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Recent Advances in the Cognitive Neuroscience of Absolute Pitch

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Abstract

Absolute Pitch (AP), often referred to as perfect pitch, is the musical ability to identify or produce a given pitch, without hearing it in relation to any other pitch or reference tone. It allows musicians to name any particular note they hear by quickly recalling pitch information from their long-term memory. It is not a medical condition and has no obvious societal or evolutionary advantage but instead, is a product of brain structure and capability. Although AP is rare in the population, the phenomenon is of considerable interest to musicologists and neuroscientists. As it has both genetic and environmental influences, it represents a model through which the components of nature and nurture can be evaluated experimentally.

CURRENT CONCEPTS OF ABSOLUTE PITCH

AP ability is a neurocognitive function that certain people have acquired through a genetic trait that is influenced by early musical training allowing them to map musical tones to linguistic labels 1. That is, they are able to place labels (such as B-flat or D-sharp) to the pitches or frequencies that they hear. It is through this neural functioning that AP musicians can categorise numerous individual pitches that each have their own qualities and characteristics that distinguishes each one absolutely from the next. Unlike other cognitive functions, such as linguistics or memory, AP is an uncommon skill, with a prevalence of 1 in 10,000 2. This suggests the uniqueness of AP, being regarded by many as the height of musical ability, and by others (often those who have it), a nuisance.

Pitch itself is comprised of two components, height and chroma. Chroma corresponds to certain pitches in a musical scale, that is, each tone in the space of one octave has a specific chroma. The second component, height, relates to the octave differences of each particular chroma. For example, middle C on the piano is referred to as , where the ‘4’ corresponds to the height of the chroma, C. One octave away lies , where the height has changed, but the chroma has remained the same. Possessors of AP are often seen to make octave errors when identifying or producing a pitch (they do not recognise the height), and so their ability would be more aptly named Absolute Chroma.

Two types of true AP exist relating to the identification or reproduction of a pitch. Whilst they seem similar, they are distinguishable. The identification of a pitch, demonstrated by hearing a pitch and then classifying it (usually with a specific label such as C or Do) has been called passive AP. The reproduction of a pitch, seen by singing or humming a specified pitch has been dubbed active AP. Musicians with passive AP may hear a piano tone, and recognise it as an A, or perhaps hear a clock strike and identify that the pitch produced was an E-flat. Musicians with active AP will be able to sing a B-flat if it is asked of them. These two types of AP do not totally overlap. Not all possessors of passive AP will be able to sing or hum a specified note; however, most active AP musicians will have passive AP as well. In one study, only 92% of AP possessors that were tested said they could vocally produce a tone without a reference 3.

AP is usually seen as a combination of pitch memory and pitch labelling as defined by Daniel Levitin’s Two Part AP Model. The memory for pitch is actually an ability that everybody has, since when we hear any given pitch, despite not knowing what particular pitch it is, it does not sound ‘new’ to us. Another example is that we don’t forget any particular pitches, like waking up one day with the inability to sing or hum an F-sharp. Pitch labelling on the other hand, is subject to only AP musicians. It is this characteristic that separates people with AP from the rest of the wider community. They are able to label the sounds that they hear.

However, it is useful to note, that whilst the latter attribute is termed ‘pitch labelling’, the ‘labels’ need not be verbal. Musicians that are notation-illiterate could still demonstrate AP if asked to reproduce a sounded note on their particular instrument 4. Therefore, this idea of ‘pitch labelling’ is really just a shorthand way of saying an AP musician requires an associative memory component – something to which they can associate each specific pitch. This suggests that these memory associations, whilst usually note names (as demonstrated by most AP musicians), could be colour associations, solfa or names like ‘Fred’ or ‘Ethel’ 5.

Whilst there are musicians with AP, most of us have what is called Relative Pitch (RP). Whereas AP ability focuses on the recognition of individual pitches, RP is based around two or more pitches relative to each other. Another way to put it is that RP centres on the differences or intervals of two pitches. RP possessors are able to distinguish between two tones, but are not able to label the individual tones – a prerequisite for Levitin’s AP Model. This could be likened to the processing of colour, where people are able to discriminate between two different colours fairly easily, but are not able to place labels on individual shades or hues. AP and RP do not manifest themselves such that if a person does not have AP, they have RP and vice versa. Instead, the two lie on a continuum of AP skill. Between RP and AP lies Quasi-Absolute Pitch (QAP), which demonstrates variability in AP skill. That is, a QAP possessor may be able to identify or produce one single note (or a few), such as a B-flat for a trombone player (since the B-flat is the tuning note for trombonists), and use intervallic recognition (RP skill) to determine and classify a specific pitch. In other words, QAP musicians require a greater number of neural processes to complete pitch-naming tasks than AP musicians.

QAP musicians use different strategies to AP musicians when identifying a pitch. Whereas an AP possessor would use the pitch information stored in their long-term memory, those with QAP make use of: reference tones, as previously described, where a particular tone may be very familiar and recognisable, and all other tones are worked out through intervals; Timbrel facilitation, where a specific timbre will allow the musician to identify pitches; and the use of harmonic information, where the harmonics produced allow the musician to identify the tone. QAP musicians tend to demonstrate a more accurate identification of the notes C, G and A than other notes due to the use of reference tones. Those who use timbrel facilitation show more accuracy with pitch naming than QAP musicians with other strategies 6.

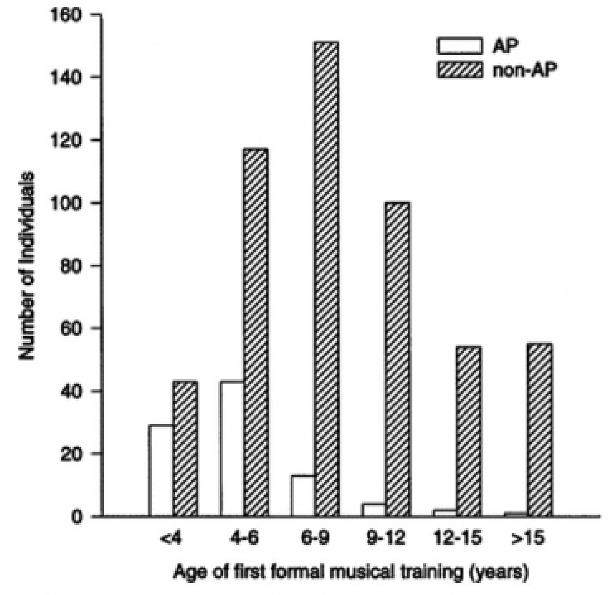
For an AP possessor, the encoded pitches in their long-term memory, that is, the memory for pitches and their associations (names/labels), is called the AP Template. An AP musician will have each pitch encoded into this template, with which they automatically compare any note they hear. This is what allows AP musicians to quickly identify a pitch. They already have the pitch and its association in their memory. RP possessors do not have this internal template. Thus they have no reference system for pitch, preventing them from quickly identifying pitches. Variability in AP skill, shown by QAP ability, creates variability in the AP Template. Some QAP musicians will have a more limited AP Template, where only a few specific pitches are encoded into memory. This is why the notes C, G and A are more accurately identified, as these specific tones are the ones that are encoded into the template. ‘Gaps’ in the AP Template (the pitches that aren’t encoded) can often be filled by RP judgements (intervallic recognition) to identify a pitch, however this uses more neural processes and lesser automacity than an AP musician would require. The QAP musicians who use timbrel or harmonic strategies would have a different kind of AP Template that would still have encoded pitches into the memory, but would require specific pitch sounds to be properly activated. With age, a person’s AP Template may shift by as much as a semitone, causing their pitch perception to be a substantially out from reality.

RECENT RESEARCH ON ABSOLUTE PITCH

Research has shown that AP is a product of hereditary factors combined with musical training from an early age 7. It is suggested that there is a certain ‘sensitive period’ in a child’s development that if musical exposure and tuition is administered, the child will be more likely to gain AP. One study of professional musicians showed that 40% of individuals who began training before the age of 4 had developed AP. In contrast, only 4% had developed AP with training starting between 9-12 years, and 2.7% for those who started after 12 years showing that earlier training allows greater development of AP. Since the percentage of those who began tuition before age 4 was only 40%, then even with early musical training, AP may not be developed. This is due to the nature of the training. Most of the training that musicians receive is based around RP, that is, the relationships between the notes are taught, not the specific pitches themselves. The early learning requires an exposure to the mapping of tones to their labels. At an early age, musicians should be taught the labels to each specific pitch. The type of instrument the musician is learning will also affect AP development. If the instrument is not a fixedpitched instrument, such as a violin or guitar where tuning is not always exact, it may be more difficult to encode fixed pitches into their AP Template. Other research has brought about the 'unlearning theory', stating that everyone is born with the ability to develop AP, but it is lost due to the aforementioned factors. Since some people still develop AP despite these factors, it is important to note that this early learning, whilst significant, does not account for all variance in the population.

Figure 1

Age of First Musical Training and Absolute Pitch



The question of the brains processing of pitch and recognition has been assessed in a variety of ways. The brains of persons with AP show some differences from similarly skilled musicians without AP. In 1995 Gottfried Schlaug showed that musicians with AP had an asymmetry in volumes between the right and left Planum Temporale (located in the Temporal Lobe), specifically a leftward asymmetry, shown using functional MRI testing 8. Researchers believe that the Planum Temporale is significant to the neurobiological basis for the AP Template, however, its exact function is yet to be understood, leaving room for further research in determining the biology of this template.

In the Frontal Lobes lies the Right Frontal Cortex that is important for monitoring pitch information (including pitch labels) in the working memory. In other words, it indexes the 'updating' of a person's 'memory system'. This area is activated in non-AP possessors and signals that pitch information is being updated into the memory when a tone is heard. AP musicians do not show this same response, presumably because pitch information is already encoded into the long-term memory (part of their AP Template), and therefore does not need constant updating. Another area in the Frontal Lobes is the Posterior Dorsolateral Cortex, which responds preferentially in AP musicians than non-AP musicians. This area is known to be part of the establishing and retaining of associative memory components (the labels or names associated with pitches). The activation of this area may provide the link between pitches and their labels for AP musicians.

The other main factor suggested for AP development is that of genetics 9. There are two main points for why genetics is regarded as important. The first is the significance of familial AP. Recent research has shown that of those who claimed to have AP, 48% indicated they had a first degree relative who also had AP, whereas only 14% of non-AP possessors indicated a relative with AP10. There have also been significant findings on siblings who demonstrate AP, with a sibling recurrence rate of about 8-15%. This figure is similar to other traits that have been classified as heritable, such as schizophrenia, with a ~9% recurrence rate. Also, other musical traits may have a genetic basis, such as congenital amusia, which has a higher incidence rate in identical twins. The other point suggesting genetics is the distribution of AP across different races. In one study of music students, AP occurrence was around 47.5% for Asians and only 9% for Caucasians. There has been some dispute over the credibility of this second point, where some researchers argue that it is not genetics that cause this greater incidence in Asians, but is to do with language. Speakers of tonal languages such as Mandarin and Vietnamese that use specific pitches to denote different meanings when pronouncing vowel sounds (where one vowel sound can mean four different things depending on the pitch) are more susceptible to developing AP than speakers of non-tonal languages (such as English). The speakers of these languages have remarkable absolute pitch memory when speaking these words, and it is suggested that this linguistic AP is easily transferred over to musical AP, accounting for the greater incidence of AP in Asians. However, this argument may be invalid as neither Japanese nor Korean are tonal languages, both of which have high AP occurrence, and Asian-Americans are also shown to have higher incidence rates than European-Americans. Thus genetic predisposition may indeed play a role in the development of AP.

SUMMARY

Many think of AP as an amazing ability. However, the worth of AP to the working musician is debatable since it provides no greater musical skill than a non-AP musician. Composers with AP do not necessarily write better music than those without, and it does not allow a possessor to perform at a greater level. In some cases, AP may actually be an annoyance or a bother. The automacity and constant awareness of their pitch-labelling can make enjoying music difficult. One AP possessor stated, “I don’t hear melodies; I hear pitch names passing by”. Anxiety and discomfort can also be felt when a piece is played out of slightly out of tune or transposed to a different key. AP musicians also process RP tasks (when hearing intervals) slower than other musicians. This is because they use their AP ability to determine the notes, and then use their knowledge of scale relations to work out the intervals. Thus, the chords AP possessors hear may not be thought of as consonant or dissonant, or capable of arousing emotions as they are for other music listeners, but instead may just be thought of as a series of individual notes being played simultaneously.

Absolute Pitch, although a rare phenomenon, provides a useful model for the neurocognitive processes involved in pitch recognition. Although possessed by many elite musicians, it is not essential for musicianship at the highest level. Recent research has highlighted some important interplays between genetics and environment and this area of musicology offers a unique window into brain function.

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