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Exploring the Genetic and Environmental Causes of Perfect Pitch

Naomi Lester
Natural Sciences (Life and Physical Sciences), School of Biological Sciences, University of Leicester
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Abstract
Perfect pitch, or absolute pitch, possessors can recognise, recall, and label musical notes quickly, and do not require a reference note, like those with relative pitch abilities do. The phenomenon is seen as advantageous to musicians, with notable performers and artists throughout history possessing it. This paper aims to explore the effects that genetics, language, culture, and education can have on perfect pitch, and discuss which are the most crucial to its development.

Keywords: *Perfect Pitch; Biology; Genetics; Music; Language*

Introduction
Perfect pitch, also known as absolute pitch, is the ability to recognise, recall, and label musical notes and tones quickly, without the need for a reference note [1-8], although the definition is variable depending on the literature. The distribution of people with absolute pitch in society indicates familial aggregation, with families like the Bach family having high prevalence of absolute pitch [1], suggesting that there could be a genetic component, although it is difficult to predict the distribution in society. Due to the different distributions of absolute pitch amongst ethnicities, there could be other underlying factors that contribute to perfect pitch, which this paper will explore in more detail.

Neurobiology
People with absolute pitch show a difference in brain morphology through a leftward asymmetry of the temporal lobe [1], and are suggested to have dominance in the left hemisphere [2, 3, 9]. Auditory processing in the brain is contralateral, and the left side processes the sounds heard in the right ear [2]. Experiments with musicians showed that those with absolute pitch had faster reaction times and more accuracy for tones when they were played in the right ear only [2]. As people with absolute pitch have also displayed higher neuronal activation, the activation and processing sounds is related to absolute pitch [2]. This neurological difference can be explained in the differences in auditory processing, as the left side processes rapidly-changing and fine-grained sound information, whereas the right-hand side processes slower changing cues [3]. Greater left-sided activity has displayed in people with musical activity compared to those without, and there is greater activity in absolute pitch possessors compared to those without [3]. This suggests that greater attention is paid towards the elements of sound by the trained group compared to the untrained group [3].

In the opposite situation, people with congenital amusia, or tone deafness, also have asymmetrical processing of musical signals in their auditory cortices [9]. In those with congenital amusia, microlesions, small areas of damaged brain tissue, were present in the grey matter of the brain in the right-side, and there was decreased intrinsic connectivity within the auditory cortex in both hemispheres of the brain [9]. Like with absolute pitch, there are indications of familial aggregation of tone deafness, suggesting that there are genetic factors that can lead to the spectrum of musical processing abilities [9]. Amusia can also be acquired, as in the case of the composer Ravel [9].

Distribution Amongst Ethnicities
With distinct neurobiological differences in people with absolute pitch compared to those that do not, there is a suggestion that these develop in utero and that absolute pitch is entirely genetic [1]. The data on

the ethnicities of possessors of absolute pitch can also support the theory that it is entirely genetic. In studies on music students of conservatories, there were consistently more students with Asian or Pacific Islander heritage who had absolute pitch than Caucasian students [1, 8], and there were different specific genes of interest between European and Asian possessors of absolute pitch [1].

Genetic aspect

The linkages of genes related to absolute pitch are different in people of European and East-Asian descent; 8q24.21, and 7922.3 are the two areas of interest respectively [1]. The most significant region of genes of musical aptitude are found on chromosome 4, 4q22, which are overexpressed when listening to and performing music [1], and several other loci on chromosome 4 are connected with singing and musical perception [9]. The genes *AVPR1A* on chromosome 12 [1], and *SLC6A4* on chromosome 17 are both associated with musical memory [9]. Specific *AVPR1* haplotypes that enhance creativity are also more frequent in dancers when compared to athletes and non-dancers, and *SLC64A* has been linked to successful choral singing [1]. On the opposite end of the spectrum, *FOXP2* genes are associated with amusia, and mutations in humans can result in severe speech and language impairments [2]. Because of this, there is a suggestion that language learning is similar to perfect pitch, and so environmental and cultural factors are more impactful than genetic factors.

Impact of First Language

As described above, the *FOXP2* genes that exist in humans can result in language impairment when mutated. Orthologs of this gene exist in songbirds and bats, with them being crucial for song location, and echolocation [2]. This indicates that language learning is originated from other sound processing, with music and language evolutionarily linked, and shared brain mechanisms [3]. Furthermore, the ethnic variations in absolute pitch possessors has been linked to languages. Having a tonal language, like Mandarin Chinese, Vietnamese, and Japanese, where the tone differences in speech have different implications, as a first language may predispose someone to identifying subtle differences in notes, and could lead to an increased affinity for perfect pitch [1-3]. However, other research indicates that, while learning tonal languages may help to form an association between pitches and labels, it does not appear to improve one's ability to discriminate between them [2]. Furthermore, the differences in distribution could be due to altered cultural attitudes towards musical education [8] rather than the language itself.

Education

If perfect pitch is not fully genetic and innate, then it is logical to conclude that it can be taught. The critical period theory suggests that, like learning languages, there is a period during childhood development where acquiring perfect pitch is the easiest [5]. This is supported by learning studies that find increased success in teaching children absolute pitch than adults or adolescents [2]. Earlier musical training is also associated with absolute pitch being more prevalent, with the majority of possessors having begun their musical studies below the age of seven [1, 2, 8]. There is also the phenomenon of the Levitin effect, where people without absolute pitch can recall tunes and sing them back in the original key without a reference note, like nursery rhymes or popular songs on the radio or TikTok, indicating some capacity for learning [6, 7].

Conclusion

Overall, absolute pitch cannot be attributed to a single factor alone. Likely many factors contribute towards helping to develop the skill. While there are potential genetic factors, like with athletes, if these are not trained or utilised effectively, then the predisposition is not necessarily an advantage. Other factors, like language, cultural upbringing, and the age at which musical education begins can all have an impact on absolute pitch. It is also difficult to truly discern how prevalent absolute pitch is within the population, as studies focus on musically educated people, which can lead to it being difficult to separate the environmental and genetic factors [8]. Furthermore, relative pitch, where a reference note is used, is often more useful, particularly when transposing music live [3, 4]. Having or lacking absolute pitch does not dictate the success of a musical career, and relative pitch can be just as useful, if not more so in practice.

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