ABSOLUTE PITCH:
SELF-REFERENCE AND HUMAN MEMORY

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Abstract

A number of recent articles have demonstrated the existence of widely held misperceptions and misunderstandings about the nature of "absolute pitch." Fundamentally, absolute pitch is a cognitive ability that relies on self-referencing (to an internalized pitch template), and a highly developed coding mechanism that links verbal labels with abstract representations of perceptual input. Many researchers in genetics, cybernetics, and other fields (e.g. Baharloo, et al., 1998; Drayna, 1998) labor under the misconception 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 (Levitin, 1996). Further, many equate "absolute pitch" with "perfect pitch" whereas in fact, absolute pitch possessors do not perceive pitch any better than non-absolute pitch possessors.

In this paper, I will review what is known about absolute pitch, correct common and pervasive misconceptions, and present new data on the nature of absolute pitch from our psychoacoustics laboratory. I also discuss why absolute pitch is of interest to cognitive psychologists, philosophers of mind, linguists, and cyberneticists, in terms of what the ability reveals about the processing, coding, and memory functions of human beings. Finally, I propose the first arguments toward a coherent theory of absolute pitch ability.

keywords: absolute pitch; self-referencing; human memory; mental codes

1 Introduction – What is Absolute Pitch?

By definition, Absolute Pitch (AP) possessors are able to produce or identify tones without reference to an external standard, presumably through reliance on a highly developed internal template, or self-referencing mechanism. People with this ability are able to retain absolute information about sounds along the unidimensional continuum of auditory frequency, and they are able to attach labels to these sounds.

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1.1 Why is the study of Absolute Pitch interesting?

AP possessors are of interest in the study of human information processing, because they apparently violate the so-called 7±2 rule (Miller, 1956). This rule states that for essentially all unidimensional psychophysical continua (and auditory frequency is such a continuum), resolution in single-interval absolute identification tasks is limited: subjects are able to absolutely identify only five to nine stimuli over the stimulus range with perfect consistency, or alternatively, they are able to place the stimuli drawn from this range into only five to nine categories consistently. In contrast, AP possessors can classify or identify well over 60 stimuli (five octaves of twelve tones each), although because octave errors are common in some, it might be better to think of AP labeling ability as using the 12 categories of pitch chroma, and this doesn't create as large a violation of the 7±2 role. In any event, APers' abilities exceed that of most normal subjects in absolute judgment experiments and so a better understanding of how APers differ from non-possessors can address questions about the resolution of sensory memory, and the underlying mental codes involved in remembering auditory stimuli.

1.2 Absolute Pitch vs. Relative Pitch

Absolute Pitch (AP) should not be confused with Relative Pitch (RP). Relative pitch refers to the ability to identify musical <u>intervals</u>, while AP refers to the ability to identify individual musical pitches. To illustrate, if we present an RP possessor with the tones <u>A</u> and <u>C</u>, 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 <u>A</u>, her knowledge of interval and scale relations will allow her to identify the second tone as <u>C</u>. On the other hand, if we had told the subject that the name of the first tone was <u>D</u>, she would have no reason to disbelieve us, and would happily identify the second tone as <u>F</u> - the tone that is a minor third above <u>D</u> - 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. In contrast, if we played an <u>A</u> for an AP possessor and told him that it was a <u>D</u> he would know this was not correct. Most AP possessors actually have difficulty identifying musical intervals directly, and 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, who deduce the tone names from their ability to identify the interval they define.

Unfortunately, there persists a confusion in the literature about precisely what skills are involved in "absolute pitch" and "relative pitch." Some of this confusion arises because researchers in different disciplines (who, naturally are interested in different research issues) do not employ the terms in the same way.

Remember that the accepted definition of "absolute pitch" is that it is the ability to identify or produce a musical tone without reference to an external standard.

Historically, the cue for identification and production was a musical tone name or frequency such as "C," "Do" or "261 Hz." Elsewhere, I have argued that the use of other, informal names (such as "that's the first note in the song 'Hotel California' ") should also be accepted as evidence of absolute pitch (Levitin, 1994; 1996; 1999).

To the music educator, "relative pitch" is the ability to identify musical intervals such as "minor third" or "perfect fourth," or the similar skill of being able to name a tone if given an initial referent. But to the psychologist concerned with "absolute identification" vs. "relative identification," AP is the ability to label a tone without reference to others tones; RP is the ability to say that one pitch is higher than another, or to label it with respect to a standard given to the RPer. An additional source of confusion is that the ability to classify intervals is really a hybrid of absolute and relative ability. It is absolute because the interval is being named absolutely (and in a way that violates the 7 +/- 2 rule) and relative because it doesn't matter where the interval exists in pitch space.

1.3 Absolute Pitch is not "Perfect Pitch"

Recent articles by geneticists (e.g. Baharloo, 1998) have demonstrated confusion about the nature of AP by using the term "Perfect Pitch" interchangeably with the term "Absolute Pitch." The unfortunate implication of the term "Perfect Pitch" is that possessors of the ability have some sort of super resolution in their pitch perception, and that they can tell whether a tone is perfectly in tune or not. In fact, there is nothing "perfect" about absolute pitch. APers are no better at tone discrimination than other individuals (Bachem, 1954; Burns & Campbell, 1994; Levitin, 1996), and they are no more accurate at noticing deviations from perfect intonation. What they are better at is labeling tones along the unidimensional continuum of frequency, but there is some "slop" or "hysteresis" in their category boundaries, which will be explained below.

An important and related point is that AP is not an unusual ability in the domain of "pitch perception," despite the fact that Baharloo, et al. (1998, p. 229-230) repeatedly refer to the ability this way. AP is a skill in labeling (a form of long-term memory and categorization/classification behavior, involving self-referencing) and has nothing to do with pitch perception per se.

1.4 Methodological issues and confounds

1.4.1 Single tone AP; single instrument AP or "absolute piano"
Some subjects have an ability to identify or produce a single tone consistently. This occurs most frequently in the case of a musician who develops AP for their tuning note. Many violinists, for example, can produce or recognize "A" although they do not have any immediate labeling abilities for other tones. Others are able to label all the tones of their principal instrument (presumably because timbral cues help them to identify the tones). Lockhead and Byrd (1981) proposed the term "absolute piano" to refer to this

phenomenon. In their laboratory, some of their pianist subjects were able to correctly identify 90% of piano tones presented, but their performance dropped to less than 60% when tested with sine tones. Although with practice this performance increased, it underscores the need to distinguish those whose absolute pitch ability is independent of timbre, from those who may be relying on timbral cues. Those who do rely on such timbral cues are not of course, always able to identifies piano timbres better than others. Levitin (1996) found that among flute and violin players, identification of sine tones could sometimes exceed identification of piano tones. (Baharloo, et al., 1998, p. 226 erroneously state that "all individuals who scored well on the pure-tone tests would also score well on the piano-tone tests.")

1.4.2 Absolute production vs. absolute recognition

Some APers perform better in production than in recognition, although in most APers, these abilities are highly correlated. Levitin (1996) proposed a higher order factor, Pitch Memory (PM), to account for these correlations, although it should be noted that there exist large individual differences, and that in order to give subjects "the benefit of the doubt," both abilities should be tested.

1.4.3 AP vs. RP in the laboratory: the role of mental chronometry

Since the time of Bachem (1954) it has been known that some RPers are able to masquerade as APers (either inadvertently or intentionally) by using their knowledge of intervals to correctly name those musical tones presented during an experiment. If the RPer can learn the identity of just one pitch, he can use his knowledge of intervals to navigate through pitch space and correctly answer all of the test items. For these reasons, it is important to eliminate any cues to the subject during the testing session. The use of feedback should be avoided, for example, and tones should be randomly drawn from a large frequency range (3 octaves is often used) with the restriction that successive tones be separated by at least one and a half octaves (e.g. Miyazaki, 1988). Most importantly, the speed of identification is a critical measure in distinguishing those with AP (who are able to access tone names directly from their internal template) from those with RP (who must calculate intervals from a single, internally-referenced tone). Bachem (1954), Miyazaki (1990) and others have shown such reaction time (RT) measures to be the most reliable method for distinguishing the two populations, but Baharloo et al. inexplicably did not employ RT as a dependent variable in their studies, calling all of their data into question. Without RT, we have no way of distinguishing true AP possessors from those who have AP for a single tone and are using RP to "calculate" the remaining tones.

2 Absolute Pitch: Nature/nurture and musical training

Is absolute pitch genetic? Can absolute pitch be learned? These questions have been prominent in discussions of AP for the last century. Partly because certain prominent APers have argued that it is the ultimate in musical endowment (e.g. Berlioz; Scriabin), many musicians have sought to train themselves in this ability, and commercial products are available to assist in this training.

To begin with, one might reasonably argue that the correct question is not "why do only some people have AP," but rather, "why doesn't everyone have AP?" We know that there a frequency-selective neurons at every stage of the auditory system - why is that all of us are apparently unable to use this information for identification and recognition of tones?

The answer is, once again, because AP is not an ability of perception, but of linguistic coding. Baharloo, et al. argue that musical training develops AP, but this is not true. It is not musical training, but some *deliberate training* of pitch naming that develops absolute pitch. The term "musical training" in their paper is thus misleading. Actually, the goal of most musical training is contrary to that of absolute pitch training; the goal of most musical training is to teach children to attend to relational features of melodies, not the absolute features.

In fact, Dixon Ward popularized a theory of absolute pitch originally attributed to Abraham (1901, cited in Ward & Burns, 1982) that all musicians start out with AP, and unlearn it. This unlearning theory posits that as one becomes a better musician, one becomes trained to abstract out melodic patterns at the expense of absolute pitches. Indeed, jazz musicians practice for hours on end with the express goal of being able to play any motif or passage in any key, equally well.

A satisfactory theory of pitch labeling must account for the reasons that some people have the ability and others do not. A key aspect of this problem hinges on recognition memory. When the APers hear a tone, they are able to recognize it and place it in a context, and this context includes a link to a specific label. Non APers apparently experience no such recognition or context. The emerging consensus among psychologists is that AP ability requires activation and training during a critical period (analogous to the critical period required for language acquisition) and that the child must learn to make tone-label associations during this time. Preliminary evidence is that this critical period runs roughly from birth to age 6 (Cohen & Baird, 1990; Levitin, 1996).

2.1 Why doesn't everybody learn to label pitches?

Miller and Johnson-Laird have described the nature of the problem in attaching labels to sensory stimuli, using the example of the child's acquisition of color terms (Miller & Johnson-Laird, 1976, pp. 351-352). A parallel account of a child's learning tone labels might go something like this, dividing the problem (as they do) into two aspects, conceptual and linguistic. Conceptually, the child must learn to:

(a) make the appropriate abstraction of pitch from the other aspects of the auditory experience, including timbre and loudness;
(b) establish certain landmark pitches; and
(c) locate all pitches along the continuum of audible sound with respect to those landmarks.

On the linguistic side, the child must:
(a) learn specific uses of tone labels in particular contexts;
(b) learn to isolate the tone labels from other words as a contrastive set; and
(c) learn the referential value of each term.

Similar to what Miller and Johnson-Laird described for color learning, a host of problems are presented for the child learning tone labels. The child's peers might not use tone names frequently; the child presumably hears a variety of intermediate and non-focal tones for which she hears no names; tone labels are generally irrelevant to any task that is meaningful to the child. The problem of sorting out the pitch attribute from a complex auditory stimulus should not be underestimated. Since any exemplar of a tone will generally be an object with multiple attributes, including timbre, duration, attack and decay envelopes, a nontrivial induction is required to determine that aspect of the sound that is stable as other attributes vary from one exemplar to the next.

But perhaps the strongest factor conspiring against the acquisition of tone labels is that focal tones have no biological salience in the human brain in the manner that focal colors do. While it is true that frequency-sensitive neurons exist throughout every stage of the auditory system, there is no evidence that particular frequencies hold any special status in the brain. There are no cross-cultural musical universals, insofar as pitch is concerned. Even a lifetime of exposure to a certain system of pitches (such as the western A440 scale) does not appear to create salient markers for pitch in the absence of musical context (Levitin, Stern, & Stern, in preparation). Thus, while the association between basic category color terms and focal colors is supported by the biology of vision, there is no evidence for such a linguistic/biological association in audition.

How then do some children develop AP at all? The most likely explanation is that AP is acquired and developed through systematic training, albeit training of which the subjects themselves, as adults, are unaware. (Most AP possessors can not recall the specific episodes of their training. Such acquired knowledge would be considered a part of semantic memory and one would not expect the APers to remember the specific episode of learning.) Cuddy (1970) has developed methods for the training of AP and her results support the acquisition-through-training hypothesis.

2.2 The search for an Absolute Pitch gene

The most troubling course of research to me is the search for an absolute pitch gene. I am not smart enough to understand how the Baharloo team can hope to distinguish genetics from environment in this endeavor. Just because something runs in families does not make it genetic, does it? Speaking French runs in families, too, but I doubt anyone would propose a genetic basis for Francophonity - it simply "runs in families" because French-speaking parents tend to teach French to their offspring. Likewise, families in which a parent has AP are going to be more likely to provide the type of environment in which a child can develop AP. I am reminded of Lloyd Jefress' letter to the editor of JASA in 1962:

> "The very circumstances which have caused people to believe the trait to be inherited are those which would bring about its 'imprinting.' The children of people having absolute pitch are sure to be examined early for the existence of the trait and their first fumbling steps rewarded. in a home where the parents cannot tell "c" from coal scuttle, no such hospitable environment for growth of the trait will exist . . . only in the home of musical parents could absolute pitch develop; where the parents have absolute pitch it is almost sure to." (p. 987).

Baharloo et al. report on questionnaire studies of families in which a child with AP is more likely to have a sibling with AP than a child without AP. they claim this to be strong evidence for the genetic basis of AP. I would be more convinced by the <u>opposite</u> result. I assume that children reared together have similar environments. If one could demonstrate that siblings reared in the same environment as an AP possessor are LESS likely to develop AP, THEN I will be more convinced that there must be a gene for it.

3 The nature of APers internal representations

Music theory and analysis tends to treat pitches categorically: any pitch belongs to one category or another, and variations of "in-tuneness" are a rather esoteric branch of analysis. One question that emerges about people with good pitch memory and pitch labeling - a question that relates to "categorical perception" - concerns the underlying representation of the pitch that accompanies a given label. Petran (1939, cited in Takeuchi & Hulse, 1993) believed that AP possessors will accept a <u>range</u> of frequencies as a given pitch; that some subjects will argue that the pitch is not a single frequency, but is anywhere within a range of frequencies. Accordingly, one possibility is that people have a "wide net" notion of pitch, and believe that "A#" refers to a range of pitches, with a many-to-one mapping of pitches to labels. When asked to produce a given pitch, or rate the goodness of pitches, such respondents might not distinguish among tones within the category. Alternatively, people might have a very narrow range of pitches that they consider to be "A#," presumably in the midpoint of the category, and corresponding to the focal tone. This range of pitches could constitute a "narrow anchor" for each focal tone.

For the last three decades, it had been believed that APers had a so-called "wide net" notion of pitch, or in other words, that they had categorical perception CP) for pitch and were unable to detect changes within a pitch category. This belief was based on the work of Siegel (1972; Siegel & Siegel, 1977) who claimed that APers had categorical perception, but actually provided no evidence for such a claim. The confusion no doubt arose from the fact that Siegel was not using the term "categorical perception" according to its accepted definition in cognitive psychology. The prevailing definition of CP is that subjects must show (1) clear category boundaries in a categorization task and (2) an enhanced ability to discriminate stimuli near or across category boundaries, relative to stimuli in the center of a category (Studdert-Kennedy, Liberman, Harris & Cooper, 1970). Note that this definition differs from the "strong" definition of CP, that subjects cannot tell the difference among stimuli within a category (Harnad, 1987). What Siegel did find is that APers perceive pitch categorically, that is, they are able to place non-focal pitches within the proper category. Later studies by Miyazaki (1988) found that APers do show clear category boundaries (requirement #1 above), but these experiments did not test discrimination ability in these subjects (requirement #2 above), leaving the CP question unresolved.

To further understand CP, Levitin (1996) presented subjects with tones in varying degrees of "in-tuneness," by paying focal scale tones and detuned variants of those tones in 20 cent increments. If subjects rate only the focal or prototype tone as the best exemplar of the category, this is evidence for the "narrow anchor" view of absolute pitch; by contrast, if subjects rate one or two tones on either side of the focal tone as equally good exemplars for the category, this is evidence that APers have a "wide net" notion of pitch. The results of this experiment confirmed that APers to have a "narrow anchor" notion of pitch: the subjects' goodness ratings formed a sinusoidal pattern, with the peaks of the curve corresponding to focal points and the troughs corresponding to the boundaries between categories.

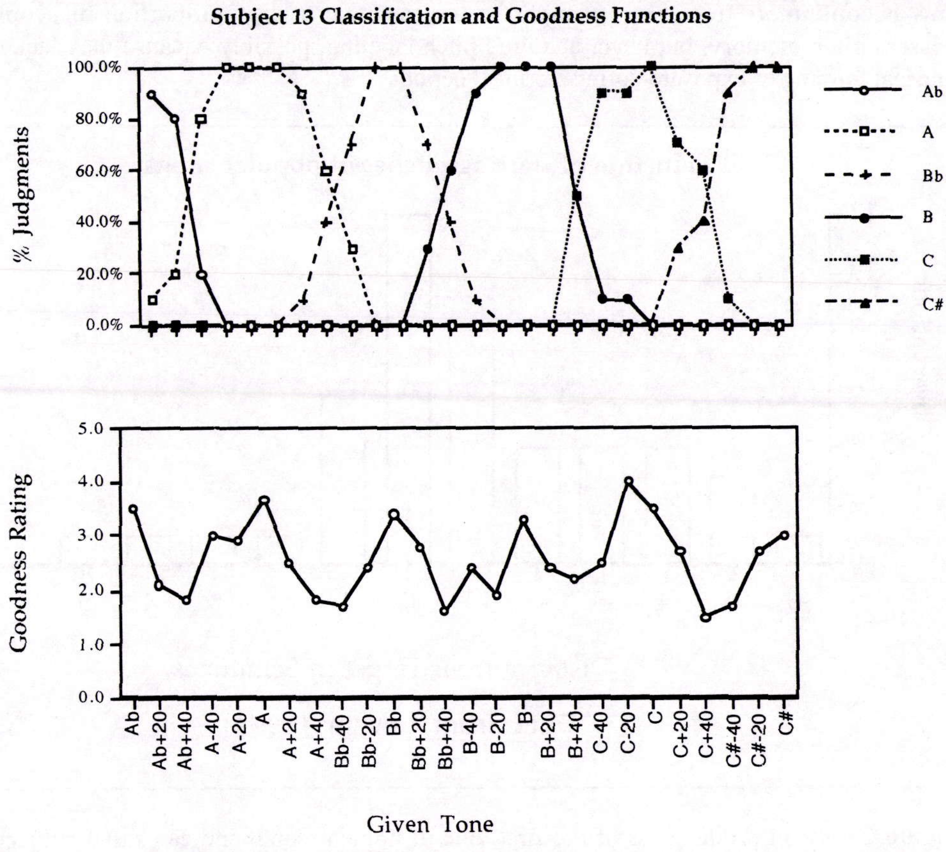

Figure 1: Previously unpublished data from Levitin (1996) for a typical AP subject. Subjects were asked to classify tones from along the continuum from Ab3 to C#3, and then to provide goodness ratings for each tone. The scalloped or sinusoidal nature of the goodness functions is evidence that AP possessors have the ability to distinguish tones from within a category, and that they do not have "categorical perception" for pitch.

4 A theory of Absolute Pitch ability

Levitin (1994) proposed a two component theory of AP, requiring both "Pitch Memory" and "Pitch Labeling." In that experiment, subjects unselected for musical ability were asked to sing their favorite popular songs (songs which were only known in one canonical version). Most subjects reproduced the songs at or very near the correct pitches, providing support for the notion that these two components are separable. The puzzle of why AP, as traditionally defined, exists in such small numbers, and why previous studies have hinted at the existence of "latent absolute pitch abilities," may now become more tractable. It might be the case that a large proportion of people possess pitch memory, but never acquired pitch labeling, possibly because they lacked musical training or exposure during a critical period.

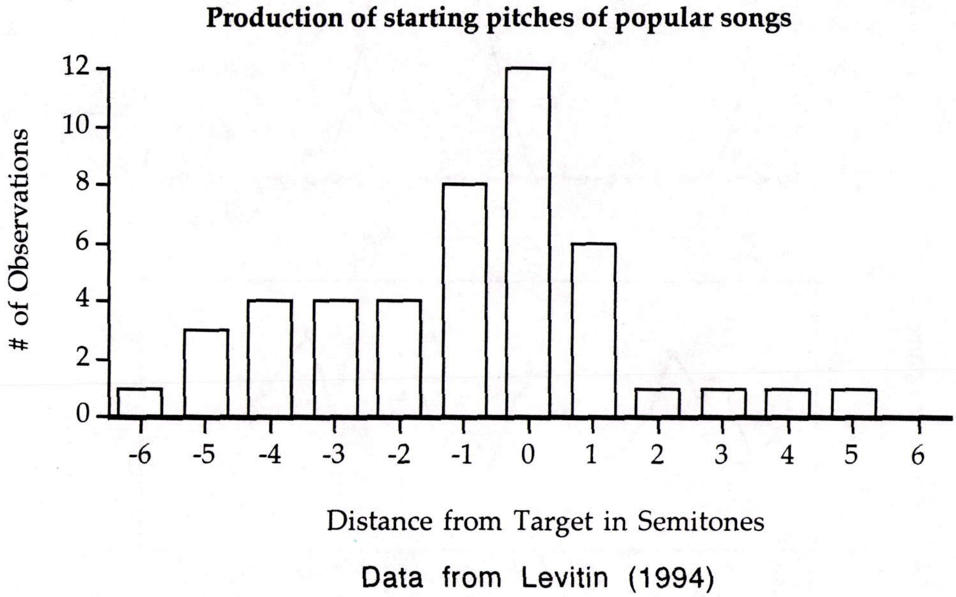

Figure 2. Vocal productions of the first tone of popular songs indicates that subjects have accurate memory for musical pitches, even if they cannot label those pitches using traditional names.

Over fifty years ago, the Gestalt psychologists proposed that memory is the residue of the brain process underlying perception. In a similar vein, Massaro (1972) argued that "an auditory input produces a preperceptual auditory image that contains the information in the auditory stimulus. The image persists beyond the stimulus presentation and preserves its acoustic information" (p. 132). The present finding of absolute memory for pitch supports this view.

Taken together, the present study and previous findings suggest that the people are capable of retaining both abstract relational information (e.g., melody) as well as some of the absolute information contained in the original physical stimulus, and further, that these representations are separable. One should be cautious, however, about jumping to conclusions. Subjects who exhibit pitch memory are not necessarily exhibiting *perceptual memory* (as in the perceptual residue the Gestalt psychologists spoke of), but it is clear that their memories are to some extent *veridical,* and that they retain access to some absolute features of the original stimulus. We might now ask to what extent - and in what other sensory domains - this type of dual representation exists.

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