different about these individuals in their development or neural architecture.

Absolute pitch versus relative pitch

AP should not be confused with relative pitch (RP), an ability all trained musicians learn that allows them to identify or produce musical 'intervals', or relations between pitches (see [Box 1](#)). A trained musician presented with the tones *A* and *C* will identify the musical interval as a 'minor third' without being able to name either component tone. Told that the first note was an *A*, she will use her learned knowledge of musical scales to report that the second note was a *C*. Interestingly, if we tell the musician that the first note was *G*, she will report that the second note was a *Bb* – the note a minor third above *G* – and not know that she had been deceived. The *absolute* labels for notes are typically not attended to by RP possessors except when performing music from a score. Indeed, most musical training in the classical, jazz and popular traditions emphasizes the ability to play musical patterns and scales equally well in all keys.

In general, RP information is used to recognize and produce melodies, but some residual AP information might also be coded (see [Box 2](#)). This issue relates to a longstanding debate in the animal literature about the extent to which learning and internal representations are relational or absolute, and whether the function of memory is to preserve the details of experience or rather, to form abstractions and preserve the *gist* of experience [8].

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Box 1. Categories of pitch: scales and intervals

Musical practice subdivides the auditory frequency continuum into discrete pitches, forming the basis of scales. All musical cultures have scales based on frequency ratios of 2:1, the 'octave' [13]. Western musical tradition further subdivides the octave into 12 (logarithmically) equally spaced pitch classes. These repeat cyclically throughout the range of useable musical tones. An 'interval' is the distance between two tones. The smallest of these in the Western system is the semitone (1/12th of an octave), equivalent to adjacent keys on the piano. Tones an octave apart share certain perceptual features, and are often confused with one another; such 'octave equivalence' is a musical universal. The cyclical repetition, and the equal spacing of scale tones, enables 'transposition', the ability to play and recognize melodies regardless of their starting tone – it is the *pattern* of interval distances between the tones that defines the melody, not its absolute pitches. An exception is that the memory schemas for melodies held by AP possessors evidently include an integrated representation of absolute pitch levels that is impossible to separate from the interval information.

Many cultures and traditions have scales with fewer than 12 tones. Western classical music typically uses only seven of the 12 at a time (the 'diatonic scale') and a five-note ('pentatonic') scale is the basis of blues and rock music. No known cultures, however, have scales with *more* than 12 tones, perhaps because of cognitive processing limits [9,13].

'Tuning' refers to the precise relationship between the frequencies of a given tone and a standard, or between two tones of a nominal interval class. Orchestral musicians 'tuning up' before a performance are synchronizing the tuning of their instruments (which naturally drifts as the wood, metal, strings and other materials expand and contract as a result of temperature and humidity changes) to a standard frequency. Expert musicians often alter musical intervals for expressive purposes while they are playing (except of course on a keyboard instrument); sounding a note slightly lower or higher than its nominal value can impart emotion when done skillfully.

Although it has been claimed that Indian and Arab-Persian music uses 'microtuning', close analysis reveals that their scales also rely on only 12 tones and the others are simply expressive variations, glissandos and momentary passing tones [13], similar to the American blues tradition of sliding into a note for emotional purposes.

The existence of a small number of individuals who have learned to label upwards of 70 musical frequencies appears to contradict the oft-quoted 7 ± 2 limit of information processing [9]. Therefore, the study of pitch memory in general (and AP in particular) is relevant for theories of information processing, the accuracy and nature of long-term memories [8], and the ways in which perceptual stimuli are (or are not) coded into mental categories [10,11].

AP: phenomenology

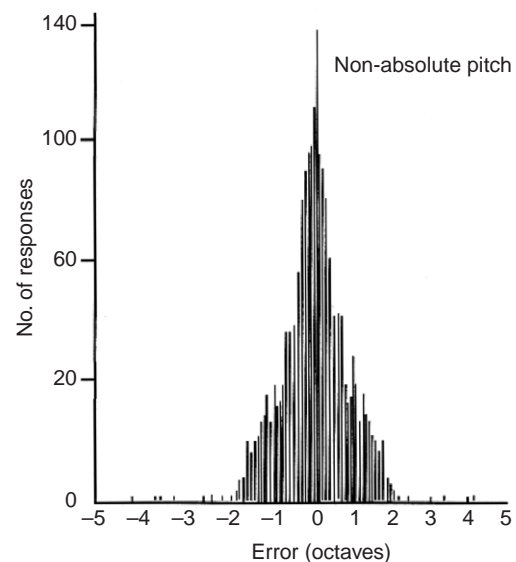
The mental codes used to represent color invoke categories (e.g. red, green, blue). For AP possessors, pitch categories are as fixed and familiar as color categories are for the rest of us, although category width can be idiosyncratic from person to person [10] (Figure 1). When AP possessors hear a familiar piece of music played in the wrong key (either when it is transposed, or when an instrument has been tuned to a different standard), they often become agitated or disturbed. To get a sense of what it is like, imagine going to the produce market and finding that, because of a temporary disorder of visual processing, the bananas all appeared orange, the lettuce yellow, and the apples purple.

Box 2. Does everyone have absolute pitch to some extent?

The human auditory system encodes absolute frequency information, but until recently, many assumed that this information was discarded by non-AP possessors. Because AP information is not required to recognize melodies or voices, it was deemed irrelevant information that a parsimonious system need not retain. But growing evidence suggests that many people might have stable, long-term auditory memories for pitch – one of the components of true AP ability, termed 'pitch memory', the other being 'pitch labelling' [62].

When people without AP are asked to identify a pitch [18] or musical key, the modal response is to answer correctly (see Figure 1). Even in the absence of explicit labelling, pitch memory is stable across time: everyday speech is apparently coupled to absolute pitch memory [63,64], and the mean pitch of one's speech correlates with perceptual judgments made in the 'tritone paradox' [42], an ambiguous auditory pattern. Asked to sing popular songs that exist in only one key and thus have an objectively correct pitch, most people sing at or very near the correct pitches [62]. People might indeed be capable of labelling pitches to some degree, but rather than using the specialized labels that musicians learn (such as *C, D, Bb, or Do, Re, Te*) they use ad hoc codes tied to the lyrics of the melody (many experimental participants know, for example, that the word *hotel* in 'Hotel California' is to be sung on *G*). This finding was replicated in a production task [65], and a new paradigm for testing pitch memory for isolated tones in non-musicians was recently introduced [66].

Taken together, these findings are consistent with other research showing that people remember visual experience with astonishing accuracy [67], and they suggest that elementary attributes of the auditory stimulus including pitch, tempo and timbre [30,43,65,68] might be stored in a memory system that is connected to the perceptual representation system [69]. If accurate memory for low-level features of the stimulus exists alongside an abstract memory for higher-level features (the sequence of relative pitches that allows for melody identification) then this constitutes evidence for 'multiple-trace memory models' [8,69], which are rapidly gaining support among cognitive scientists.



TRENDS in Cognitive Sciences

Figure 1. Errors made by non-AP possessors. When asked to label a tone, even those without AP do so with surprising accuracy, and their modal response is to give the correct answer. However, their variance is far greater than that for true AP possessors. These results suggest that even individuals not normally identified as AP possessors do possess something akin to AP. Data redrawn with permission from [18].

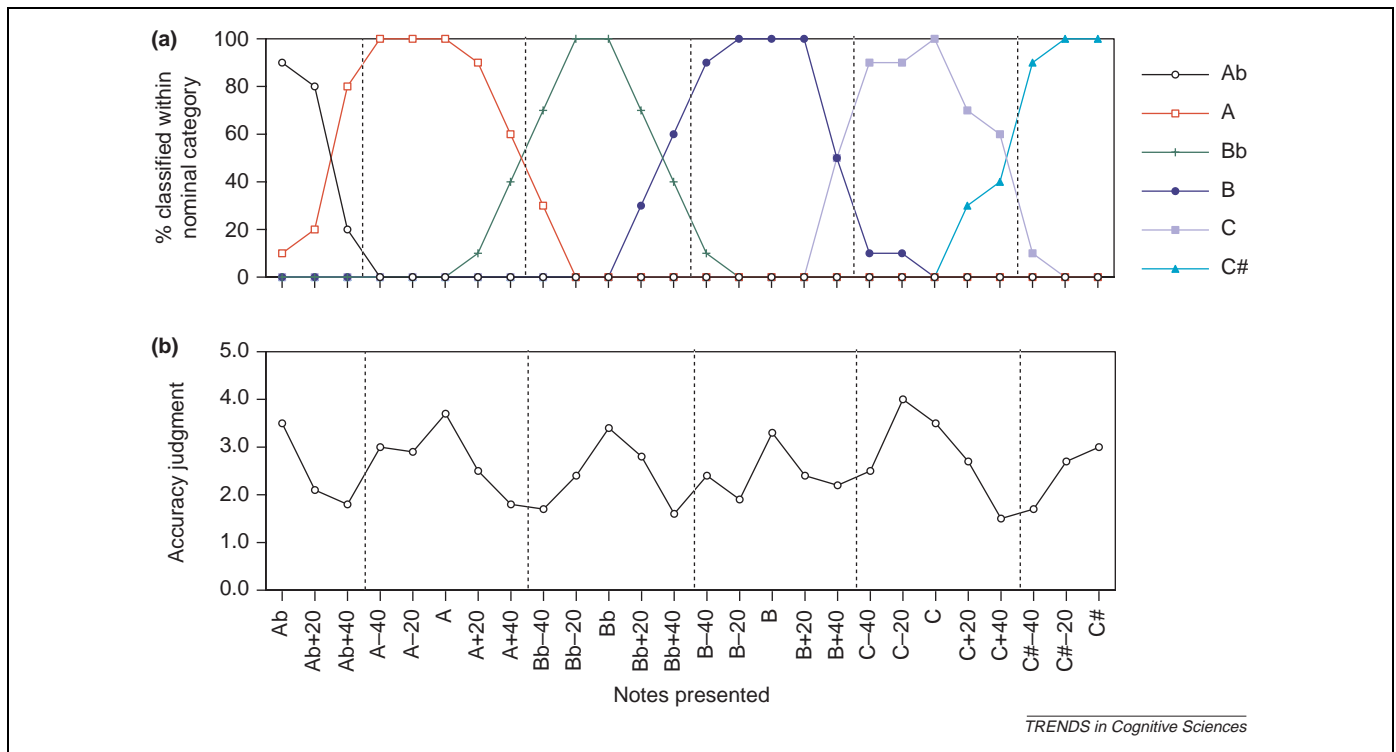


Figure 1. Classification functions for a typical AP possessor. The participant was presented with tones randomly drawn from the interval 207 Hz (*Ab*) to 277 Hz (*C#*), some of which were in tune and some of which were out of tune in 1/5th semitone (20 cent) increments. The task was first to identify the tone by name, and second, to rate how good an exemplar of its category the tone was. (a) AP possessors tend to place tones in categories with very little error, and to place even mistuned tones in their nominal categories. (b) Evidence that AP possessors do not have 'categorical perception' – perceiving all members of a nominal category as equivalent – comes from their judgment of accuracy, or the goodness function. The 'scalloped' shape of the goodness function, which is monotonically decreasing as the tone becomes more out of tune, reveals that this participant had a well-refined ability to detect differences among members of the same nominal category.

Some researchers believed that AP possessors had 'categorical perception' for pitch [12], as for color, exhibiting heightened discrimination for tones that cross category boundaries compared with tones within a category. This was subsequently refuted: AP possessors do treat pitches categorically, in that they place tones in nominal categories, but that category structure does not affect their *perception* of pitch [10,11], only their ability to label. Although all musicians treat intervals categorically (e.g. minor third, perfect fifth etc) [13] only AP possessors treat *isolated pitches* categorically.

AP is automatic, qualifying as a form of 'perceptual expertise' [14]: categorization occurs without deliberation [15], is accompanied by marked differences in speed of performance compared with non-experts, and experts can engage in other tasks while making judgments [16].

Absolute pitch is not 'perfect' pitch

It is important to emphasize that AP possessors do *not* have an exceptional pitch acuity. Absolute pitch is neither 'absolute' nor 'perfect' in the ordinary uses of those words; 'absolute' refers to judgments established independently, rather than by comparison. The terms 'absolute' and 'perfect' both imply in the lay mind a level of precision not typically present in AP possessors, who frequently make octave errors (confusing tones that are half or double the frequency), and semitone errors (confusing tones that are 6% apart) [17–19]. Like most human traits, AP is not an all-or-none ability, but rather, exists along a continuum [10,17,20,21]. Self-identified AP possessors score well

above chance (which would be 1 out of 12, or 8.3%) on AP tests, typically scoring between 50 and 100% correct [19], and even musicians *not* claiming AP score up to 40% [18]. Still, even those who score better than 90% show similar discrimination thresholds to, and are typically no better than, other musicians at noticing when one tone is out of tune with respect to another [11,17]. Clearly, there is nothing 'perfect' about AP; rather AP is the ability to place or produce tones within nominal categories.

Some people with AP can only label tones produced by one particular instrument. Because this instrument is often the piano, this has been termed 'absolute piano' [18]. This phenomenon suggests that their internal template for pitch is bound up with the timbre of that particular instrument, and the individual is consulting those multiple cues contained in the instrument's unique spectrum to encode pitch labels.

Some people have AP for only a single tone – often their tuning note – and fail to show the automatic and rapid identification found in true AP possessors (hence, this is termed 'quasi-AP'). They are able to obtain high scores on standard AP tests by calculating tone names from their one internal referent. It is only when reaction times are collected that they can be distinguished from true AP possessors.

Occasionally, someone develops AP on an instrument that is mistuned with respect to pitch standards (e.g. the commonly used $A=440$ Hz), as when a child grows up with an old piano that had been tuned down a semitone. This child will make consistent semitone errors on

Box 3. A genetic basis for absolute pitch?

A reasonable explanation for the unequal distribution of AP in the general population is that there exist genetic predispositions towards some of the underlying traits necessary for its development. A significant association between siblings who *claim* AP has been shown [60], although AP status was not confirmed in that report. Other evidence is an ethnicity cluster for AP; that is, a higher rate of AP among Asians [34] that is not attributable to sociocultural variables, because the elevated rate is also found in Americans of Asian descent. Speaking a tonal language cannot alone account for this finding, as not all Asian languages are tonal [70].

A genetic predisposition might be necessary but clearly is not sufficient: tone labels must still somehow be learned. When the type of musical training received was compared across ethnic groups, Asians were significantly more likely to have received ‘fixed pitch training’ (i.e. reinforcing tone/name associations), such as the Suzuki method, compared with Caucasians (29% versus 6%) [34]. This is predicted by the ‘unlearning theory’ [2], which posits that all children are born with AP but musical-interval training causes them to unlearn it.

The most convincing evidence for a genetic basis for AP would be to

compare adopted children with their biological and adoptive parents, or to study monozygotic twins reared apart (MZA), as has been successfully done for several traits, including religiosity, honesty and phobias. However, the number of MZA and AP possessors both being rare might render this approach impractical.

The search for a genetic component of AP may be inherently doomed [10] because of the difficulty in separating genes from environment in a skill that certainly must be taught, learned and nurtured. By analogy, most parents who speak French raise French-speaking children, but one need not invoke a genetic explanation – French is simply what those children are taught. Most importantly, one must ask what such putative genes would be coding for, and what the possible evolutionary value would be. Whereas pitch labelling might not confer any obvious value, a good pitch memory would, enabling those with it to detect subtle pitch changes in the voice of friends and foes, changes that might indicate anger, pleasure, stress or illness. The link between good pitch memory and pitch labelling is not yet clear, but the former would seem to be a prerequisite for the stable category formation associated with AP.

standardized tests (owing to no fault of his own), and yet might perform with near zero variance. The *best* AP possessor is therefore not necessarily the one with the fewest errors, but with the lowest variance [2].

Origins of AP: phylogeny and ontogeny

Many animals show preferential processing for absolute qualities of stimuli over relational information; it is a cornerstone of learning theory that relational processing requires greater cognitive sophistication. With regard to pitch processing, rats and wolves have been shown to use AP information, in the latter to identify members of their own pack. Starlings and rhesus monkeys first attempt to solve pitch tasks with AP, and if that fails, can resort to RP as a secondary strategy [22]. Monkeys but not songbirds show ‘octave equivalence’ (treating two tones an octave apart as the same; see Box 1), indicating that this form of RP developed after the divergence between birds and mammals [23].

The natural predisposition for pitch production and perception in human infants is an area of active research [24–26] (see Box 3). During the first few months of life, the fundamental frequency of infants’ cries stabilizes to a fairly constant pitch, a given infant showing a variation of less than one semitone [27]. This suggests the existence of an auditory–motor control feedback network that attends to absolute pitch values. Two experiments found AP to be the dominant perceptual mode of processing for 8-month olds [24,28], followed by a developmental shift towards RP. However, RP information can be elicited by (AP) infants in certain tasks [29], and one study concluded that AP information is *not* available to 6-month olds [30,31], so the picture is not clear as yet. Task demands and stimulus configuration clearly influence the types of results obtained and further work in this area is being actively pursued.

Critical periods

Studies suggest that AP is acquired before the age of 9 [32–34], and no case exists of an adult successfully acquiring it [2]. This has led to conjecture that, like

grammar and phonology in spoken [35] and signed languages [36], AP must be acquired during a ‘critical period’ or maturational stage before the development of other cognitive skills that might undo it. Indeed, the existence and high incidence of late-acquiring AP possessors among developmentally delayed populations such as Williams Syndrome [37] and autism [38] supports the maturational stage idea. The discovery of a small number of individuals who apparently acquired AP outside the critical window [38,39] does not, of course, contradict the critical-period hypothesis, given the statistical properties of biological distributions [40] (see Figure 2).

Further evidence in favor of a critical period for AP is that many AP possessors are better at identifying or producing the white notes of the keyboard, those tones

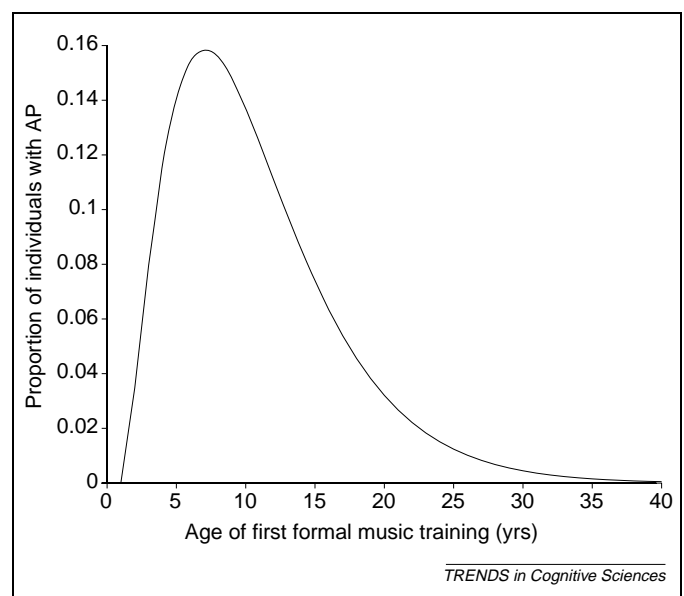


Figure 2. Data from retrospective reports on age of acquisition of AP, as modeled by a Gamma function. This suggests the possible existence of a critical period for AP acquisition. Gamma functions are consistent with a number of biological, developmental processes, because they are constrained at zero. The modal age of acquisition is around 7 years old. The existence of individuals beyond the mode should not be taken as evidence against the critical period hypothesis; a small number of individuals in the tails of the distribution are to be expected on statistical grounds. Redrawn with permission from [40].

that are generally learned first during music lessons, than they are the black notes [19]. In addition, speakers of tonal languages, like Mandarin Chinese, are more likely to have AP than speakers of non-tonal languages, suggesting that an early attentional focus on the pitch attribute of the auditory stream creates a better climate for AP acquisition [41,42].

Pitch labelling can be trained more successfully in children than in adults. With one week of training, adults learned to attach a label to a *single* tone and to produce or identify that tone well above chance [43]. Children of 5–6 years of age and adults were similarly trained for single-tone AP [44], and the accuracy of the 5–6 year-old group far exceeded that of the adult group and a group of younger children, strongly supporting the critical period hypothesis, at least for single-tone acquisition.

AP: neuroanatomy

AP possessors show neuroanatomical differences and different results on neural tests from non-possessors, especially in working memory and associative memory systems [3], although cause and effect have not yet been teased apart. When listening to transposed tone sequences non-possessors show a mismatched negativity and an attentive P3 evoked response potential (ERP), indicating the activation of working memory [45,46], whereas AP possessors appear to use long-term memory instead [47]. This is presumably because AP possessors need not use working memory to keep a mental representation of pitch active; they can recode the tone to a verbal label [3,48].

Anatomically, regions of right superior temporal cortex and planum temporale (PT) are smaller in AP possessors than non-possessors [49,50]. That AP is fundamentally a *labelling* ability and not a difference in perception, as is often argued, is best illustrated by two findings. First (as already noted), AP possessors and non-possessors have equivalent acuity and perceptual thresholds for pitch differences [10]. Second, in fMRI studies, when asked to name tones or intervals, AP possessors show focal activation in posterior dorsolateral frontal cortex (an area implicated in conditional associative learning), whereas RP possessors activate this same region *only* when naming intervals [51] (see Figure 3). That is, each group, naming that pitch attribute at which they are highly competent, recruits a neural region with known involvement in labelling, with no significant neural differences in primary auditory cortex (where pitches are initially processed).

Tracking brain activations in non-AP musicians during pitch-memory tasks over time [52] reveals early left-lateralized activation of superior temporal gyrus and the PT, and bilateral dorsolateral frontal regions (0–2 s post stimulus). This is followed by continued activation in the left lateral superior temporal plane and of the *right* PT, activation in the left frontal operculum and adjacent left mid-dorsal prefrontal cortex (3–4 s), and of the PT bilaterally (5–6 s). Throughout the 6-s post-stimulus period, the cerebellum is significantly activated bilaterally, consistent with other studies of tonal processing revealing a role for the cerebellum beyond motor control [53–55].

It has been claimed that persons blinded early in life (younger than 2 years) outperform late-blind and sighted people when reporting the direction (up or down) of pitch change between two successive tones [56]. However, their initial discrimination thresholds might be all that is better; their overall thresholds (deduced from the percent correct data) are actually worse than trained normals. Early-blind musicians are far more likely to possess AP than sighted ones, with nearly 60% of one sample reporting AP, compared with less than 20% of sighted musicians [57]. This has been attributed to the recruitment of unused neural resources from the visual cortex [58], although one study found that the same cortical networks were activated in a blind AP possessor as in sighted AP musicians [59].

How is AP acquired?

Controversy exists as to whether AP acquisition requires explicit training [32,40] or can result merely from incidental exposure to music [38,60]. Most possessors report having acquired the ability without remembering when or how it occurred [32]; all report having had music instruction. The failure to remember the learning episode can be taken as evidence that AP is a form of ‘semantic memory’ but does not necessarily imply that the learning was incidental.

Our own view is that AP is probably acquired just like other labels in the developing child’s vocabulary. The acquisition of pitch categories might parallel that of color categories, for both of which the child must learn to distinguish one perceptual quality (pitch chroma, or hue) from several other perceptual attributes as a prerequisite to creating the correct mappings between tone (or color) and its linguistic label [10]. How and why these associations are formed in a relatively automatic way in AP possessors is still unknown, but the most parsimonious explanation is simply that most children are not taught pitch labels (but are taught color labels). Active practice is necessary to produce plastic alterations in the cortex [61], lending support to the musical training argument.

A two-component model proposes that AP consists of ‘pitch memory’, which is widespread in the population (see Box 2), and ‘pitch labelling’, which is possessed exclusively by persons with AP [62]. AP and RP both rely on long-term memory (LTM) but in distinctive ways. At lower levels of processing, virtually all listeners extract the pitch component from a complex tone, separating it from other features such as loudness, timbre, and so on. The AP possessor then – automatically, for this is a hallmark of AP – compares the pitch of the tone with a stored LTM representation or ‘pitch template’ associated with a linguistic label. The RP possessor might hold the tone in working memory long enough to compare it with unlabelled temporally adjacent tones and then compare these intervals with a stored ‘interval template’ that is associated with linguistic labels, but few RP musicians report that they label intervals automatically. Rather, it requires conscious effort. In this sense, tonal processing among all but AP possessors may be analogous to ‘gist memory’ for speech [43], retaining the meaning without

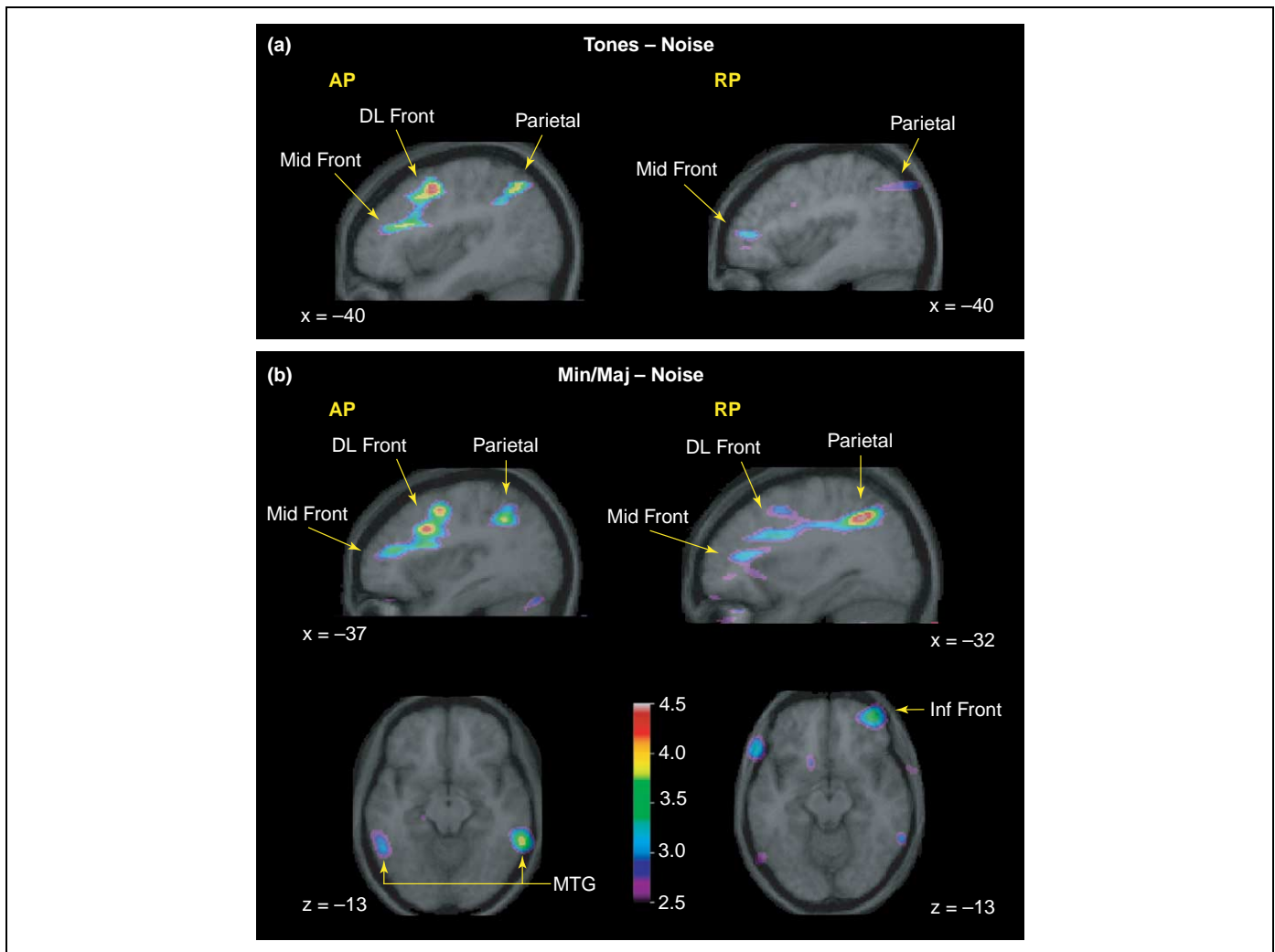


Figure 3. Data from a PET study of AP and RP possessors, who labelled (a) isolated tones and (b) intervals. The Blood Oxygenated Level Dependent (BOLD) signal for the task in comparison with broadband noise is illustrated. When naming tones, AP but not RP possessors recruit structures in left posterior dorsolateral prefrontal cortex ('DL Front' in figure), a region implicated in conditional associative learning (i.e. associated with object labelling). Both groups show activation in that region in response to labelling an interval as major or minor. This same region is recruited by non-musicians, once they are taught to label chords. Thus, it seems that for as yet unknown reasons, the associative function of DLPFC is enhanced or facilitated in AP possessors to help them form tone-label associations automatically. Reproduced with permission from [51] Copyright (1998) National Academy of Sciences, USA.

the stimulus details. On the other hand, the long-term memory representation for well-known songs might combine both absolute and relative pitch cues, suggesting a hybrid model and supporting the notion of accurate and stable 'pitch memory' distinct from labelling [59,62].

Box 4. Questions for future research

- Why do some AP possessors learn to generalize tone identification across instruments (and even to sinewave tones) whereas others do not?
- Why do some develop AP for only a single tone?
- What are the relative contributions of genetics and environment in developing AP?
- Assuming there exists a critical period for AP acquisition, what are the necessary and sufficient conditions?
- How is the planum temporale involved in AP? In general, are the observed neuroanatomical differences between possessors and non-possessors a cause or an effect of AP?
- What might be the evolutionary value, if any, for AP?
- The nature of pitch encoding in mammals has not been fully explored. It is unknown whether dogs, cats, pigs or primates could use both AP and RP information if given the right task and rewards.

Conclusions

A small percentage of the population has direct access to pitch information in the form of linguistic codes that they can apply to pitches. Research in this area suggests that access to some of this information might exist in a much larger proportion of the population. Infants appear to be born with the capacity to attend to and make use of absolute pitch information in melodic recognition tasks, although general development or musical training causes a strategic shift towards relative pitch processing in most normally developing (as opposed to developmentally delayed) individuals. Those who do acquire absolute pitch most probably do so within a critical period of development; they might have a genetic or neural predisposition to do so (Box 3), but some form of systematic training appears to be necessary (see also Box 4). Neuroanatomical studies have confirmed differences between AP possessors and non-possessors, although cause and effect have not been distinguished. New work on the neuroanatomy of pitch memory may yield additional clues. Understanding both the nature of

absolute pitch, and why it occurs in some individuals and not others, might tell us more about how humans process melodies and pitch, and has already informed work on perceptual expertise and memory, and theories about cognition, perception, and the interaction between the two.

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References

- Parncutt, R. and Levitin, D.J. (2001) Absolute pitch. In *The New Grove Dictionary of Music and Musicians* (Sadie, S. ed.), pp. 37-39, Grove
- Ward, W.D. (1999) Absolute pitch. In *The Psychology of Music* (Deutsch, D. ed.), pp. 265-298, Academic Press
- Zatorre, R.J. (2003) Absolute pitch: A model for understanding the influence of genes and development on neural and cognitive function. *Nat. Neurosci.* 6, 692-695
- Miyazaki, K. and Rakowski, A. (2002) Recognition of notated melodies by possessors and nonpossessors of absolute pitch. *Percept. Psychophys.* 64, 1337-1345
- Miyazaki, K. Recognition of transposed melodies by absolute pitch possessors. *Jpn. Psychol. Res.* (in press)
- Bimler, D.L. et al. (2004) Quantifying variations in personal color spaces: Are there sex differences in color vision? *Color Research and Application* 29, 128-134
- Imaizumi, K. et al. (2004) Modular functional organization of cat anterior auditory field. *J. Neurophysiol.* 92, 444-457
- Goldinger, S.D. (1998) Echoes of echoes? An episodic theory of lexical access. *Psychol. Rev.* 105, 251-279
- Miller, G.A. (1956) The magical number seven plus or minus two: Some limits on our capacity for processing information. *Psychol. Rev.* 63, 81-97
- Levitin, D.J. (2004) L'oreille absolue. *L'Année Psychologique* 104, 103-120
- Burns, E.M. and Campbell, S.L. (1994) Frequency and frequency-ratio resolution by possessors of absolute and relative pitch: Examples of categorical perception? *J. Acoust. Soc. Am.* 96, 2704-2719
- Siegel, J.A. and Siegel, W. (1977) Categorical perception of tonal intervals: Musicians can't tell sharp from flat. *Percept. Psychophys.* 21, 399-407
- Burns, E.M. (1999) Intervals, scales, and tuning. In *The Psychology of Music* (Deutsch, D. ed.), pp. 215-264, Academic Press
- Palmeri, T.J. et al. (2004) Computational approaches to the development of perceptual expertise. *Trends Cogn. Sci.* 8, 378-386
- Johanson, M.K. and Palmeri, T.J. (2002) Are there representational shifts during category learning? *Cogn. Psychol.* 45, 482-553
- Gauthier, I. and Tarr, M.J. (2002) Unraveling mechanisms for expert object recognition. *J. Exp. Psychol. Hum. Percept. Perform.* 28, 431-446
- Levitin, D.J. (1999) Absolute pitch: Self-reference and human memory. *International Journal of Computing Anticipatory Systems* 4, 255-266
- Lockhead, G.R. and Byrd, R. (1981) Practically perfect pitch. *J. Acoust. Soc. Am.* 70, 387-389
- Miyazaki, K. (1988) Musical pitch identification by absolute pitch possessors. *Percept. Psychophys.* 44, 501-512
- Deutsch, D. (2002) The puzzle of absolute pitch. *Curr. Dir. Psychol. Sci.* 11, 200-204
- Vitouch, O. (2003) Absolutist models of absolute pitch are absolutely misleading. *Music Perception* 21, 111-117
- Wright, A.A. et al. (2000) Music perception and octave generalization in rhesus monkeys. *J. Exp. Psychol. Gen.* 129, 291-307
- Hauser, M.D. and McDermott, J. (2003) The evolution of the music faculty: A comparative perspective. *Nat. Neurosci.* 6, 663-668
- Saffran, J.R. (2003) Absolute pitch in infancy and adulthood: The role of tonal structure. *Dev. Sci.* 6, 35-47
- Saffran, J.R. (2003) Mechanisms of musical memory in infants. In *The Cognitive Neuroscience of Music* (Peretz, I. and Zatorre, R.J. eds), pp. 32-41, Oxford University Press
- Trehub, S.E. (2003) Musical predispositions in infancy. In *The Cognitive Neuroscience of Music* (Peretz, I. and Zatorre, R.J. eds), pp. 3-20, Oxford University Press
- Wermke, K. et al. (2002) Developmental aspects of infant's cry melody and formants. *Med. Eng. Phys.* 24, 501-514
- Saffran, J.R. and Griepentrog, G.J. (2001) Absolute pitch in infant auditory learning: Evidence for developmental reorganization. *Dev. Psychol.* 37, 74-85
- Saffran, J.R. Changing the tune: The structure of the input affects infants' use of absolute and relative pitch. *Dev. Sci.* (in press)
- Plantinga, J. and Trainor, L.J. Memory for melody: Infants use a relative pitch code. *Cognition* (in press)
- Plantinga, J. and Trainor, L.J. (2003) Long-term memory for pitch in six-month-old infants. *Ann. N. Y. Acad. Sci.* 999, 520-521
- Chin, C.S. (2003) The development of absolute pitch: A theory concerning the roles of music training at an early developmental age and individual cognitive style. *Psychology of Music* 31, 155-171
- Costa-Giomi, E. et al. (2001) Absolute pitch, early music training and spatial abilities. *Ann. N. Y. Acad. Sci.* 930, 394-396
- Gregersen, P.K. et al. (2000) Early childhood music education and predisposition to absolute pitch: Teasing apart genes and environment. *Am. J. Med. Genet.* 98, 280-282
- Kuhl, P.K. (2003) Language, mind, and brain: Experience alters perception. In *The New Cognitive Neurosciences* (Gazzaniga, M.S. ed.), pp. 99-115, MIT Press
- Newman, A.J. et al. (2002) A critical period for right hemisphere recruitment in American Sign Language processing. *Nat. Neurosci.* 5, 76-80
- Lenhoff, H.M. et al. (2001) Absolute pitch in Williams Syndrome. *Music Perception* 18, 491-503
- Brown, W.A. et al. (2003) Autism-related language, personality, and cognition in people with absolute pitch: Results of a preliminary study. *J. Autism Dev. Disord.* 33, 163-167
- Brown, W.A. et al. (2002) Early music training and absolute pitch. *Music Perception* 19, 595-597
- Levitin, D.J. and Zatorre, R.J. (2003) On the nature of early training and absolute pitch: A reply to Brown, Sachs, Cammuso and Foldstein. *Music Perception* 21, 105-110
- Deutsch, D. et al. (2004) Absolute pitch, speech, and tone language: Some experiments and a proposed framework. *Music Perception* 21, 339-356
- Deutsch, D. and Henthorn, T. (2004) Speech patterns heard early in life influence later perception of the tritone paradox. *Music Perception* 21, 357-372
- Levitin, D.J. (2002) Memory for musical attributes. In *Foundations of Cognitive Psychology: Core Readings* (Levitin, D.J. ed.), pp. 295-310, MIT Press
- Russo, F.A. et al. (2003) Learning the 'special note': Evidence for a critical period for absolute pitch acquisition. *Music Perception* 21, 119-127
- Fujioka, T. and Trainor, L.J. A comparison of automatic melodic contour and interval encoding in musicians and nonmusicians. *J. Cogn. Neurosci.* (in press)
- Shahin, A. et al. Enhancement of neuroplastic P2 and N1c auditory evoked potentials in musicians. *J. Neurosci.* (in press)
- Hirose, H. et al. (2002) People with absolute pitch process tones with producing P300. *Neurosci. Lett.* 330, 247-250
- Zatorre, R.J. and Beckett, C. (1989) Multiple coding strategies in the retention of musical tones by possessors of absolute pitch. *Mem. Cogn.* 17, 582-589
- Keenan, J.P. et al. (2001) Absolute pitch and planum temporale. *Neuroimage* 14, 1402-1408
- Zatorre, R.J. (1998) Functional specialization of human auditory cortex for musical processing. *Brain* 121, 1817-1818

- 51 Zatorre, R.J. *et al.* (1998) Functional anatomy of musical processing in listeners with absolute and relative pitch. *Proc. Natl. Acad. Sci. U. S. A.* 95, 3172–3177
- 52 Gaab, N. *et al.* (2003) Functional anatomy of pitch memory: An fMRI study with sparse temporal sampling. *Neuroimage* 19, 1417–1426
- 53 Ackermann, H. *et al.* (2004) Temporal organization of ‘internal speech’ as a basis for cerebellar modulation of cognitive functions. *Behav. Cogn. Neurosci. Rev.* 3, 14–22
- 54 Levitin, D.J. and Menon, V. (2003) Musical structure is processed in ‘language’ areas of the brain: A possible role for Brodmann Area 47 in temporal coherence. *Neuroimage* 20, 2142–2152
- 55 Parsons, L.M. (2001) Exploring the functional neuroanatomy of music performance, perception, and comprehension. *Ann. N. Y. Acad. Sci.* 930, 211–230
- 56 Gougoux, F. *et al.* (2004) Pitch discrimination in the early blind. *Nature* 430, 309
- 57 Hamilton, R.H. *et al.* (2004) Absolute pitch in blind musicians. *Neuroreport* 15, 803–806
- 58 Rauschecker, J.P. (2003) Functional organization and plasticity of auditory cortex. In *The Cognitive Neuroscience of Music* (Peretz, I. and Zatorre, R.J. eds), pp. 357–365, Oxford University Press
- 59 Ross, D.A. *et al.* (2003) Cortical plasticity in an early blind musician: an fMRI study. *Magn. Reson. Imaging* 21, 821–828
- 60 Baharloo, S. *et al.* (1998) Absolute pitch: An approach for identification of genetic and nongenetic components. *Am. J. Hum. Genet.* 62, 224–231
- 61 Pantev, C. *et al.* (2003) Representational cortex in musicians. In *The Cognitive Neuroscience of Music* (Peretz, I. and Zatorre, R.J. eds), pp. 382–395, Oxford University Press
- 62 Levitin, D.J. (1994) Absolute memory for musical pitch: Evidence from the production of learned melodies. *Percept. Psychophys.* 56, 414–423
- 63 Braun, A. (2001) Speech mirrors norm-tones: Absolute pitch as a normal but precognitive trait. *Acoust. Res. Lett. Online, J. Acoust. Soc. Am.* 2, 85–90
- 64 Braun, M. (2002) Absolute pitch in emphasized speech. *Acoust. Res. Lett. Online, J. Acoust. Soc. Am.* 3, 77–82
- 65 Schellenberg, E.G. *et al.* (1999) Name that tune: Identifying familiar recordings from brief excerpts. *Psychon. Bull. Rev.* 6, 641–646
- 66 Ross, D.A. *et al.* (2004) A nonmusical paradigm for identifying absolute pitch possessors. *J. Acoust. Soc. Am.* 116, 1793–1799
- 67 Magnussen, S. *et al.* (2003) High-fidelity perceptual long-term memory revisited – and confirmed. *Psychol. Sci.* 14, 74–76
- 68 Trainor, L.J. *et al.* (2004) Long-term memory for music: Infants remember tempo and timbre. *Dev. Sci.* 7, 289–296
- 69 Schacter, D.L. *et al.* (2000) Memory systems of 1999. In *Handbook of Memory* (Tulving, E. and Craik, F.I.M. eds), Oxford University Press
- 70 O’Grady, W. and Archibald, J. (2000) *Contemporary Linguistic Analysis: An Introduction*, Pearson Education Canada Inc

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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.

References

- Blood, A. J., Zatorre, R. J., Bermudez, P., & Evans, A. C. (1999). Emotional responses to pleasant and unpleasant music correlate with activity in paralimbic brain regions. *Nature Neuroscience*, 2, 382-387.
- Blood, A. J., & Zatorre, R. J. (2001). Intensely pleasurable responses to music correlate with activity in brain regions implicated in reward and emotion. *Proceedings of the National Academy of Sciences*, 98, 11818-11823.
- Brown, S. (2000a). Evolutionary models of music: From sexual selection to group selection. In F. Tonneau, & N. S. Thompson (Eds.) *Perspectives in ethology. 13: Behavior, evolution and culture* (pp. 231-281). New York: Plenum Publishers.
- Brown, S. (2000b). The "musilanguage" model of music evolution. In N. L. Wallin, B. Merker, & S. Brown (Eds.) *The origins of music* (pp. 271-300). Cambridge, MA: MIT Press.
- Brown, S. (2001). Are music and language homologues? In R. Zatorre, & I. Peretz (Eds.) *The biological foundations of music* (pp. 372-374). New York: New York Academy of Sciences.
- Brown, S. (In press). "How does music work?" Towards a musical pragmatics. In S. Brown, & U. Volgsten (Eds.) *Music and manipulation: On the social uses and social control of music*.
- Brown, S., Merker, B., & Wallin, N. L. (2000). An introduction to evolutionary musicology. In N. L. Wallin, B. Merker, & S. Brown (Eds.) *The origins of music* (pp. 3-24). Cambridge, MA: MIT Press.
- Brown, S., Parsons, L. M., Martinez, M. J., Hodges, D. A., & Fox, P. T. (Submitted). The song system of the human brain.
- Brown, S., Parsons, L. M., Martinez, M. J., Hodges, D. A., & Fox, P. T. (In preparation). Music and language side by side in the brain.
- Darwin, C. (1871). *The descent of man, and selection in relation to sex*. London: J. Murray.
- Gardner, H. (1983). *Frames of mind: The theory of multiple intelligences*. New

York: Basic Books

- Miller, G. S. (2000). *The mating mind: How sexual selection shaped the evolution of human nature*. New York: Doubleday.
- Penhune, V. B., Zatorre, R. J., & Evans, A. C. (1998). Cerebellar contribution to motor timing: A PET study of auditory and visual rhythm reproduction. *Journal of Cognitive Neuroscience*, 10, 752-765.
- Perry, D. W., Zatorre, R. J., Petrides, M., Alivisatos, B., Meyer, E., & Evans, A. C. (1999). Localization of cerebral activity during simple singing. *NeuroReport*, 10, 3979-3984.
- Pinker, S. (1997). *How the mind works*. New York: Norton.
- Rao, S. M., Mayer, A. R., & Harrington, D. L. (2001). The evolution of brain activation during temporal processing. *Nature Neuroscience*, 4, 317-323.
- Sober, E., & Wilson, D. S. (1998). *Unto others: The evolution and psychology of unselfish behavior*. Cambridge, MA: Harvard University Press.
- Wallin, N. L. (1991). *Biomusicology: Neurophysiological, neuropsychological and evolutionary perspectives on the origins and purposes of music*. Stuyvesant, NY: Pendragon Press.
- Zatorre, R. J., & Belin, P. (2001). Spectral and temporal processing in human auditory cortex. *Cerebral Cortex*, 11, 946-953.
- Zatorre, R. J., Belin, P., & Penhune, V. B. (2002). Structure and function of auditory cortex: Music and speech. *Trends in Cognitive Sciences*, 6, 37-46.
- Zatorre, R. J., Evans, A. C., & Meyer, E. (1994). Neural mechanisms underlying melodic perception and memory for pitch. *Journal of Neuroscience*, 14, 1908-1919.

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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; Welles, 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 because they were taught it and made an effort to learn it. This is not inconsistent with the notion that there may indeed be *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.

References

- Bachem, A. (1937). Various types of absolute pitch. *Journal of the Acoustical Society of America*, 9, 146-151.
- Bachem, A. (1954). Time factors in relative and absolute pitch determination. *Journal of the Acoustical Society of America*, 26, 751-753
- Baggaley, J. (1974). Measurement of absolute pitch. *Psychology of Music*, 22, 11-17.
- Baharloo, S.; Johnston, P. A.; Service, S. K.; Gitschier, J.; Freimer, N. B. (1998). Absolute pitch: An approach for identification of genetic and nongenetic components. *American Journal of Human Genetics*, 62:224-231.
- BBC (2001). "Frontiers," feature show on Perfect Pitch, BBC Radio 4, broadcast date May 9, 2001.
- Brady, P. T. (1970). Fixed-scale mechanism of absolute pitch. *Journal of the Acoustical Society of America*, 48, 883-887.
- Burns, E. M., & Campbell, S. L. (1994). Frequency and frequency-ratio resolution by possessors of absolute and relative pitch: Examples of categorical perception? *Journal of the Acoustical Society of America*, 96, 2704-2719.
- Chaloupka, V., Mitchell, S., & Muirhead, R. (1994). Observation of a reversible, medication-induced change in pitch perception. *Journal of the Acoustical Society of America*, 96, 145-149.
- Cuddy, L. L. (1968). Practice effects in the absolute judgment of pitch. *Journal of the Acoustical Society of America*, 43, 1069-1076.
- Cuddy, L. L. (1970). Training the absolute identification of pitch. *Perception & Psychophysics*, 8, 265-269.
- D'Amato, M. R. (1988). A search for tonal pattern perception in debus monkeys: Why monkeys can't hum a tune. *Music Perception*, 5, 453-480.
- Deutsch, D. (1991). The tritone paradox: An influence of language on music perception. *Music Perception*, 8(4), 335-347.
- Deutsch, D. (1992). The tritone paradox: Implications for the representation and communication of pitch structure. In M. R. Jones & S. Holleran (Eds.), *Cognitive bases of musical communication*. Washington, D.C.: American Psychological Association.
- Deutsch, D. (2002). The puzzle of absolute pitch. *Current Directions in Psychological Science*, 11(6), 200-204.
- Deutsch, D., Henthorn, T., and Dolson, M. (1999). Absolute pitch is demonstrated in speakers of tone languages. *Journal of the Acoustical Society of America*, 106, 2267.
- Deutsch, D., Kuyper, W.L., & Fisher, Y. (1987). The tritone paradox: Its presence and form of distribution in a general population. *Music Perception*, 5(1), 79-92.
- Deutsch, D., Moore, F.R., & Dolson, M. (1986). The perceived height of octave-related complexes. *Journal of the Acoustical Society of America*, 80(5), 1346-1353.
- Glanz, J. (1999). Study Links Perfect Pitch to Tonal Language. *New York Times*, November 5, 1999, p. 1.
- Hulse, S. H., Cynx, J., & Humpal, J. (1984). Absolute and relative pitch discrimination in serial pitch perception by birds. *Journal of Experimental Psychology: General*, 113, 38-54.
- Jeffress, L. A. (1962). Absolute pitch. *Journal of the Acoustical Society of America*, 34(7), 987.
- Levitin, D. J. (1994). Absolute memory for musical pitch: Evidence from the production of learned melodies. *Perception & Psychophysics*, 56, 414-423.
- Levitin, D. J. (1996). Mechanisms of memory for musical attributes. Ph.D. Dissertation, University of Oregon, Eugene, Oregon, U.S.A. Dissertation Abstracts International, 57(07B), 4755. (University Microfilms No. AAG9638097).
- Levitin, D. J. (2000). In search of the musical mind. *Cerebrum*, 2(4), 2-24.
- Lockhead, G. R., & Byrd, R. (1981). Practically perfect pitch. *Journal of the Acoustical Society of America*, 70, 387-389.
- Miyazaki, K. (1988). The identification of musical pitch by absolute pitch possessors. *Perception & Psychophysics*, 44, 501-512.
- Miyazaki, K. (1992). Perception of musical intervals by absolute pitch possessors. *Music Perception*, 9, 413-426.
- Miyazaki, K. (1993). Absolute pitch as an inability: Identification of musical intervals in a tonal context. *Music Perception*, 11, 55-72.
- Parncutt, R. & Levitin, D. J. (2001). Absolute pitch. In S. Sadie [Ed.], *New Grove dictionary of music and musicians*. New York: St. Martins Press, 37-39.
- Profita, J., & Bidder, T.G. (1988). Perfect pitch. *American Journal of Medical Genetics*, 29, 763-771.
- Rakowski, A., & Morawska-Büngeler, M. (1987). In search of the criteria for absolute pitch. *Archives of Acoustics*, 12, 75-87. Toozee, Z. J., Harrington, F. H., & Fentress, J. C. (1990). Individually distinct vocalizations in timber wolves, *canis lupus*. *Animal Behavior*, 40, 723-730.
- Saffran, J. R. and Griepentrog, G. J. (2001). Absolute pitch in infant auditory learning: Evidence for developmental reorganization. *Developmental Psychology*, 37, 74-85.
- Schlaug, G., Jäncke, L., Huang, Y., & Steinmetz, H. (1995). In vivo evidence of structural brain asymmetry in musicians. *Science*, 267, 699-701.
- Sergent, D. (1969). Experimental investigation of absolute pitch. *Journal of Research in Music Education*, 17, 135-143.
- Shepard, R.N. (1964). Circularity in judgments of relative pitch. *Journal of the Acoustical Society of America*, 36(12), 2346-2353.
- Slonimsky, N. (1988). *Perfect pitch: A rueful autopsy*. New York: Oxford University Press.
- Vernon, E. (1977). Absolute pitch: A case study. *British Journal of Psychology*, 68, 485-489.
- Ward, W. D. (1999). Absolute pitch. In D. Deutsch (Ed.), *The Psychology of music, 2nd Edition*. San Diego: Academic Press, pp. 265-298.
- Wellek, A. (1938). Das absolute Gehör und seine Typen. *Zeitschrift für Angewandte Psychologie und Charakterkunde - Beihefte*, 83, 1-368.
- Wynn, V. T. (1992). Absolute pitch revisited. *British Journal of Psychology*, 83, 129-131.
- Zatorre, R. J., Perry, D., Becket, C., Westbury, C., Evans, A. C. (1998). Functional anatomy of musical processing in listeners with absolute and relative pitch. *Proceedings of the National Academy of Sciences*, 95, 3172-3177.

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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, now 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-