

## MEDICAL REVIEW

# Music of the Left Hemisphere: Exploring the Neurobiology of Absolute Pitch

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*I have a reasonable good ear in music.*

— William Shakespeare

*A Midsummer Night's Dream*

What did Mozart and Beethoven possess that Wagner and Tchaikovsky reportedly did not [1]? The answer is absolute pitch (AP)<sup>b</sup>, commonly referred to as “perfect pitch.” These terms denote the cognitive auditory ability to spontaneously and effortlessly identify and vocally produce specific musical tones without a reference note. AP musicians can also identify chords and key signatures of compositions solely upon first hearing. Musicians with relative pitch may acquire the same listening skills, but with one important exception: they need a reference note in order to label and vocalize tones.

Much attention has been directed toward elucidating the neuroanatomical, developmental and genetic correlates of AP. This mini-review will briefly describe these efforts and point to future research challenges.

## THE PLANUM TEMPORALE AND ABSOLUTE PITCH

AP is an auditory phenomenon—as such, it should not be surprising that neuroanatomical correlates are linked to the auditory cortex. This region occupies the dorsal surface of the temporal lobe and is quite complex in structure and function. It is now known to have 15 subdivisions, each serving a unique function in auditory processing and projection [2]. One such region is the planum temporale (PT), a triangular area of the superior temporal plane located posterior to the primary auditory field [3].

Despite its bilaterality, evidence of hemispheric asymmetry of the PT was discovered over 30 years ago [4]. Individuals who are right-handed have some degree of left PT asymmetry, and the PT is larger on average in the left hemisphere of the general population overall regardless of handedness [4]. One of the primary functions of the left hemisphere, particularly in right-handed individuals, is language production and comprehension [5]. Right-handed

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<sup>b</sup>Abbreviations: AP, absolute pitch; PT, planum temporale; MRI, magnetic resonance imaging.

individuals with language deficits, such as the inability to process phonological stimuli, have decreased PT asymmetry [6]. However, left-handed individuals are also less left-lateralized (i.e., have a smaller degree of asymmetry) than normal right-handers [7]. This loss of asymmetry can be attributed to the fact that the right cerebral hemisphere is more important in certain tasks than others — left-handedness being one of them.

Connections between auditory language processing and a leftward asymmetry of the PT have been inferred for two reasons. First, primates exhibit the first signs of a leftward asymmetry, suggesting lateralization associated with the beginnings of language [8]. Second, the left PT coincides with an area of the brain in the superior temporal gyrus, Wernicke's area (cytoarchitectonic area 22), which is central in language perception and comprehension [9,10]. This sensory speech area is distinct from the motor speech area, termed Broca's area (cytoarchitectonic area 44), located at the inferior frontal gyrus [10].

Since the left PT has been associated with language perception, there has been interest in determining whether the perception of other forms of sound, such as music, also correlates with a leftward PT symmetry. Anatomical functional magnetic resonance imaging (fMRI) studies revealed differences in the PT between musicians and a musically naive control group [9]. Specifically, musicians with AP exhibited exaggeration of the leftward asymmetry compared to both nonmusicians and musicians without AP. Further, nonmusicians demonstrated right hemispheric predominance when given music perception tasks, while trained musicians demonstrated activity in the left temporal cortex [9].

## THE DEVELOPMENT OF ABSOLUTE PITCH

Early musical training may induce a functional reorganization of the cerebral cortex [11]. This training appears to be related primarily to refining perceptual and motor abilities enabling the skilled musician to achieve proficiency in sight-reading and improvisation along with manual dexterity. Of interest, MRI has revealed increased representation of the left-hand fingers on the somatosensory cortex of accomplished violinists [12].

Early exposure to music also appears to be a key factor in acquiring absolute pitch [13, 14]. One study [15] reported that 95 percent of AP musicians began their training before the age of seven. Another study [16] confirmed that AP musicians began musical training at  $5.4 \pm 2.8$  years compared to non-AP musicians who began training at  $7.9 \pm 3.2$  years of age ( $p < .0001$ ).

One provocative study in infants [17] suggested that AP may be common or even universal at birth, but usually lost with subsequent development. Eight-month-old infants and adults were presented with a series of tones; after a short time delay, a second series of tones, including segments from the original sequence were played for the subjects. If these short segments are perceived as novel, subjects will be more likely pay more attention to them — if they are perceived as familiar, the subjects will not be as attentive. The infants, remarkably, responded by attending to the changes, while adult subjects did not. The experimental findings were interpreted to support the concept that absolute pitch may be a useful skill in infancy, providing flexibility in learning new languages, especially those that are tonal in nature, such as Thai or Vietnamese [15].

A related question is whether AP can be acquired through extensive musical training after childhood. The answer appears to be no, and commercial claims

to the contrary remain to be substantiated. Possible exceptions are violinists who develop a strong recognition for the "A" note (440 Hz) because they are trained to tune their instruments relative this pitch. But true AP apparently cannot be developed through tonal memorization or association, however intense.

### THE PREVALENCE OF ABSOLUTE PITCH

AP is rare in the general adult population (1 in 10,000) [18]; higher in musicians (1 in 1500) [19]; and even higher (15 percent) in virtuoso musicians [20]. One study showed a differential prevalence of AP in different groups of academic musicians: 24.6 percent in conservatory; 7.3 percent in university-based schools of music; 4.7 percent in a liberal arts/state university music program [16]. Furthermore, data suggest a notably higher prevalence of AP in Asians (including Pacific Islanders) compared to other ethnic groups in various music programs. Overall, 32.1 percent of Asians had AP versus 7 percent of non-Asians in one combined survey of music programs [16].

### DOES ABSOLUTE PITCH HAVE A GENETIC BASIS?

Whether AP is a genetically inherited trait is a subject of some controversy. Some authors have postulated that AP develops during gestation and infancy. [20] Available data suggest that early musical training is essential for its development [21]. Familial aggregation of the AP phenotype has been reported with AP being more prevalent in siblings in the musically trained population at large. This finding raises the possibility of a major-gene locus associated with this trait [14]. However, familial AP includes individuals brought up in similar, musically-enriched

environments. Because of such confounding environmental factors, careful genetic pedigree mapping will be necessary to provide concrete evidence of heritable factors in this complex phenotype [16, 22].

Since AP has been strongly associated with a leftward asymmetry of the PT, a predisposition to this trait should involve prenatal factors involved in lateralization of this region of the auditory cortex [23]. This hypothesis is based on the finding that PT asymmetry appears *in utero* between the 29th and 31st gestational weeks [24]. However, in one study, gyral and sulcal patterns in monozygotic twins discordant for handedness (one twin right-handed, the other left-handed) were dissimilar — the right-handed twins show normal leftward PT asymmetry, while their left-handed siblings lacked PT asymmetry. This observation suggests that epigenetic factors may play an important role in the development of PT asymmetry, and, therefore, probably also of AP [25].

Epidemiologic studies of genetic and non-genetic factors are hampered and likely biased by the currently available techniques to detect the AP phenotype. These methods, involving tests with tone identification, essentially require that the subjects with identifiable AP have at least some knowledge of the diatonic musical scale. Further, music conservatories and musically-oriented schools are also likely to attract individuals with AP [16].

### ABSOLUTE PITCH AND NEUROPATHOLOGY

AP has been found to be highly prevalent among three neurologically impaired groups — the autistic, those with savant syndrome, and those with Williams syndrome. Autistic disorder is characterized by severe disturbances of social relatedness, language and communication difficulties, and restricted, repetitive behav-

ioral patterns. There is strong evidence that genetic factors play a significant role in the etiology of this syndrome [26]. Interestingly, about five percent of autistic individuals possess AP [18].

Individuals with severe developmental disabilities may display skills at a level inconsistent with their general intellectual functioning as part of "savant" behavior [27]. Whether savants have distinctive cognitive strengths or motivational dispositions is unclear. In one study, all members of this category apparently demonstrated AP [18].

Williams syndrome, due to a gene deletion on chromosome 7, is associated with a distinctive facial appearance, cardiac abnormalities, infantile hypercalcemia, and growth and developmental retardation [28]. Along with these detrimental physiologic traits is hyperacusis, most likely due to a relative enlargement of the primary auditory cortex [29]. Auditory, musical, and verbal skills are highly developed compared with large deficits in visual and conceptual abilities. Therefore, it would be interesting to test for exaggerated PT asymmetry in this unusual population of musically gifted individuals [18].

## CONCLUSIONS AND FUTURE DIRECTIONS

Over the past 30 years, considerable progress has been made in elucidating the basis of AP. Many tantalizing questions, however, remain to be answered. An exaggerated leftward asymmetry of the physiologically lateralized PT is a key neuroanatomic finding. Musical training in early childhood appears to be critical. The development of tonal language may also be important. The role of genetic factors is unresolved. Future studies will profitably focus on more detailed genetic analyses, studies of AP monozygotic twins, an assessment of AP individuals with

acquired neurologic lesions [6], PT anatomy in left-handed AP musicians, and longitudinal analysis of infants and children to better define the prevalence and developmental basis of this unique gift.

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