Amusia: The Science Behind Tone Deafness

Written by Emily Aldrich

What is Tone Deafness?

For most, the ability to distinguish basic pitch, rhythm, and melody of music is something that comes naturally. The brain is attuned to hearing certain sounds and perceiving them as music, allowing for listeners to enjoy what they are listening to as well as imitate what they hear. This seemingly simple, unconscious knowledge of music for individuals is something that about 2.5% of the population lacks (Lehmann et al., 2015). Congenital amusia, often referred to as "tone deafness", is a disorder present at birth that is characterized by the impairment of musical perception. Although amusic individuals know that the sound they are hearing is supposed to be a song, the concept of music as a whole is lost on them. Those with congenital amusia have an inability to perceive music as a coherent network of melodic elements (Szyfter & Wigowska, 2021). Instead, they recognize it only as disorganized noise in the environment, and can have deficits in perception of tune, melody, and rhythm – all factors that make up music.

Audition Process

Auditory processing occurs during any moment where sound is made and can be perceived, triggering the activation of neural pathways in the brain. Sounds start as air pressure waves that go through the ear canal, which is then detected by hair-like projections called stereocilia, located on the basilar membrane of the cochlea (Kulsoom & Karim, 2021). At this point in processing, these vibrations are transformed into electrical signals that are then sent to neurons in the spiral ganglion, whose axons form the auditory nerve (Kulsoom & Karim, 2021). The auditory nerve then sends the signal to the brainstem's auditory nuclei, a relay station for these signals to then be sent out to numerous different areas of the brain for further processing. Although these signals extend far out into different parts of the brain, this auditory process occurs all in the span of milliseconds.

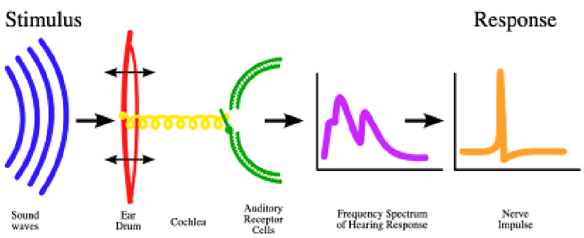

Figure 1. Audition process where sound waves become nerve impulses (Gollisch & Herz, 2005).

Physiological Aspects

Biological differences between those with amusia and the general population have been studied to better understand how tone deafness manifests in both the nervous system and the genetics of the affected group. One area that has been shown to have ties with amusia and general musical ability is the brainstem (Lehmann et al., 2015), a structure that sits just below the brain and connects to the spinal cord. The brainstem mediates many pathways of neuronal activity, allowing for the coordination of different brain functions. Researchers used complex auditory brain responses (cABRs) to measure the subcortical processing of complex sounds like tones, speech, and in this case, music (Anderson & Kraus, 2013). For amusic individuals who process music irregularly, their cABRs have shown decreased spectral amplitude meaning frequencies were weaker in magnitude, and slower onset responses; the stronger the disability in musical processing, the stronger these differences show up as cABRs (Lehmann et al., 2015). These areas of deviation from the norm show that there are specific locations and pathways where music is processed. When these pathways are not processed correctly, this may elicit a misunderstanding of sound in a way that amusics perceive as disorganized and not melodious. This information indicates that the physiological differences between amusics and non-amusics affect how their perceptions of complex sounds like music.

Genetic Components

There is likely a genetic component regarding congenital amusia, as many people who have this disorder are shown to have other family members with similar musical deficits. To learn more about the genetic underpinnings of congenital amusia, researchers began to study self-identified amusic individuals who also did poorly on the Montreal Battery of Evaluation of Amusia (MBEA), a test to determine the level of musical capability one has by assessing scale, contour, interval, rhythm, metric, and music memory–all components of music processing (Nunes-Silva & Haase, 2012). They had both amusic and non-amusic control groups encourage family members to take an assessment similar to MBEA that tested the same musical skills to determine whether or not these family members would have a comparable score to their relative. This study deduced that 39% of first degree relatives of people with amusia also have the same disorder, while only 3% of relatives have amusia in the control group (Peretz et al., 2007). The heritability of amusia is very evident, meaning genetics plays an important role in the phenotype of congenital amusia.

Sociocultural Impacts of Amusia

A highlighting feature of amusia is the consistent inability to recognize musical tunes, which also extends to music memory. It is strongly connected to deficits in recognizing small pitch changes. A noteworthy feature from amusia studies is that although difficulties in musical perception does not extend to the language realm for non-tonal languages like English, amusical people who use tonal languages like Mandarin or Vietnamese do slightly struggle in speech perception. In tonal languages, the pitch or tone of a syllable itself can change the meaning of words. In Mandarin, for example, the syllable /ma/ can mean either “mother”, “horse”, “hemp”, or “to scold” depending on which tone is used, as shown in Figure 2 (Li et al., 2021). Amusics who do speak tonal languages are able to produce the correct tones when creating speech, but have greater difficulty in accurately imitating pitches for tones they hear (Liu et al., 2013). Although they are still able to produce language at a proficient level, there is still some overlap between the presence of amusia and speech imitation in tonal languages because they are so reliant on the ability to use the correct pitches and match them accordingly.

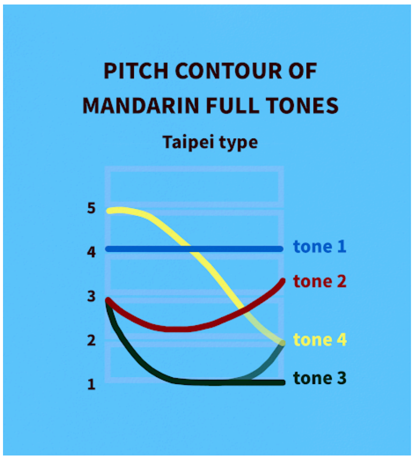

Figure 2. Standard Chinese tone contours (Wikimedia Foundation, 2021).

Further Look into Amusia

The progression of our understanding of congenital amusia has gone very far in just the past few decades. There have been many groundbreaking studies that further explain both the origins and long-term effects of this cognitive deficit. It is essential that we learn more about this lifelong disorder. From the progression in research that we have seen so much of, there are even more thoughts and questions that are important to answer. We now know there is a strong genetic component of this disorder. Future research can help identify amusia-related genes in individuals to learn more about how it is inherited, as well as finding treatments to target amusia. Additionally, it would be interesting to dig deeper in the social impact amusia has on its individual–particularly how the emotions that are elicited when listening to a certain song compares to controls, as well as its possible impact on individuals who speak pitch-accent languages. Through further research, we could potentially gain greater understanding of how amusics perceive and experience the world around them.

References

1. Anderson S, Kraus N. The Potential Role of the cABR in Assessment and Management of Hearing Impairment. Int J Otolaryngol. 2013;2013:604729. doi: 10.1155/2013/604729. Epub 2013 Jan 30. PMID: 23431313; PMCID: PMC3572655.

2. Gollisch, T., & Herz, A. (2005, January). *File:processing-of-sound.svg*. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Processing-of-sound.svg

3. Kawamura M, Miller MW. History of Amusia. Front Neurol Neurosci. 2019;44:83-88. doi: 10.1159/000494955. Epub 2019 Apr 30. PMID: 31220839.

4. Kulsoom B, Karim N. Sound: Production, perception, hearing loss and treatment options. J Pak Med Assoc. 2022 Apr;72(4):725-732. doi: 10.47391/JPMA.4051. PMID: 35614609.

5. Lehmann A, Skoe E, Moreau P, Peretz I, Kraus N. Impairments in musical abilities reflected in the auditory brainstem: evidence from congenital amusia. Eur J Neurosci. 2015 Jul;42(1):1644-50. doi: 10.1111/ejn.12931. Epub 2015 Jun 18. PMID: 25900043.

6. Li Y, Tang C, Lu J, Wu J, Chang EF. Human cortical encoding of pitch in tonal and non-tonal languages. Nat Commun. 2021 Feb 19;12(1):1161. doi: 10.1038/s41467-021-21430-x. PMID: 33608548; PMCID: PMC7896081.

7. Liu F, Jiang C, Pfordresher PQ, Mantell JT, Xu Y, Yang Y, Stewart L. Individuals with congenital amusia imitate pitches more accurately in singing than in speaking: implications for music and language processing. Atten Percept Psychophys. 2013 Nov;75(8):1783-98. doi: 10.3758/s13414-013-0506-1. PMID: 23877539.\

8. Nunes-Silva M, Haase VG. Montreal Battery of Evaluation of Amusia: Validity evidence and norms for adolescents in Belo Horizonte, Minas Gerais, Brazil. Dement Neuropsychol. 2012 Oct-Dec;6(4):244-252. doi: 10.1590/S1980-57642012DN06040008. PMID: 29213804; PMCID: PMC5619336.

9. Peretz I, Cummings S, Dubé MP. The genetics of congenital amusia (tone deafness): a family-aggregation study. Am J Hum Genet. 2007 Sep;81(3):582-8. doi: 10.1086/521337. Epub 2007 Jul 20. PMID: 17701903; PMCID: PMC1950825.

10. Szyfter K, Wigowska-Sowińska J. Congenital amusia-pathology of musical disorder. J Appl Genet. 2022 Feb;63(1):127-131. doi: 10.1007/s13353-021-00662-z. Epub 2021 Sep 21. PMID: 34545551; PMCID: PMC8755656.

11. Vuust P, Heggli OA, Friston KJ, Kringelbach ML. Music in the brain. Nat Rev Neurosci. 2022 May;23(5):287-305. doi: 10.1038/s41583-022-00578-5. Epub 2022 Mar 29. PMID: 35352057.

12. Wikimedia Foundation. (2021, December). File:Mandarin Tone Contours (beijing standard).svg. Wikipedia. https://en.m.wikipedia.org/wiki/File:Mandarin_tone_contours_(Beijing_standard).svg

About the Author

Emily Aldrich is a Freshman majoring in Neuroscience with minors in Linguistics and Psychology on the pre-med track. Emily joined Brain Matters to gain a deeper understanding of the brain through exploring current research topics in neuroscience. In her free time, she enjoys listening to music, reading, and spending time with friends.