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In their own words: Analyzing the extents and origins of absolute pitch

Elizabeth West Marvin[1], Joseph VanderStel[1] and Joseph Chi-Sing Siu[2]

Abstract

Although tests of absolute pitch (AP) possessors' abilities have been studied extensively in the laboratory, few researchers have focused their study on the experiences of AP possessors engaging in musical and nonmusical activities in their daily lives. We recorded semi-structured interviews with 30 AP musicians to investigate three research questions: what is it like to experience AP, how does AP impact musicianship and performance, and how do first-hand accounts correspond with published findings on AP types and acquisition? Recorded interviews were transcribed and coded by two independent researchers; after coding, we determined themes and connections that emerged from the data. These fall into three areas: AP associations (cross-modal); AP strength (including limitations); and AP applications (to music-making). These themes are described, illustrated with quotations, and related to current research. We document the positive and negative impacts of AP on musicianship and performance. Finally, AP possessors' accounts lead us to endorse theories of distinct AP types and to posit an important role for implicit learning (daily updating or reinforcement of AP).

Keywords

absolute pitch, auditory perception/cognition, aural skills, informal learning, qualitative, timbre

Absolute pitch (AP) is the rare ability to identify or to produce a specific pitch without reference to an external standard (Baggaley, 1974; Deutsch, 2013; Ward, 1999). It has been estimated that fewer than one in 10,000 people in the general population of North America and Europe possess this ability (Levitin & Rogers, 2005; Profita, Bidder, Optiz, & Reynolds, 1988; Takeuchi & Hulse, 1993). However recent research has documented a much higher proportion of AP possessors in subpopulations such as collegiate music students (Deutsch, Dooley, Henthorn, &

[1]Eastman School of Music, University of Rochester, Rochester, NY, USA
[2]University of Maryland Baltimore County, Baltimore, MD, USA

Corresponding author:
Elizabeth West Marvin, Eastman School of Music, 26 Gibbs Street, Rochester, NY 14604, USA.
Email: bmarvin@esm.rochester.edu

Head, 2009; Deutsch, Henthorn, Marvin, & Xu, 2006; Gregersen, Kowalsky, Kohn, & Marvin,1999; Sergeant & Vraka, 2014).

This study explores collegiate music students' experiences with respect to their AP by analyzing their responses to questions in a semi-structured interview. Our primary research questions are:

1. What is it like to experience AP?
2. How does AP possession impact musicianship and performance?
3. How do first-hand accounts correspond with published theories of AP types and AP acquisition?

The first two questions guided our initial interviews, while the third arose *post hoc*, stemming from emergent themes in the data analysis.

To provide context for the third question, we review results from several independent labs that have classified AP possessors into distinct types (Bachem, 1937; Baharloo, Johnston, Service, Gitschier, & Freimer, 1998; Ross, Gore, & Marks, 2005). Bachem proposed a three-tier model: (1) Universal AP (infallible or fallible); (2) Limited AP; and (3) Borderline AP. Those with Infallible Universal AP (8% of Bachem's participants) could accurately identify notes over the whole range of the piano in any timbre, including pitches in sounds of daily life; responses were immediate and definite. Listeners with Fallible Universal AP (49% of his participants) might make octave or semitone errors, especially in very high or low registers, and be less likely to recognize pitches sounding from everyday objects. Listeners with Limited AP (22%) identified pitches confidently only in a three- to four-octave range or when heard on particular instruments; these listeners were less certain of their answers, and took significantly more time to identify a note. Finally, Borderline AP listeners (21%) were slow and indecisive, and made regular errors that were larger than a whole-tone.

In a study investigating genetic factors in AP acquisition, Baharloo et al. (1998) also divided their AP subjects into groups: AP-1 listeners scored high on identification of pure tones, while AP-4 listeners displayed high accuracy on piano tones, but performed poorly on pure tones. AP-2 and AP-3 listeners scored between. Barharloo et al. (1998) hypothesized that the variability observed in the different types of AP possessors might be related to different underlying cognitive or physiological processes. For example, AP-1 individuals may have identified notes based only on the fundamental frequency, while AP-4 individuals may have relied upon information in the overtone structure of each pitch (i.e., its timbre) to help them identify pitches correctly.

Ross et al. (2005) categorized AP listeners into just two types: either APE ("ability to perceptually encode") or HTM ("heightened tonal memory"). According to these authors, physiological differences in APE listeners enable them to encode the frequency of any auditory stimulus automatically, at a pre-categorical level—before assigning learned pitch labels. Their abilities are consistent across timbres, tuning systems, and pitch-height extremes; they also identify pitches in everyday sounds. In contrast, HTM possessors acquire AP through early musical training, and they recognize pitches by rapid comparison to a learned pitch template stored in long-term memory. They can label pitches only in musical stimuli, not other auditory stimuli, and their accuracy might be impaired when listening to unfamiliar timbres or tuning systems. Ross et al. categorized 36% of their AP subjects as APE and 64% as HTM possessors.

Criteria for dividing AP listeners into types overlap somewhat with theories of AP acquisition. The hypothesis that AP is innate is supported by experimental evidence that infants can process pitches absolutely (Saffran & Griepentrog, 2001). Researchers have also traced AP possessors within families and between identical and non-identical twins (Gingras, Honing, Peretz, Trainor, & Fisher, 2015; Zatorre, 2003) as support for a genetic factor. Neuroimaging studies provide evidence for physiological differences—perhaps genetically determined—in the brains of AP musicians, such as a leftward asymmetry in the planum temporale and differences of cortical thickness (Dohn et al., 2013; Loui, Li, Hohmann, & Schlaug, 2011; Schlaug, 2001; Zatorre, 2003). Even so, researchers are unsure whether these differences are caused by genetics or whether they are the result of brain plasticity as learners acquire AP abilities.

An alternative hypothesis holds that AP is learned in childhood, possibly during a critical period, either via explicit training designed for AP acquisition or by implicit learning during instrumental lessons and music listening. Many studies have reported that AP possessors began their musical training at or before age 6 (Deutsch, 2013; Sakakibara, 2014; Takeuchi & Hulse,1993). Longitudinal studies of AP training for children also provide evidence for an early-learning hypothesis. Sakakibara (2014), for example, trained children ages 2 to 6, for several years. All children who completed the training acquired AP, although the time required to achieve this result varied widely. Vraka (2009) explored differences in childhood music pedagogy and cultural attitudes toward AP in Japan and Greece, finding a higher incidence of AP in Japan, where children began music study at a younger age, studied with a fixed-do pedagogy (pitches are explicitly and consistently labeled, *do* = C, *re* = D, etc.), practiced longer, and experienced a cultural ethos of high achievement. Finally, it may be that AP relies upon constant updating of the frequency-to-pitch-label association via implicit learning from music heard in the listener's environment. Hedger, Heald, and Nusbaum (2013) tested whether AP possessors gradually introduced to a pitch standard lower than A440 (in Hz) would "adjust" their AP labels following exposure, and demonstrated that the new standard was implicitly learned.

This article fills a lacuna in previous research by focusing primarily on the experience of living with AP, and noting where this ability assists or impairs music-making. Although some previous studies have reported interview data (Barharloo et al., 1998; Ross et al., 2005; Vraka, 2009), these data were not the primary focus of the investigations, but instead complemented analysis of behavioral measures (and their interviews may have included only a subset of the participants). Finally, we align AP possessors' personal experiences with current theories of AP types and AP acquisition.

Method

Participants

Thirty-two self-identified AP possessors were recruited from the Eastman School of Music (Rochester, NY) to participate in the study. Participants' AP status was confirmed by a short pre-screening test, and two were excluded because they did not meet the eligibility requirement (.85 correct). The remaining 30 AP participants scored a mean of .98 (SD = .04) on a test consisting of 36 synthesized piano tones spanning three octaves, ranging from C_3 (131 Hz) to B_5 (988 Hz), with an inter-onset interval of 4 seconds. The format of the test and use of piano timbre were chosen to correspond with previous work by the Deutsch lab (Deutsch et al., 2009; Deutsch et al., 2006; Dooley & Deutsch, 2010, 2011) and to maximize our participant numbers, since many researchers have shown higher AP accuracy with piano timbres than pure tones. The tones were presented in three sets of 12 pitches (preceded by four practice tones, presented without feedback), arranged so that the interval between successive tones was always greater than one octave.

Participants (17 females, 13 males) ranged in age from 18 to 34 (M = 21.7; SD = 4.09). Twenty-nine of the 30 participants were music majors with an average of 13.78 years of formal music training (SD = 4.37); the single non-music major had likewise received 14 years of formal music training. The average age at which participants began sustained musical activities was 5.63 years (SD = 2.47, range 2 to 12 years); 63% began music study at age 6 or younger, 37% at 7 or older. All were instrumentalists; 22 of 30 (73%) reported piano as their first instrument (Appendix A, posted in supplemental materials online, provides descriptive data about our participants, including their instruments). Although enrolled in a U.S. university, participants were a mix of American and foreign students: for 42% their first language was a tone language (Mandarin, Cantonese, Vietnamese), for 36% English, and for 21% another language (Appendix A).

Procedure

After consent and AP prescreening, participants were engaged in a semi-structured interview, which was recorded and later transcribed. The interviewers asked 20 questions (Appendix B, supplemental materials online), but also freely asked follow-up questions. Questions explored the participants' earliest memories of AP, the perceived extents of their AP ability, and their thoughts about how AP has affected their daily lives as musicians.

Data coding protocol

Each recorded interview was transcribed by a research assistant, and proofread for transcription errors by another. A thematic analysis of the transcripts was implemented in multiple stages, modeled after the inductive methodologies of Grounded Theory (Charmaz, 2008; Glaser & Strauss, 1967). In the first stage, each transcript was coded for recurrent themes by two researchers working independently. All coders consulted a master list of codes, developed incrementally as the transcripts were analyzed, and codes were eventually organized into larger categories. Next, the authors reconciled the independent work of the two coders, and worked dynamically to frame thematic content into more abstract categories. In the final stage, the authors mapped relationships among themes graphically onto illustrative models.

Results

Three themes emerged from our analysis of interview transcripts: (1) AP associations; (2) AP strength; and (3) AP applications. We present each theme in turn, with sample quotations from participants (participant numbers in parentheses) and diagrams where appropriate. Quotations represent ideas that emerged from the data, but are only representatives (others may have volunteered similar information). The diagrams summarize hierarchical relationships among themes: ovals enclose lower-level themes, and rectangles enclose higher-level themes. Tallies within the ovals represent the number of participants who mentioned a lower-level theme. Numbers within rectangles aggregate numbers in ovals and thus may sum to more than 30.

AP associations

We asked participants to describe any involuntary nonmusical associations with pitch. Responses more often cited associations with *keys* rather than individual pitches, which we

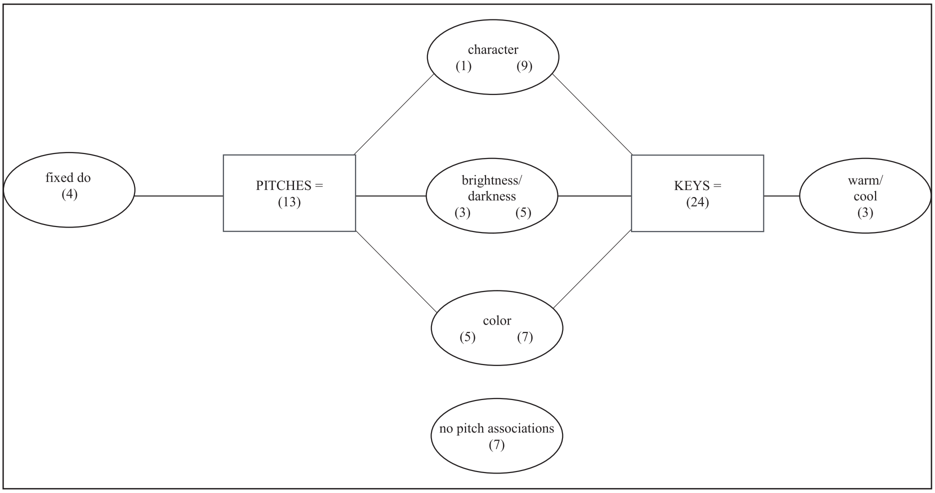

Figure 1. AP associations. Numbers in ovals reflect the number of participants who mentioned a theme.

coded separately (Figure 1). Character and color were the most frequent associations; however, seven participants specified that they had no associations other than pitch name.

Character. Character associations involve emotions, personalities, or moods.

- There's a lot of horn stuff in F major, so it's a triumphant key maybe. (#27, key)
- I feel a lot of connection with Beethoven and Mozart, in like the personalities they choose, like with E♭, you know, being heroic. (#10, key)

Color. Most color associations involved keys, sometimes linked to specific composers or styles.

- When I play a Mozart piece in F major … especially for Mozart, F major for me sounds more like a light green color. (#13, key)
- I do have color associations and it does help me when I'm figuring things out … B major to me, if I hear that I'll get shades of a really rich yellow. Or D♭ always has this orange-ish color to me. C is blue. I hear E♭ or E as green. (#2, key)

Brightness. Eight participants cited brightness: three for individual pitches and five for keys. Interestingly, reports of brightness differed between enharmonic pitches, such as G♯ and A♭.

- A brighter note I think of like an E, or a B, or a G♯, but not an A♭. (#17, pitch)
- Different keys sound different ways to me as far as how deep or bright they sound … If I think a piece is in a sharp key it sounds different than if it's in a flat key. Like F♯ sounds a ton different than D♭, but not very much different than C♯ major. (#27, key)

Fixed-do solfège. Four participants who were taught a fixed-do system for pitch naming and singing in childhood noted that these syllables came to mind unbidden when they listened to music.

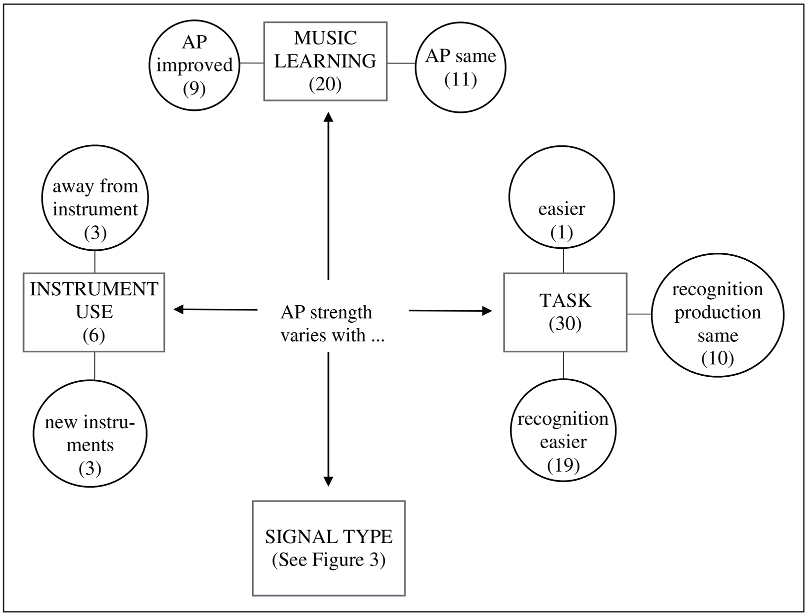

Figure 2. AP strength: Effects of instrument use, music exposure, and task. Numbers in ovals reflect the number of participants who mentioned a theme.

- There is a spontaneous solfège syllable attached. I mean I just hear like, *do re mi fa so la si* in my own like native accent and that's how it's represented. (#3, pitch)
- My dad, like, I remember he taught me piano, and like he played the C ... He said "this is *do, re, mi*" and that's how I hear it, like, every pitch sounds like a solfège syllable. (#15, pitch)

Warmth. Flat key signatures were warmer for three participants. (Whether "warmth" reflected physical heat or warm color was sometimes unclear.)

- The flat keys are warm and cozy. (#30, key)
- I tend to like flat keys, those sound warmer to me, but they feel different. So Gb major... would feel warmer than F#, which is kind of funny. (#21, key)

AP strength

Participants reported various factors that affect the strength and accuracy of their AP ability. Figure 2 groups themes into four categories: AP varies with task, music exposure, instrument use, or signal type.

Task. For 19 of 30 participants, recognizing (labeling) pitches is easier than producing them vocally. This may reflect a problem correctly activating the vocal tract or self-critique of their ability to sing in tune. Conversely, 10 participants asserted no difference between recognition and production.

- [Production] is a little bit harder just because it takes a little bit more effort—it's like connecting, you know, what I hear upstairs to my vocal chords, as opposed [to] just saying, "Oh yeah, that's an A, that's a B." (#2)

- I can't always just sing a pitch … When someone asks me to give a pitch I always take out my phone and play a song and then (laughs) I hear those first notes of the song and then "oh okay this is, D" and then I sing. (#8)

Music exposure. Eleven participants reported that their AP ability did not change significantly over time, nor did it vary with increasing or decreasing music exposure. However, nine reported improvement over time: their responses suggest that AP improved because of increased music exposure in school. They describe implicit learning from listening to performances and attending music classes rather than explicit training of AP labels.

- I used to have … more trouble hearing voice, but with aural skills [class] and doing a lot more singing, it's gotten a lot easier to hear pitch with voice. (#30)
- I remember that it was easy for me to hear the pitch but not always label the right octave when I was younger … But I think now I have less trouble with labeling the octaves. (#8)

Instrument use. Six participants experienced a decline in AP strength with decreasing exposure to their primary instrument; for example, when they took time away from instrumental practice, or when they divided their time between multiple instruments.

- After my master's I took four years off … During those four years I didn't get to perform as much 'cause I was teaching full time. [I] definitely felt it going away … So I was freaking out! Because I wasn't on the piano as much. (#21)
- It's kind of difficult for me now because I'm switching between so many instruments. I'm playing violin and bass … and it's just affecting my pitch. When I'm like, jumping back and forth between various instruments it's harder. (#5)

Signal type. Participants mentioned four features of the acoustical signal that affected their AP accuracy: timbre, register, tuning, and pitch class. Figure 3 reproduces the lowest branch of Figure 2 ("varies with signal type") in greater detail. Factors that weaken AP strength are shown in dark grey, those that improve it are light grey, and those that neither weaken nor improve it are an intermediate patterned shade.

Timbre. Vocal timbre was the most challenging, as were vibrato, synthesized sounds, overtones, and simultaneous pitches. Eleven participants noted that pitch identification on their own instrument was easiest. For seven, timbre had no effect.

- It's definitely easier on instruments without vibrato … and sometimes when I hear singers, it's very difficult for me to recognize the pitch. (#14)
- There are some tests where they'll play a sound where there's no articulation in the beginning it's just like pure tone. Sometimes that screws me up because I listen for the timbre and the color of the instrument too to help me … (#2)

Register. Many participants noted that extremely high or low tones were difficult, while eight participants reported that register had no effect on AP ability.

- I think the lower register … sometimes it takes a little bit of time to recognize it because the vibration of the strings inside a piano. (#19)

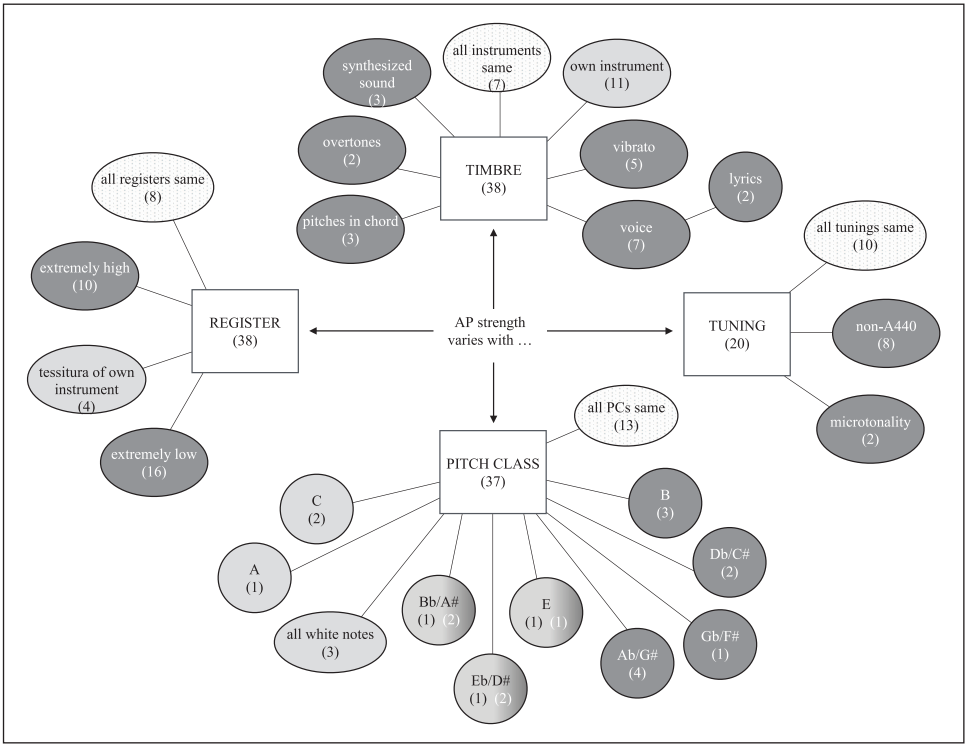

Figure 3. AP strength: Effects of signal type. Numbers in ovals reflect the number of participants who mentioned a theme. Dark grey ovals indicate factors that weaken AP; the lightest grey shows factors that improve it. Factors that neither weaken nor improve AP are shown in a medium patterned shade.

- Register helps … and a white [note] … like if you play a B ♭ or in a very high register, it's going to be harder. (#15)

Tuning. While ten participants reported no effect of tuning on their AP, eight participants struggled with unfamiliar tuning standards such as Baroque tuning (typically A = 415 Hz, rather than A = 440 Hz).

- If it's transposed to Baroque tuning, like, everything's in the cracks, it's hard to hear. One time I had to transcribe this one piece by Beethoven and I was just wondering why couldn't I hear anything. And then it dawned on me that it was in Baroque tuning and my heart just started racing really, really fast and I started crying … my body just had a meltdown. (#5)
- Usually what happens is my pitch adjusts to whatever it is that I'm listening to … One night I was listening to a bunch of Debussy piano music, but it was played by a German guy. So it was, you know, 444, 446 [Hz] or whatever and I left it on overnight, and then when I woke up the next morning and tried to listen to an American jazz group that was usually in tune, it was awful! It was so flat. (#7)

Pitch class. For 13 participants, AP was consistent across all pitch classes, but others cited specific pitch classes that were more challenging than others.

- ♭ are very difficult. I don't know why. I just hear them as a leading tone to C … I just know it's a B because it doesn't register as fast. So like, if it doesn't click it's a B. (#5)
- The main pitches that I play on my instrument are easier … I pick those up really fast, but ones I don't normally play like G♯s or F♯s sometimes even C♯s, it takes me just a few seconds longer to figure it out. (#1)

AP applications

Participants were asked about advantages and disadvantages of AP in their music-making. Figure 4 divides responses into two categories: aural skills and music performance. Light grey shading represents advantages and dark grey, disadvantages. Four themes located in the middle represent skills that overlap categories; numbers in the middle of ovals were ambiguous as to category. Two themes appear twice because some cited them positively and others negatively. Five participants noted that there is no musical disadvantage to AP possession.

Aural skills. This category includes tasks explicitly taught in aural skills classes, as well as a general ability to imagine or internalize music.

Aural skills class (e.g. relative-pitch tasks, chord identification)

- For classes, like theory and aural skills, it's … so much easier if you have perfect pitch … For example, we have to like, write down modulations … people have to like, actually think about … the bass line and stuff. But then for us, I just … hear it and then I'll know it. (#6; helps)
- I can identify … the chords and the notes but I can't tell you what quality, like what the actual quality of the chord is … I'd have to pick out each note and put it together. (#18; hurts)
- I do find that like from taking music theory classes, I have a hard time with relative pitch. (#18; hurts)

Internalizing music

- I think that it … makes it easier to study music, listen to music without the score and understand what's going on. (#3; helps)
- We tend to listen to the individual notes instead of the whole group of the melody. Sometimes it's a little bit … distracted, because you focus on each note instead of the … whole tune. (#19; hurts)

Music performance. As Figure 4 shows, most participants describe positive aspects of AP in music-making, although over 30 comments articulated distinct AP impairments. We present a sampling of positive and negative observations.

Intonation

- Playing the bassoon … intonation is horrendous on our instrument, generally, and being able to hear where the notes go is obviously a huge advantage on such a flexible instrument where you can produce notes 30–40 cents sharp or flat … (#28; helps)
- Tun[ing] with other people who I know are really out of tune—I guess that's the most difficult part … I found that me just saying, you know, "I'm right, you're wrong" doesn't really work. (#1; hurts)

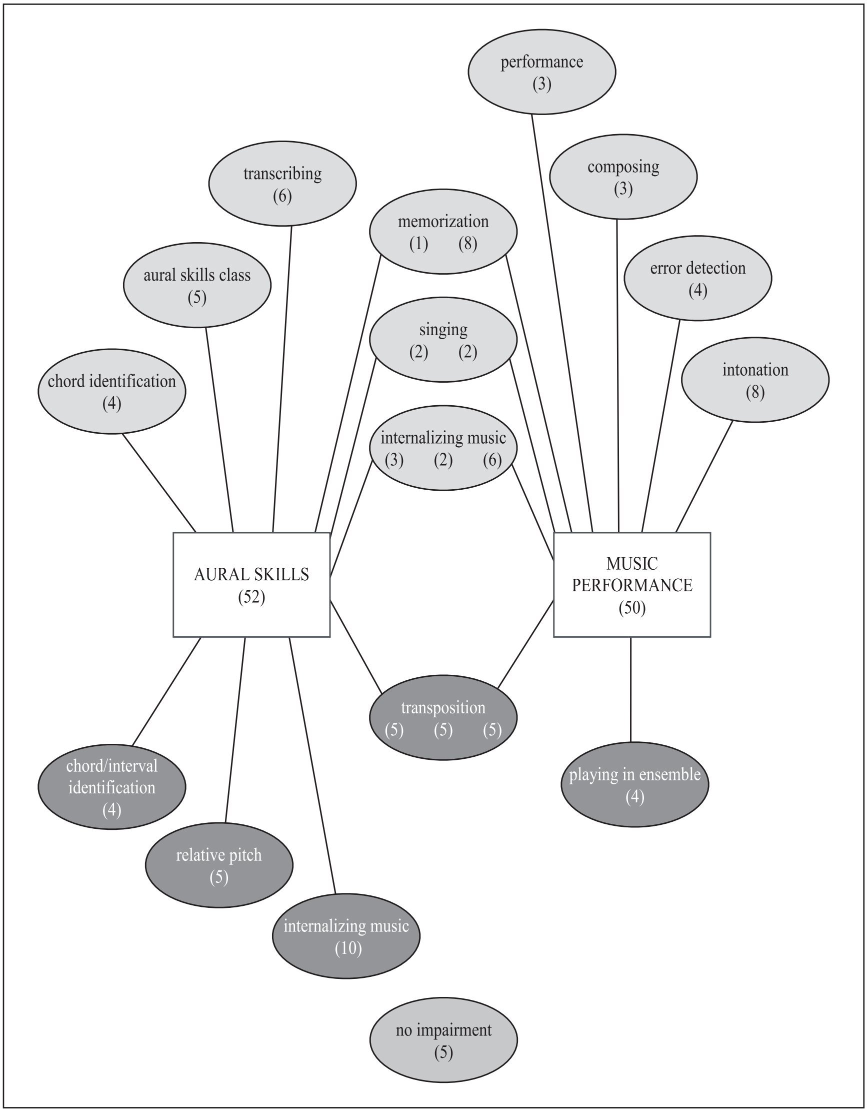

Figure 4. AP applications: Musical activities affected by AP. Numbers in ovals reflect the number of participants who mentioned a theme. Dark grey ovals indicate factors that weaken AP; the lightest grey shows factors that improve it. Factors that neither weaken nor improve AP are shown in a medium shade.

Singing

- It's easier for you to sing in the right pitch when you sing a song. If you don't have any keyboard or instruments with you to see which pitch that is, you can still [sing], because in your brain you have an idea about how the pitch sounds like. (#19; helps)

Memorization

- I memorize everything and [AP] just helps 'cause you feel like you have a connection to the pitch which is not tangible ... You know, like you feel like you can actually touch the music although you can't, you just have some connection to it like it's actually a part of you. (#5; helps)

Error detection

- If I am acting as a coach or teacher to somebody, it's a lot easier to tell when they've messed up. Either out of tune on an instrument or just playing the wrong note on a piano or whatever. (#27; helps)

Transposition

- I think that's why you don't find a lot of AP in brass players, or woodwinds … because it's a hindrance … because you can't transpose … I mean I'm not engaging in music itself like spontaneously, I can't do it, I just have to think and transpose everything mentally/psychologically … (#21; hurts)
- Sometimes my teacher asks me to transpose to another key while I sing … I think people [who do not] have absolute pitch they can sing directly, use their feeling of the music and the melody. But for me I have to see how the note in the original key transposes to the other one. (#13; hurts)

Playing in ensemble

- [AP] can actually be more of a disadvantage if you don't know how to … use it in a context that's musical. Let's say you're playing in an orchestra … you have a harder time fitting your own part into what's going on because you're viewing it as notes, as like sort of an absolute thing. (#2; hurts)
- I think I've worked deliberately to get my perfect pitch less of a prominent part of how I think of music a little bit because it seems like it impedes phrasing some. If I'm just constantly thinking about note names it's very distracting. (#28; hurts)

Discussion

Our first two research questions focused on participants' descriptions of their experiences with AP, both in everyday life and in their musicianship—singing, instrumental practice and performance, playing in tune with others, and studying music theory and aural skills. Their responses support converging evidence that AP possession is not a uniform ability. AP possessors may produce nearly identical scores on a note-naming test, yet have quite different experiences—synthesthesia or not, verbal associations or not, timbral or registral limitations or not, adaptability to non-A440 tunings or not, difficulties with relative pitch or not, challenges in performance or not. Our third research question considered how statements offered by our participants correspond with published theories of AP types and acquisition. Their observations, especially those that fell within our "AP Strength" theme, support a categorization of AP possessors into the two distinct types proposed by Ross et al. (2005), and suggest an important role for implicit learning, both as a means of acquiring AP and of reinforcing a pitch and tuning standard through daily exposure.

Impact on musicianship

AP is often admired as an extraordinary musical ability, as a sign of musical excellence or talent. While AP ability has clear musical value, as our participants note (#3, #6, #19 and #28), it also poses unique challenges to musicianship. Some negative effects on day-to-day musical life reported by our participants (Figure 4) confirm previous experimental findings: for example, difficulties with unfamiliar timbres (Miyazaki, 1989), vocal timbres (Vanzella & Schellenberg, 2010), unfamiliar tunings (Hedger et al., 2013; Miyazaki, 1993), and extremes of range (Takeuchi & Hulse, 1993). Most of these challenges to pitch labeling are consonant with the early-learning hypothesis, which posits that AP possessors store in long-term memory a template of pitches and labels that are learned during childhood music study, including their instrument's timbre, tuning, and range. Our finding that vocal timbres interfere with pitch identification supports Vanzella and Schellenberg (2010), who suggest that vocal timbres may activate neural pathways associated with language processing, which interferes with musical pitch identification.

As reported by our participants, AP possessors show enhanced performance at musical transcription (Dooley & Deutsch, 2010) and have an advantage in aural skills classes (#6, #21), except where relative-pitch skills are required. Relative-pitch difficulties have been documented by other researchers, but without the added insights offered by the participants' own words. Such tasks include the ability to transpose (Miyazaki, 2004) and to identify interval or chord types apart from their component pitches (Miyazaki, 1993; however, see Dooley & Deutsch, 2011 for differing results). A number of our participants (#4, #7, #14, #15, and #18) explicitly noted that they had difficulty naming interval types (e.g., major sixth) or chord qualities (e.g., diminished triad), but instead identified the individual notes of the interval or chord and used this information to analyze the quality (which may account for results in Dooley & Deutsch, 2011). These AP listeners make such identifications accurately, but typically use a two-step process (pitch identification, then analysis) rather than perceiving the qualities directly.

A challenge unique to AP musicians is the occasional inability to focus on phrasing or musicality, when confronted cognitively by a continual string of note names (#1, #28). Levitin and Rogers (2005) suggest that this note-by-note listening strategy is largely irrelevant to musical processing. It can even hinder some types of meaningful engagement with music, such as the ability to internalize relationships among notes. In an effort to counteract this issue, at least one participant attempted to suppress her AP ability altogether (#28). These comments notwithstanding, 11 participants felt that AP is beneficial and helps them internalize music, hear a score inwardly, and detect errors in performance.

When asked about intonation as an aspect of musicianship, many participants responded with anecdotes citing precise pitch frequencies measured in Hertz (rather than letter names) or intervals measured in cents (rather than interval names). These comments suggest that AP listeners do not perceive pitch categorically, as has been debated in the literature (Burns & Campbell, 1994; Levitin & Rogers, 2005; Siegel & Siegel, 1977). Categorical perception, in this context, refers to the human perception of continuous stimuli (like frequencies) falling into discrete categories (like pitch names). When stimuli are divided incrementally into small gradations between category boundaries, listeners accurately identify each of the category's gradations until that boundary point is reached; at the same time, they discriminate poorly between two gradations on the same side of the boundary. In contrast, our participants seem able to discriminate between pitch gradations when they describe hearing Baroque ensembles playing at A415 Hz (#3) or European piano music at A444–446 Hz (#7), or they characterize out-of-tune playing precisely in terms of cents (#28). Another possible explanation is that AP listeners perceive pitch categorically, but have more categories to draw upon than relative-pitch listeners (as noted by Zatorre, 2003). For example, several participants cited differences between enharmonically "equivalent" notes, such as G♯ and A♭ (#17, #27), which may belong to different categories for them.

AP types

Although it was not our original intention to divide AP participants into groups, the themes that emerged from our analysis led us to reconsider the two-tiered categorization of Ross et al. (2005). These authors hypothesized that APE possessors encode frequency information differently, resulting in pre-categorical identification that is unaffected by changes in timbre, range, and tuning. HTM listeners, they surmise, unconsciously refer to a learned pitch template associated with a particular timbre, range, and tuning; thus their abilities are impaired when asked to identify pitches that don't conform to this template. Our participants fell into distinct groups with respect to the pitch attributes we categorized as AP strength (Figure 3). For range, eight participants said that all pitches are equally easy to identify (possibly APE), but 10 identified difficulties with high tones and 16 with low tones (possibly HTM). For timbre, nine noted that all timbres are equally easy (APE), but others specified timbral qualities that impaired identification (HTM). A limitation of our study is that our AP pre-test included only piano tones; one that included pure tones and other instrumental timbres, as well as extremes of range, would assist in classifying listeners. For tuning, 10 AP possessors said that they were able to adjust when asked to perform in non-A440 tunings (APE), while eight found these tunings difficult (HTM), describing a "meltdown" (#5) or "shaking and sweating" (#10).

Ross et al. recounted that APE listeners associated pitch labels with sounds in everyday life. Further, they typically could not remember having learned AP, and thought that everyone else had AP as well. Both of these ideas were represented in our participants' commentary.

- Well, you know I didn't actually know what perfect pitch was until I was in tenth grade and my friend was hitting a pencil against a plastic cup and I could tell what pitch it was, and I never thought that it was weird that I could tell what pitches were. (#17)
- In high school … I took AP [Advanced Placement Music Theory] and then we were doing dictation and I just did everything, and then my teacher mentioned, "Oh, it must be nice to have absolute pitch …" Then that's when I said "(gasp) what do you mean? Don't all musicians have this?" So, that was an eye-opening thing. (#21)

In contrast, HTM listeners could recount either explicit training or teaching themselves AP. Only one of our participants remembered explicit training in AP, but several reported working actively to improve their AP after discovering their ability.

- I played this video game called *Banjo Tooie* … The theme had this pedal C in the melody, so I learned it on piano and afterwards I realized that whenever I thought of that piece I always thought of it in the same key. So then I started to recognize what a C was and from there I kinda learned everything else. (#7)

Many of our participants described a sense that they always had AP. Music lessons provided a label for something that they already knew. For example, participants #5 and #7 noticed consistent keys for songs; participants #3 and #18 played melodies on instruments in the correct key, by ear.

Because most participants were unable to remember learning AP, it was solely from their commentary regarding timbre and tuning that we attempted to categorize their AP type. We looked at the intersection of three APE indicators: the ability to identify pitches equally in all timbres, to adapt to nonstandard tunings, and to identify pitches in every-day sounds. Participants sharing these APE characteristics represent 27% of our sample (Ross et al. [2005]

categorized 36% of their sample as APE). Of those identified as potentially APE listeners (#1, #3, #6, #22, #23, #25, #28, and #29; see Appendix A in the supplemental materials), five are pianists and three are violinists; all except one began instrumental study at age 7 or younger. Five are Asian (four speak Cantonese and one Korean as their first language) and three are Caucasian/white (two English and one Hebrew as first language); five are male and three female.

Implicit learning

Our participants' commentary provided evidence for implicit learning—or at least for an implicit reinforcement or updating—of AP labels through musicians' daily exposure to fixed-pitch instruments, ensemble tunings, and recordings that implicitly establish a standard. Evidence comes from strong reactions to non-A440 tunings. Several described extreme discomfort with music at other tuning standards (#5, #10). Our study also provides a real-world example of the effect achieved in an experiment by Hedger et al. (2013), where experimenters adjusted the pitch standard of a symphonic recording gradually flatter, in microtonal increments over time. Their AP listeners correspondingly shifted their standard downward, learning the new one implicitly. Similarly, our participant #7 fell asleep listening to a recording where the piano was tuned to a higher pitch standard (A444 or 446); when he awoke he had adjusted to the new pitch level.

Some participants reported a decline or improvement in their AP abilities, possibly related to changes in the contexts for implicit learning. Declines were associated with time away from an instrument or changing between instruments (#5, #14, #21); either would interfere with implicit reinforcement of AP labels in the tuning and timbre of their instrument. Several noted improvement over time, particularly when they enrolled in a music school for college—not because they were explicitly trained in AP there, but because they were surrounded by more music and engaged in daily performance (from which implicit learning could take place).

Implicit learning also provides an explanation for the finding that white notes—as in white piano keys—are identified more quickly and accurately than black (Bermudez & Zatorre, 2009; Miyazaki, 1989; Takeuchi & Hulse, 1993). As Simpson and Huron (1994) have noted, the white-key advantage corresponds with the greater frequency with which white notes appear in Western tonal music; greater frequency leads to better implicit learning. Indeed, three of our participants volunteered that all white notes were easier to identify than black. Others identified particular pitch classes, such as C, A, and E as easiest. Every black pitch class was specifically mentioned by at least one person as difficult. Surprisingly, one white note was identified by three different participants as particularly difficult: B. A possible explanation is its half-step displacement from C, a melodic anchoring effect (Bharucha, 1984). In fact, participant #5 specifically cited the leading-tone quality of B (to C) as a source of confusion.

This study provided AP musicians an opportunity to reflect upon their AP abilities freely in response to open-ended questions. By aligning their responses with the results of published behavioral testing, we provide support—from AP possessors' own self-reflection—for a more nuanced understanding of AP that acknowledges differences in AP abilities (such as poorer performance for some possessors when the timbre and tuning do not match a learned template, or the possibility of a decline in pitch identification accuracy when AP possessors are away from their instruments for a period of time). We understand such differences through the lens of two distinct AP types, as proposed by Ross et al. (2005). These types may be associated with differences in processing mechanisms and with the mode of acquisition. In future work, we intend to refine our demographic and prescreening materials to include measures intended to tease apart AP types, and we recommend these strategies for other researchers as well. For example, our demographic questionnaire will ask how and when participants learned or discovered their AP, and whether they perceive some pitches, ranges, or timbres as more difficult to identify. Our AP prescreening test will include high and low extremes of range and at least three timbre types (e.g., pure tones, piano tones, and an unfamiliar timbre) to explore differences among listeners. Other implications of this research are pedagogical in nature: since our participants received very different types of musical training in their childhoods (especially when comparing responses from American vs. international students), we hope to explore more fully regional differences in music pedagogy and their implications for the development of high-level musicianship and performance.

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Supplemental material

Supplemental material for this article is available online.

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