Identifying Absolute Pitch Possessors Without Using a Note-Naming Task

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Most researchers measure absolute pitch (AP) using note-naming tasks that presume expertise with the scales of Western music. If note naming constitutes the only measure, then by fiat, only trained musicians can possess AP. Here we report on an AP test that does not require a note-naming response. The participants were 15 AP possessors and 45 nonpossessors defined by note naming. We presented sine tones tuned to the 12-note chromatic scale in a go/no-go discrimination between the first and second 6 notes in 3 successive octaves. This half-octave discrimination test predicted AP performance in the note-naming test with high accuracy and in particular never falsely predicted that a nonpossessor defined by note naming was an AP possessor. We found 2 heterogeneities in the AP performance of our participants. Incremental AP possessors scored above the criterion for AP in 2 note-naming tests but required 2 sessions to attain accurate half-octave discriminations. Variable AP/NAP (nonabsolute pitch) possessors scored above criterion for AP in 1 naming test and below criterion in a second naming test but below criterion on the half-octave test. Our findings suggest the use of the half-octave discrimination test in future research into heterogeneities in AP and, most important, in the search for AP possessors untutored in music.

Keywords: pitch-range discrimination, half-octave discrimination, note naming, pitch classification and production, independence of AP from age of onset and duration of music training

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Most people have an implicit form of absolute pitch (AP) in that they can produce or identify a small number of often heard pitches without using an external referent: for example, the pitch of the telephone dial tone (Smith & Schmuchler, 2008) or the starting pitches of a few recorded popular songs (Levitin, 1994). Also, many people are influenced by the absolute position of a pitch within an octave while making relative pitch judgments (Deutsch, 1991).

Most important here, only a small number of people (true AP possessors) can accurately identify, classify, or produce the pitches of dozens of acoustic frequencies without an external referent (Takeuchi & Hulse, 1993; Ward, 1999). Several research groups (e.g., Athos et al., 2007; Levitin & Rogers, 2005) measure AP by requiring participants to identify notes by naming them, which presumes fluency with the names and positions of notes on the chromatic scale of Western music—in Levitin and Roger’s (2005) terms, linguistic coding of note names. Of course, if note naming is part of the definition of AP, then by fiat, only trained musicians can possess AP.

As a first step in determining whether music training (and perhaps linguistic coding) is necessary to AP, one needs simple, valid alternative tests of AP that do not require note-naming responses. The main alternatives are tests that require participants to either classify or produce the pitches of test tones, without needing to name them.

Ross, Olson, Marks, and Gore (2004) used a pitch reproduction task to identify AP possessors and found that musicians who were accurate in that task were also accurate at note naming. A correct response on Ross et al.’s (2004) task requires a match between the test stimulus tone and a note participants produced by adjusting a tone generator after an 8-s or 16-s delay filled with interfering tones. In the language of perceptual science, this is a production task, defined by the response it uses to measure AP.

Our protocol is meant to provide converging evidence with Ross et al.’s (2004) and other methods in the difficult task of identifying AP possessors without significant music training. Our task requires participants to identify notes by classifying them into half octaves in a simple “go,” “no-go” operant discrimination. Describing this as an operant discrimination may be unfamiliar to some students of music perception but the term is in common use in the learning literature (Lattal & Perone, 1998; Simont, Beecher Moody, & Stebbins, 1976). A go/no-go operant discrimination is a contin-
gency in which one or more stimuli (the go stimuli) are occasions upon which a response is followed by reinforcement; one or more other stimuli (the no-go stimuli) are occasions upon which the same response is not followed by reinforcement. Provided they possess the perceptual and cognitive abilities to distinguish among the stimuli, individuals come to respond following go stimuli and omit responses following no-go stimuli (expanded from a definition first proposed by Skinner, 1953).

We adapted the half-octave discrimination from the pitch-range operant discriminations developed almost two decades ago to study pitch height AP in songbirds and humans (Njegovan, Ito, Mewhort, & Weisman, 1995). In recent research with human AP possessors and nonpossessors, Weisman et al. (2010) presented 40 sine tones. Alternating ranges of five sine tones, spaced 120 Hz apart, were designated go and no-go ranges. The 40 tones were each selected at random without replacement and played, then the process was repeated several times, eliminating all sequential pitch cues to which were go and no-go stimuli.

Notice that Weisman et al.’s (2010) tones increased in frequency arithmetically and hence were mismatched to the chromatic scale of Western music. That is, our ranges of go and no-go tones were out of step with the frequencies of notes on the chromatic scale, which double in frequency from one octave to the next. The effect of this mismatch was that a tone within the boundaries of a note in one octave may be a go tone, but a tone within the boundaries of the same note in an adjacent octave may be a no-go note. In Weisman et al.’s (2010) experiment, to discriminate between ranges, AP possessors had to remap the tones from their octave names classification to go and no-go classes defined by their consequences.

As might be expected based on the difficulty of this remapping, note-naming AP possessors learned to discriminate go from no-go tones slowly, over 4,000 trials spread over several sessions separated one from another by at least 24 hours, to a mean accuracy of 72%. Correct and nonpossessors learned to a mean of only 55% (chance = 50% correct). The final % correct scores of nonpossessors did not overlap with those of AP possessors. By scoring 22% better than chance, AP possessors demonstrated their perceptual and cognitive superiority on a pitch classification task. That AP possessors acquired the discrimination slowly and with much less than perfect accuracy reflects the difficulty of this unfamiliar mapping task.

In the present research, we greatly reduced the difficulty of the auditory discrimination by presenting tones tuned exactly to the chromatic scale across three octaves and parsing the 12 notes in each octave into half-octave ranges of six go and six no-go notes per octave. The goal was to produce a simple accurate operant classification test of AP that does not require a note-naming task. Notice that acquisition of the discrimination is the AP test. To establish the validity of the protocol, we tested to determine whether musicians who were accurate at the half-octave discrimination were also accurate at note naming.

**Method**

**Participants**

Sixty participants were recruited at the University of Alberta and Queen’s University by advertisements in local newspapers and posters on campus. We invited experienced musicians and especially those who might have AP to participate. The participants provided their ages and the details of their music and language training in writing in response to a formal questionnaire. Each gave informed written consent, and the Research Ethics Boards at the University of Alberta and Queen’s University approved our research protocols.

Participants ranged from 18 to 38, $M = 23$, years of age. There were 33 women and 27 men. The year they began music training ranged from 2 to 15 years of age ($M = 6.7$) and had from 5 to 28, $M = 14$, years of music experience (combined training and playing). Only 87% of the participants chose to list their music histories. As shown in Table 1, the participants learned to play a variety of instruments but almost 50% appeared to have begun with the piano and nearly 20% with a bowed string instrument. (Some may have listed their favorite instrument first, so caution is advised.) Most participants played at least one additional instrument and most still played at least one instrument.

Only 90% of the participants chose to list their first language (see Table 2). Most participants (70%) learned English as their first language. About 20% learned a language other than English first, but only three or less learned each individual language, which is too few to conduct any kind of meaningful analysis.

**Apparatus, Stimuli, and Procedure**

The procedure (programmed in Visual Basic) was presented on a Toshiba Tecra laptop using Sennheiser HD 580 headphones. There were three phases: an initial note-naming test, a half-octave discrimination-learning test conducted in two sessions, and a second note-naming test. The study was conducted over two visits to the laboratory. Normally, the initial note-naming test and first session of discrimination training were conducted during the first visit. The second discrimination session and the second note-naming test were conducted during the second visit. There were several exceptions: for example, participants sometimes completed both sessions of discrimination training during the first visit. Typically laboratory visits were scheduled on consecutive days, but the second visit was always completed within 7 days of the first. This rearrangement of testing was necessary to meet participants’ individual time commitments and also occurred in our previous work (e.g., Weisman et al., 2010). In previous work, we observed no systematic differences between participants who continued training immediately or after several days. Here we did not

<table>
<thead>
<tr>
<th>First Instrument and AP Values as $M \pm SE$</th>
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<tbody>
<tr>
<td>First instrument</td>
</tr>
<tr>
<td>------------------</td>
</tr>
<tr>
<td>Piano</td>
</tr>
<tr>
<td>Violin, viola, cello</td>
</tr>
<tr>
<td>Voice</td>
</tr>
<tr>
<td>Guitar</td>
</tr>
<tr>
<td>Trumpet, trombone</td>
</tr>
<tr>
<td>Flute</td>
</tr>
</tbody>
</table>

Note. Dashes indicate missing values.
track whether participants completed half-octave discrimination training in one visit or two.

The initial note-naming test. The protocol was adapted from a procedure used by Athos et al. (2007) to study 2,213 participants: the note durations and frequencies were a direct replication of Athos et al. (2007). This allowed us to use their standardized AP testing procedure to establish the validity of our novel half-octave discrimination test. In the note-naming tests, we adopted Athos et al.’s (2007) scoring protocol: 1 point for each correct identification and 0.75 points for responses to notes ± 1 semitone from the correct note.

Sine tones presented in the test were synthesized at the frequencies of 40 notes randomly sampled from the 66 notes on the chromatic scale that spans the five and a half octaves from C2 to G8, on the basis of A4 = 440 Hz; each note was played for 1,000 ms (see Athos et al., 2007 for details). The actual notes presented were D#2, F2, F#2, G#2, A#2, B2, C#3, D3, E3, F3, G3, A3, C4, C#4, D4, D#4, F4, F#4, A4, C5, C#5, D5, E5, F#5, G5, G#5, A5, A#5, C6, D6, A6, B6, C#7, D#7, F7, F#7, B7, E8, F#8, G8, and A#8. These tones and others presented in this research were constructed at a standard 16-bit, 44.1-KHz sampling rate and ramped at onset and offset upward and downward for 5 ms. Because four of the nine tones (those in the eighth octave) lie above the notes on the piano keyboard and proved difficult to assign a pitch, participants rarely named them accurately. In practice, therefore, the test consisted of 36 notes (see Athos et al., 2007). Because the test has been standardized so extensively, we were reluctant to alter it by omitting pitches in the eighth octave.

The test began after a short practice session (eight trials) given to acquaint participants with making mouse responses to graphics on the screen and to allow participants, individually, to adjust tone amplitude from 80 dB to a comfortable level. During the test, a participant clicked on the “play” button at the top of the screen, and heard a tone selected randomly without replacement from the 40 test tones. To “name” the musical note corresponding to a tone, the participant clicked on one of 12 black and white piano keys shown on the screen. The test continued without feedback until the participant heard all 40 tones. In the note-naming and half-octave discrimination tests, participants could take as much time as they liked between trials, because a trial began only after clicking the play button. We did not record time between trials.

The half-octave go/no-go discrimination-learning test. In a simple test of their AP ability, participants were asked to classify notes into two categories to the best of their ability, without any instructions about which notes made up each category. Participants were told that discrimination training was a test of their perceptual categorization ability but not that it was a test of AP.

Participants were trained to discriminate among 36 sine tones (500 ms in duration and ramped upward and downward for 5 ms). The tones were presented in random order without replacement in two sessions of 360 trials each, 10 presentations of each tone per session. The number of sessions was chosen on the basis of our previous experience with similar go/no-go discrimination procedures (see Weisman et al., 2010), for example, how long participants might be willing to work in each session, and how much training AP possessors might need to attain high accuracy.

The training sine tones were synthesized at the frequencies of successive chromatic musical notes from C4 (261.6 Hz) to B6 (1976 Hz). In each of three successive octaves (beginning at C4), notes in the first half of the octave (C, C#, D, D#, E, and F) were S+ (go) tones and notes in the second half of the octave (F#, G, G#, A, A#, and B) were S− (no-go) tones.

In previous research (e.g., Weisman et al., 2010), counterbalancing the order of go and no-go pitch ranges produces mirror image results in both AP possessors and nonpossessors, rs > .90. Consequently, here we chose to test participants under one counterbalancing rather than needlessly dilute evaluation of our relatively rare AP possessor participants.

Participants initiated a trial by clicking on the “play” button on the screen to hear a tone. If a participant clicked on the button on the screen labeled S+ after hearing a go tone, the word “correct” appeared in a box adjacent to the S+ button and the response counted toward a modest monetary reward. If the participant clicked the S+ button on a no-go trial, the word “incorrect” appeared in a box adjacent to the S+ button, the next trial was delayed by 5 s, and the response did not earn any monetary reward. If a participant did not click the S+ button after a no-go tone the trial terminated after 2 s without feedback, as is typical in go/no-go operant discrimination procedures.

Two versions of each tone were played, recorded, at 70 dB and 80 dB (sound pressure level [SPL]) respectively, to control for amplitude, and chosen at random without replacement. This strategy made pitch a more salient determinant of the discrimination by eliminating the confounding of pitch with loudness. Each participant was allowed to adjust overall amplitude to a comfortable level during a short practice session (36 trials); this meant that actual tone amplitudes heard in the discrimination task varied across participants but differed in relative amplitude by 10 dB, helping to control for loudness as a cue in this classification task.

We recorded the percentage of total responses (% response) to each tone in each session. To assess overall accuracy (sensitivity) in Sessions 1 and 2, we used % response averaged (M) across the first half of each octave (hits) and % responses averaged across the second half of each octave (false alarms) to compute % correct, (M 1st half-octave % response + (1 - M 2nd half-octave % response)), and d’ (see Macmillan & Creelman, 2005). We have used % correct and d” in various instances here, the two measures correlated at rs ≥ .95, ps < .0001. We also calculated the average latency of responding on go trials for each participant.

The second note-naming test. Except for the stimuli, the test protocol was the same as in the first. The stimuli, that is, the range of the tones, their durations, and amplitudes all differed from the first naming test. The tones (i.e., their frequencies and durations) were exactly those presented during the half-octave discrimination

Table 2
First Language and AP Values as M ± SE

<table>
<thead>
<tr>
<th>Language</th>
<th>First</th>
<th>Naming</th>
<th>Discrimination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinese (Cantonese)</td>
<td>3</td>
<td>24.1 ± 8.5</td>
<td>2.08 ± 1.10</td>
</tr>
<tr>
<td>Chinese (Mandarin)</td>
<td>1</td>
<td>10.5—</td>
<td>0.61—</td>
</tr>
<tr>
<td>English</td>
<td>42</td>
<td>14.2 ± 9.9</td>
<td>0.77 ± .21</td>
</tr>
<tr>
<td>Farsi (Persian)</td>
<td>1</td>
<td>12.5—</td>
<td>—</td>
</tr>
<tr>
<td>Korean</td>
<td>2</td>
<td>33.6 ± 0.9</td>
<td>2.55 ± .32</td>
</tr>
<tr>
<td>Indian (Marathi)</td>
<td>1</td>
<td>6.3—</td>
<td>0.62—</td>
</tr>
<tr>
<td>Omitted answer</td>
<td>10</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Note. Dashes indicate missing values.
test. Thus, the second naming test was a systematic not a direct replication of the first. This allowed us to compare the two tests to check on their generality in identifying AP possessors and to compare the second naming test and the half-octave test as measures of AP over the same notes.

Results

We report results for the note-naming tests, the half-octave discrimination, and then consider the accuracy of prediction of naming from the discrimination. Reports on the effects of gender and music history follow.

The Note-Naming Tests

Using Athos et al.’s (2007) criterion score for highly accurate AP (≥24.5 based on 36 tones), we initially separated participants into AP possessors (n = 16), (M ± SE) 31.3 ± 6.9 and nonpossessors (n = 44), 9.9 ± 7.0, respectively, in the first note-naming AP test and 30.4 ± 7.0 and 9.1 ± 0.7, respectively, in the second test. In a mixed groups analysis of variance (ANOVA), we found a significant difference between possessors and nonpossessors, \( F(1,57) = 305.71, p < .0001 \), and no significant overall difference between tests, \( F(1, 57) = 1.25, p = .27 \), and no significant interaction, \( F(1, 57) = 2.25, p = .15 \). Scores on the two note-naming tests were highly correlated, \( r(57) = .93, p = .0001 \). An interesting group of four participants failed to score consistently above or below the criterion for AP on both tests: Three scored above criterion in the first test but below it in the second, and one scored below criterion on the first test but above it on the second. We have labeled these participants **Inconsistent AP/NAP possessors.**

The Half-Octave Discrimination Test

**Discrimination across training.** We noticed that a select group of participants improved their accuracy in the half-octave discrimination substantively from the first to the second session. Improved accuracy was evaluated using the difference in % correct from Session 1 to Session 2. Most participants’ discrimination scores were virtually unchanged, range <10%, between Sessions 1 and 2: about as many participants declined as improved in accuracy. But four participants, all identified as AP possessors by note naming, improved their accuracy by ≥34%. We labeled these participants **Incremental AP possessors.**

**Discrimination across tones.** Figure 1 simplifies presentation of the half-octave discrimination protocol and provides a good visual representation of the high accuracy of AP possessors. Participants’ % responses to each of the 36 tones, in the second discrimination session averaged separately for note-naming AP possessors and nonpossessors, are shown in Figure 1. We present performance in the second training session because, as already noted, incremental AP possessors improved from Session 1 to Session 2. AP possessors precisely tracked reward across the six ranges of go and no-go tones, whereas nonpossessors merely responded successively less across ranges (similar to previously published results, see Weisman et al., 2010). Overall, AP possessors, \( d’ M \pm SE = 2.59 \pm .39 \), were significantly and vastly more accurate than nonpossessors, \( 0.22 \pm .03 \), between groups ANOVA, \( F(1, 53) = 87.77, p < .0001 \).

**Latency of responding.** We measured the latency of participants’ responses on go trials during the second discrimination session. A between groups ANOVA, \( F(1, 58) = 22.52, p = .0001 \), found that AP possessors responded to go tones significantly more promptly than nonpossessors: \( 612 \pm 22 \text{ ms versus} 946 \pm 37 \text{ ms}. \)

**Predicting note naming from the half-octave discrimination.** The goal of this research was to demonstrate the validity of an alternative measure of AP: the simple, operant go/no-go half-octave discrimination. To determine whether the discrimination was a valid test of AP ability in individual trained musicians, we plotted individual discrimination test \( d’ \) scores (on the x-axis) against the first and second note-naming AP scores for the same individuals (on the y-axis of Figures 2a and 2b, respectively). We used a signal detection approach to deciding how well half-octave discrimination predicted note naming. We first divided the sample space in each figure into quadrants, partitioned by dashed horizontal and vertical lines in Figures 2a and 2b, which are defined by our criteria for the note-naming and half-octave discrimination AP measures. The dashed horizontal lines bisecting each figure into two unequal parts were given by Athos et al.’s (2007) criterion for note-naming AP. According to Athos et al. (2007) the probability of scoring above criterion by chance alone is about one in a trillion. Our calculations found that the criterion was very close to the 99.99% confidence interval for the mean of our sample of AP nonpossessors. The dashed vertical lines bisecting Figures 2a and 2b into two unequal parts were given by a \( d’ = 1.90 \), which corresponds to an AP criterion of 80% correct, and is very close to the 99.99% confidence interval for the mean of nonpossessors. These values are conservative estimates based on the rarity of AP.
The four quadrants of each figure provide a standard fourfold signal detection table. Clockwise from the top right, data points in the first quadrant are hits. Both tests indicated a participant was an AP possessor, points in the second are false alarms. The discrimination test indicated the participant had AP but the note-naming test did not, points in the third are correct rejections. Both tests indicated the participant was a nonpossessor; points in the fourth are misses. The note-naming test indicated the participant was an AP possessor but the discrimination test did not.

Correlations between the scores on the half-octave discrimination test and the first and second note-naming tests (Figures 2a and 2b) were evaluated using the chi-square statistic for the 2 \times 2 contingency tables shown in Figures 2a and 2b, \( \chi^2(1) \geq 45.55, p < .0001 \), confirming significant and strong concordance, \( \phi \geq 0.905 \), between scores on the half-octave discrimination AP test and on the two note-naming tests.

To further evaluate whether the results parsed the participants into different classes of AP possessors and nonpossessors, consider the open and closed symbols in the figures. The open circles identify True AP possessors and are all enclosed in the hit quadrant of Figures 2a and 2b. An additional four participants scores are enclosed in the hit quadrant: these Incremental AP possessors required some training to acquire the half-octave discrimination, as already described, but all named notes accurately. The open triangles identify nonpossessors, labeled NAP, and are all enclosed in the correct rejections quadrants. The closed triangles identify Inconsistent AP/NAP possessors, perhaps the most interesting participants. As noted earlier, these participants did not attain consistent scores on note-naming tests and, as seen in Figures 2a and 2b, and they never scored above the criterion for AP on the half-octave discrimination test. Changes in classification because of slightly different scores on different note-naming tests serve to remind us that people with marginal or highly variable note-naming AP scores may not be true AP possessors. In summary, our analysis identified four distinct categories of AP and NAP. Finally, and most important to our signal detection analysis, no participants’ joint discrimination and naming scores are enclosed in the false alarm quadrant: The half-octave discrimination test never misclassified note-naming nonpossessors as AP possessors.

**Personal History, Gender, and AP**

**Predicting AP scores from music training.** As in other studies of AP (Levitin & Zatorre, 2003), on average our AP possessors began music training earlier and had more training than nonpossessors. Hence it is not surprising that age of onset and years of training correlated significantly with both note-naming and discrimination AP scores, \( r(57) = .30, p < .05 \). Here we asked whether early and persistent music training were sufficient to engender AP and, most important, whether nonpossessors with the same experience as AP possessors had better AP scores than participants with less experience.

We matched AP possessors with nonpossessors on age of onset and years of music training; where possible we chose two nonpossessors to match each possessor (see Table 3). By definition, AP possessors differ from nonpossessors in note-naming (Figure 3a) and half-octave discrimination scores (Figure 3b). It is of interest that experience-matched nonpossessors gained no signifi-
in AP scores. The numbers of participants who played other than the piano or a bowed string instrument first were too low (≤4) to draw any useful conclusions about their AP ability. A chi-square test, $\chi^2(1) = .02, p = .98$, of the difference in the proportions of piano (30%) and string instrument (36%) players who were AP possessors found no significant relationship between first instrument and AP, $\phi = .07$.

### Discussion

The discussion consists of three parts: conclusions about the suitability of the half-octave discrimination as a screening tool; issues in AP raised by our findings; and applications of the half-octave discrimination and other AP tests to finding untutored AP possessors.

#### Conclusions About the Half-Octave AP Test

Here, using tones tuned to the chromatic scale and separated into go and no-go half-octave ranges, note-naming AP possessors required only a few hundred trials to acquire a highly accurate discrimination. AP possessors’ performance is characterized as effortless and automatic (Ross, Gore, & Marks, 2005). True to that description, here, AP possessors classified pitches in the half-octave task at latencies some 50% faster than nonpossessors.

Why did nonpossessors fail to do better at the half-octave discrimination? Perhaps they failed to obtain sufficient training in the solfeggio scale or more generally in music. True, many nonpossessors had less music training than AP possessors and many nonpossessors lacked fixed do solfeggio training. But some nonpossessors in fact did have these kinds of training and those participants did no better at the half-octave discrimination than other nonpossessors. The most likely reason nonpossessors did not do better is self-evident: they lacked AP and therefore failed to acquire it. Nonpossessors had less music training than AP possessors and many nonpossessors lacked fixed do solfeggio training. But some nonpossessors in fact did have these kinds of training.

Nonpossessors did perform slightly above chance, mainly by using pitch height perception to judge that the lowest pitches in the test were associated with reward and the highest with nonreward. In previous research (Weisman et al., 2010), we have counterbalanced reward and found that nonpossessors can also learn that the lowest pitches are associated with reward and the highest with nonreward. The distinctiveness of the endpoints in absolute judgment tasks is well-known (see Rouder, Morey, Cowan, & Pfaltz, 2004, for an example from judging line lengths). Interestingly, AP possessors showed little effect of endpoints in their half-octave judgments. All this is to say that AP possessors classified pitches in the half-octave task at latencies some 50% faster than nonpossessors.

#### First Instrument and AP

AP scores were about level across instruments except for flute players, who scored lower (see Table 1). Between groups ANOVAs found no significant differences in AP between participants based on their first instrument, $F(5, 46) = .33, ps = .90$ in either note-naming or half-octave discrimination scores. The numbers of participants who played other than the piano or a bowed string instrument first were too low (≤4) to draw any useful conclusions about their AP ability. A chi-square test, $\chi^2(1) = .02, p = .98$, of the difference in the proportions of piano (30%) and string instrument (36%) players who were AP possessors found no significant relationship between first instrument and AP, $\phi = .07$.

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To be useful in distinguishing possessors from nonpossessors, tests of AP must be both reliable and valid. We observed high correlations between the two note-naming tests and between the two sessions of half-octave discrimination training (high reliability) and high correlations between the naming tests and the half-octave test (high validity). Our findings, on their own and without further discussion, demonstrate that the half-octave operant discrimination could be used in preliminary screening to find AP possessors without musical training—and this was the purpose of the research.

**Contributions to Understanding AP**

**Remapping tones.** Using tones mistuned to the chromatic scale, Weisman et al. (2010) found that note-naming AP possessors required thousands of trials to acquire a mediocre operant pitch-range discrimination and nonpossessors attained only slightly above chance performance. Even with tones tuned to the chromatic scale in the present half-octave identification discrimination, at least some of our AP possessors required practice to remap the tones onto the go/no-go discrimination. Taken together, Weisman et al. (2010) and the present findings demonstrate that accounts of AP processing, which insist that AP possessors are always fluent, effortless, and automatic and demonstrate that accounts of AP processing, which insist that AP possessors are always fluent, effortless, and automatic and do not need to learn to remap their responses to unfamiliar scales and tasks (Levitin & Rogers, 2005; Ross et al., 2005), are incorrect.

**AP and music training.** Our analysis of \( d' \) half-octave discrimination scores ruled out a possible alternative explanation of our results: that high \( d'' \) scores reflected the early and extensive music training of AP possessors, not their skill at AP. We were able to match 22 nonpossessors to 13 AP possessors in onset and extent of music training. Nonpossessors matched in music experience to AP possessors had \( d' \) scores virtually identical to those of less experienced nonpossessors. That is, early and extensive music training without AP did not result in higher \( d' \) scores on the half-octave discrimination task.

Whatever theory one uses to account for how AP possessors learn to map tones into go and no-go pitch ranges, it must also account for the failure of trained musicians without AP to name notes or acquire the half-octave discrimination. In the parlance of causation: early and extensive music training may be necessary but they are not sufficient to produce AP. In further support of the insufficiency idea, several experienced musicians trained in the fixed do solfeggio method of sight-reading scored as nonpossessors in both the half-octave discrimination and in note-naming tests.

**Heterogeneity among AP possessors.** Baharloo, Johnston, Service, Gitschier, and Freimer (1998) found that most people scored either high (AP possessors) or low (nonpossessors) in naming both sine tones and piano notes, but some people scored intermediate, mainly by scoring higher on the piano than sine tones. Lockhead and Byrd (1981) labeled superior AP on piano notes than on sine tones, “absolute piano.” They reported that some participants could name 90% of the piano notes but less than 60% of the sine-tone notes in their tests. Absolute piano is the best known of the heterogeneities among prospective AP possessors. Lockhead and Byrd (1981) and Ross et al. (2005) attribute this form of AP to extensive music training with a specific instrument, often the piano. Confounding between AP and relative pitch is another form of ersatz AP, but using a wide range of sine tones presented in random orders can help eliminate relative pitch cues. Ross et al. (2005) proposed several differences between true AP possessors and ersatz possessors. Relative to true AP, ersatz AP is more limited by musical experience, less fluid, more effortful, and less automatic. Comparisons of performance in note-naming, pitch-range, and pitch-production tasks may help researchers answer questions about heterogeneity among AP possessors.

We found two heterogeneities in the AP performance of our participants. Incremental AP possessors, on average, named about the same number of notes as other AP possessors but required a second training session to attain accurate half-octave discriminations. Interestingly, three of four Incremental AP possessors scored lower in the second half-octave test session than other AP possessors. Variable AP/NAP possessors seem to more closely resemble people with absolute piano: They score above criterion in naming sine-tone notes in one range of octaves but below criterion in naming notes in higher or lower octaves. Again, results of the half-octave discrimination test were revealing: All four Variable AP/NAP possessors’ discrimination scores were indistinguishable from those of nonpossessors.

This is the first report of these AP heterogeneities. Our findings, through based on small samples of heterogeneous scores suggest some modest but interesting disassociations between note naming and the half-octave discrimination even in studies of experienced musicians. We suggest more extensive use of the half-octave test together with traditional note-naming tests in further research into sources of AP heterogeneity.

**Topics about which we are silent.** The first language and first instrument experience of musicians are thought to be important determinants of AP (Deutsch et al., 2006; Ward, 1999). Our study was powered to distinguish between AP possessors and nonpossessors on two AP tests, test to distinguish on the basis of language or instrument, and unsurprisingly neither variable generated significant differences in AP. Perhaps future research will devote more attention to the effects of these important variables on the half-octave measure of AP.

**Discrimination and production tests: Nonissues and issues.** Our go/no-go half-octave discrimination can be criticized because of differences between the incentives for go and no-go responses. Of course, it is well known that go/no-go protocols are biased in favor of responding, but percent response and \( d'' \) measures take the bias into account in evaluating performance. More important, hundreds of researchers have used go/no-go protocols successfully to demonstrate that humans and other animals discriminate among stimuli as diverse as pictures, speech sounds, odors, and drug doses (e.g., Sinnott et al., 1976). Production tasks, including Ross et al.’s (2005) reproduction task can be criticized because they add an extra processing step by requiring both perception and performance.

The best evidence that these criticisms are irrelevant is that both protocols agree with the results of note-naming tests of experienced musicians. That is, agreement of the half-octave discrimination protocol and the production protocol with note-naming tests put the validity of both protocols beyond doubt. It is pointless to quibble with the methodology of these protocols.
Finding Musically Untutored AP Possessors

One might suppose that finding even a single nonmusician with AP might settle the matter, but the standard for convincing evidence is much higher. For example, using their production protocol, Ross et al. (2004) found evidence of AP in an adult without music training, but the level of previous training was unverified. Also, Ross and Marks (2009) report accurate production AP in two young children. But the claim that the children were essentially musically untutored is dubious: Both children named many more notes than musically trained adults and children without AP.

To provide convincing evidence that music training is not an important determinant of AP, we will need to find much larger numbers of musically unsophisticated AP possessors. The half-octave classification test offers important benefits in the effort to cast a wider net: The protocol can be completed on any personal computer and, even better, it can be converted easily to a world-wide-web based test available to thousands of participants.

After finding people with highly accurate half-octave test scores on the web, we suggest using Ross et al.’s (2004) pitch production task in more individualized testing to help verify that these participants are true AP possessors. Converging evidence is important, because in the absence of note-naming ability, one might have only one piece of confirming evidence. In its current instantiation, Ross et al.’s (2004) production test is unsuitable for use on the web as participants must be blindfolded. However, it might still be possible to use the production test as collateral evidence. For example, individually administered blindfolded production tests could be arranged using rapid and secure shipping of compact tunable oscillators to responsible third parties for testing participants who score above the criterion for AP on a web-based version of the half-octave test.

We further suggest verifying that the participants do in fact have little or no formal music training, perhaps by administering Bermudez and Zatorre’s (2009) newly standardized note-naming AP test with minimal instructions or by weaving questions about music into an otherwise neutral questionnaire as a check on web participants’ truthfulness. All this presumes that further research will lead to the discovery of musically untutored AP possessors. But whether a careful search succeeds or fails, we will still know more about the necessity of music training to true AP than we did when music training was embedded in the definition of the phenomenon.

References


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