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Absolute Pitch

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Synonyms

Perfect pitch

Definition

In humans, the ability to name or vocally produce any musical note without using a reference note. More broadly, the ability to accurately remember auditory pitch not just in terms of the relationships among pitches.

Introduction

If you ask a musician for an example of a musical talent or gift, one of the most common answers would be absolute pitch (AP), and for good reason. Typically defined as the ability to name or produce musical notes without the need for a starting reference, AP is thought to be exceedingly rare, with an estimated incidence of occurrence of around 1 in 10,000 people (Bachem 1955). While this number may vary substantially across cultures (Miyazaki et al. 2012), it is clear that AP is disproportionately present in top music conservatories across the world (cf. Deutsch et al. 2006), and moreover, a number of well-known composers and musicians, from Mozart to Mariah Carey, have reportedly possessed AP. Yet, despite over a century of empirical research, the origins and nature of AP are still an open scientific question, situated within a broader question about the origin and nature of listening skills and expertise.

The Etiology of AP

Perhaps the most fundamental debate in the study of AP is how the ability develops. An influential theory of AP development is the *critical period theory*, which posits that AP depends entirely on musical training acquired early in life, during a critical period of development. A number of studies have reported that AP and early musical training are associated, assessed both by self-report (Bachem 1940; Levitin and Rogers 2005; Vitouch 2003) and tests of pitch identification (Deutsch et al. 2006; Lee and Lee 2011). Other early-life experiences that affect attention to pitch and that covary with AP, such as tonal language experience (e.g., Mandarin Chinese, Deutsch et al. 2004) and congenital or early-onset blindness (Hamilton et al. 2004), have also been used to support the *critical period* theory. Recently, the *critical period theory* was supported by a study demonstrating that a drug treatment, thought to "reopen" the critical period in mice (Yang et al.

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2012), potentiates acquisition of AP in adult human listeners (Gervain et al. 2013), although in this study, AP performance was well below the performance that is criterial of AP listeners.

The *genetic theory* of AP asserts that development depends on a specific genetic endowment, requiring relatively minimal environmental shaping. The fact that AP tends to run in families supports this (Theusch et al. 2009), but it is difficult to differentiate genetic from environmental factors, given that early musical training also runs in families (Baharloo et al. 2000). The rate of AP concordance among identical twins is significantly higher than the rate among fraternal twins (Theusch and Gitschier 2011). However, the "equal environment assumption" of twin studies may not be tenable, as identical twins tend to be treated as more similar than fraternal twins (Joseph 2002). Overall, despite several investigations, the putative genes for AP have not been identified, and it is clear that if there is a genetic basis to AP, it is not inherited in simple Mendelian fashion (Theusch and Gitschier 2011).

Given there has been some support for both the *critical period* and *genetic theories*, a third theory integrates these in a *hybrid theory* (Zatorre 2003). This *hybrid theory* states that early musical training within a critical period is necessary, but not sufficient, for AP to develop. Rather, early musical training must be accompanied by some genetic predisposition.

The *practice theory* conceptualizes AP as a listening skill, able to be learned at any time in life through perceptual training along with the appropriate general cognitive mechanisms for effective learning (e.g., effective attention control, sufficient working memory). Until recently, this theory has not been considered seriously because prior AP training studies have produced only modest improvements in absolute pitch identification (Takeuchi and Hulse 1993), and retention of this modest learning has been assumed to be short-term, although it has not been generally tested after a substantial retention interval. But there have been some studies that reported pitch identification performance comparable to "genuine" AP possessors after training (Rush 1989), with trained performance persisting for several months (Brady 1970). More recently, adult training of AP was shown to be statistically associated with individual differences in auditory working memory, which actually mediated the relationship between early musical training and AP learning in adults (Van Hedger et al. 2015a). These findings suggest that AP acquisition in adults may be better understood as a listening skill rather than an ability endowed at birth or crystallized within a critical period. This treats the skill of AP as similar to other perceptual skills, given that working memory has been implicated in a variety of other perceptual category-learning tasks (Lewandowsky et al. 2012).

Describing AP

Many of the controversies surrounding the origins of AP could be seen as rooted in a simple question that has no simple answer: *How should AP be measured*? The conventional definition (being able to name or produce a musical note without the aid of a reference note) is broad and does not address issues that arise when considering the actual variability in AP performance based on a number of factors, some of which are outlined below. This variability is important because, contrary to the simple definition, systematic and idiosyncratic variability in AP performance suggests the conception of the process of AP is neither monolithic nor exactly the same across people or time, which has implications for understanding how AP arises and operates.

Variability in Note Identification: The instrumental timbre and octave register of the to-be-identified note can influence categorization accuracy (Bahr et al. 2005). Individuals tend to have better AP memory for their primary instruments, sometimes to such an extent that AP ability does not manifest for other instruments (Ward and Burns 1982). There are also systematic differences in AP accuracy based on instrumental timbre, as timbres such as pure tones (Lockhead and Byrd 1981) and the human voice (Vanzella and Schellenberg 2010) tend to be harder to identify compared to timbres such as piano and violin.

Even among highly familiar instrumental timbres and octave registers, AP possessors display reduced performance when making judgments about notes that randomly switch between timbre and octave, suggesting that these attributes are an integral part of their category representations (Van Hedger et al. 2015b). Given that many tests of AP ability only present participants with one or two timbres (e.g., Athos et al. 2007), results of many AP assessments may not fully capture the diversity of AP.

Particular notes may also relate to difficulty of AP categorization. Specifically, "black-key" notes tend to be less accurately and more slowly identified compared to "white-key notes," with the notes "C" and "G" being easiest to identify (Miyazaki 1990). While this effect was initially described using a critical period framework – as white keys are generally learned at the youngest age and before black keys on a keyboard – the current prevailing view is that these note class differences stem from distributional differences in the listening environment. For example, Deutsch et al. (2011) were able to explain about 65% of the variance in note categorization accuracy with the estimated frequency of occurrence of each note in the listening environment.

The listening environment also appears to be essential in holding note categories in place. Both past and present environmental factors are important in the development and maintenance of AP (Wilson et al. 2012), with recent musical activity able to "tune up" AP ability (Dohn et al. 2014). Moreover, the "present" environment can be operationalized at a rapid timescale – within a single experimental session. When presented with music that was flattened by a fraction of a semitone, AP possessors reoriented their sense of what is "in tune" versus "out of tune" based on this listening experience (Hedger et al. 2013; Van Hedger et al. 2018).

On top of environmental influences, AP ability has been documented to shift with age, though the mechanisms for this change are not well understood. These age-related shifts have been reported as early as 40 years old and can progress to the point where individuals are two or three semitones removed from the "correct" note (Ward 1999). However, some individuals demonstrate no age-related shift, and thus more work is needed to understand the physiological and cognitive components of this effect. Given that these shifts would result in an individual consistently misclassifying a note by a fixed amount, some researchers have given partial or full credit for semitone errors (e.g., Athos et al. 2007) or assessed AP ability by the relative deviation of a response to the "correct" answer (e.g., Bermudez and Zatorre 2009).

AP as Dichotomous Versus Continuous: By this point, it should be clear that an individual's past and present experiences indelibly shape their AP "fingerprint," and thus AP is not synonymous with the perfect identification of any pitched sound. This variability in AP identification, however, means that the empirical study of AP requires establishing performance thresholds that can appropriately differentiate "AP possessors" from "non-AP possessors." Yet, the question of whether individuals can be cleanly binned into categories of "AP possessor" and "non-AP possessor" has been controversial since the earliest days of empirical research on the topic (Bachem 1937).

Support for AP as a dichotomous versus continuous ability appears to depend on the way in which it is tested. Often, tests of AP involve making a *timed* note category judgment (generally within 3–5 s). The logic for this "timeout window" is that AP should involve the *rapid* identification of a pitched sound. Indeed, when adopting this testing format, performance appears to be binned into relatively discrete populations of individuals near chance versus individuals near ceiling accuracy (Athos et al. 2007). However, allowing for longer periods to respond can reveal a more variable distribution, with many individuals falling between chance and ceiling performance (Bermudez and Zatorre 2009). As such, timed tests may exaggerate the dichotomous nature of AP.

Another factor in the consideration of AP as dichotomous versus continuous is that of *implicit absolute pitch*. While implicit AP is measured in several ways, the fundamental idea is that most individuals, regardless of explicit AP or musical training, have some long-term memory for absolute pitch based on pitch regularities in the listening environment, even if they are not able to assign cultural labels (e.g., note names) to isolated pitches. For example, individuals can differentiate popular melodies (Schellenberg and Trehub 2003), single iconic pitches such as the censor "bleep" (Van Hedger et al. 2016b), and even isolated in-tune from out-of-tune notes (Van Hedger et al. 2016a) based on absolute pitch information. These examples illustrate that the listening environment shapes long-term memory for absolute pitch across *all* individuals, not just those who can explicitly label isolated notes.

AP in Nonhuman Animals: When conceptualizing absolute pitch in broader terms – not tied to associating pitches with culturally specific labels – it becomes possible to discuss how absolute pitch manifests in nonhuman animals. For example, in an operant conditioning paradigm that has been used across species, listeners are rewarded for responding to some ranges of tones but not others, and moreover the rewarded tone ranges are interleaved with the non-rewarded tone ranges (Weisman et al. 2012). In this paradigm, most rats (*Rattus norvegicus*) and humans showed successful learning with three, but not eight, tone ranges. In contrast, pigeons demonstrate some success at the eight tone-range task, and many vocal-learning birds displayed high levels of accuracy on both three and eight tone-range tasks (Friedrich et al. 2007). From these results, it is perhaps tempting to conclude that avian species – in particular, vocal-learning avian species – have better absolute pitch abilities than mammals. However, it should be noted that humans with absolute pitch are able to perform at levels that approach vocal-learning birds, though their pattern of errors suggests that they potentially engage in different strategies (Weisman et al. 2010). Overall, comparative work is valuable for understanding the nature of absolute pitch abilities across species, though it is important to consider how absolute pitch is operationalized before claiming that particular species do or do not "possess" absolute pitch.

Conclusion

Absolute pitch has fascinated musicians, scholars, and the general population since it was first formally described, largely because of its conceptualization as a rare and mysterious expertise. In part, this idea of AP has been bolstered by oversimplifying the description of AP, and not considering just how much variability exists in AP performance across and within listeners. While there are still many unanswered questions surrounding its development, it has become clear that AP is best conceptualized as a kind of listening expertise rather than an endowed special ability. Moreover, given that implicit, long-term memory for absolute pitch appears to be present in almost everyone, as well as several nonhuman animal species, it is possible that what makes AP special is the learning by which listeners develop the musical knowledge to understand and categorize absolute pitch in the context of a culturally developed system of music.

Cross-References

- ▶ Associative Learning
- ▶ Auditory Processing and Perception
- ▶ Auditory Signals
- ▶ Cognition
- ▶ Critical Period for Song Learning
- ▶ Critical Periods
- ▶ Culture
- ▶ Dual-Store Model
- ▶ Equal Environments Assumption
- ▶ Learning
- ▶ Paired Associate Learning
- ▶ Pattern Learning
- ▶ Relational Perception
- ▶ Sensory Judgment

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