

Publication status: This preprint has not been published elsewhere.

THE BEHAVIOURAL AND SYSTEM NEUROSCIENCE OF THE EARWORMS

Helena R. Ferreira

<https://doi.org/10.1590/SciELOPreprints.14488>

Submitted on: 2025-12-09

Posted on: 2025-12-11 (version 1)

(YYYY-MM-DD)

ARTICLE

THE BEHAVIOURAL AND SYSTEM NEUROSCIENCE OF THE EARWORMS

HELENA R. FERREIRA¹

ORCID: <https://orcid.org/0009-0001-2376-2564>

ferreira.r.helena@gmail.com

¹ The University of Kansas. Lawrence, KS, USA.

ABSTRACT: Earworms, also known as Stuck Song Syndrome and Involuntary Musical Imagery (INMI), the phenomenon of having a catchy tune involuntarily replaying in one's mind, represent a compelling aspect of human cognition.

This article investigates the neurological mechanisms behind earworms, utilizing recent studies to uncover the brain processes and behavioral aspects involved. The research aims to identify why specific tunes become stuck in our heads, how various stimuli contribute to this phenomenon, and insights into the processes of auditory perception and memory.

Ultimately, aims to contribute to an understanding of how earworms occur and provide potential strategies for managing it.

Keywords: earworm, Involuntary Musical Imagery (INMI), Stuck Song Syndrome, music, working memory

NEUROCIÊNCIA COMPORTAMENTAL E SISTÊMICA DE EARWORMS

RESUMO: *Earworm* ou “músicas chiclete”, também conhecidas como Síndrome da Música Presa e Imagens Musicais Involuntárias (IMI), o fenômeno de ter uma melodia cativante tocando involuntariamente na mente, representam um aspecto fascinante da cognição humana.

Este artigo investiga os mecanismos neurológicos por trás do *earworm*, utilizando estudos recentes para desvendar os processos cerebrais e os aspectos comportamentais envolvidos. A pesquisa visa identificar por que melodias específicas ficam presas em nossas cabeças, como vários estímulos contribuem para esse fenômeno e obter insights sobre os processos de percepção auditiva e memória.

Em última análise, busca contribuir para a compreensão de como os *earworms* ocorrem e fornecer estratégias potenciais para gerenciá-los.

Palavras-chave: earworm, Síndrome da Música Presa, Imagem Musical Involuntária (IMNI), música, memória de trabalho

LA NEUROCIENCIA CONDUCTUAL Y SISTÊMICA DEL EARWORM

RESUMEN: Los *earworms*, también conocidos como "gusanos de oído" o "melodías pegadizas", como el síndrome del trap musical y la imagería musical involuntaria (IMI), el fenómeno de tener una melodia pegadiza resonando involuntariamente en la mente, representan un aspecto fascinante de la cognición humana. Este artículo investiga los mecanismos neurológicos que subyacen a las melodías pegadizas, utilizando estudios recientes para desentrañar los procesos cerebrales y los aspectos conductuales implicados. La investigación busca identificar por qué ciertas melodías se quedan grabadas en la memoria, cómo diversos estímulos contribuyen a este fenómeno y comprender mejor los procesos de percepción

auditiva y memoria. En definitiva, busca contribuir a la comprensión de cómo se producen las melodías pegadizas y proporcionar posibles estrategias para gestionarlas.

Palabras clave: earworm, Síndrome de la Música Atrapada, Imaginería Musical Involuntaria (IMNI), música, memoria de trabajo

INTRODUCTION

The occasion of having a song, a social media clip, a conversation which happened before, or a video replaying incessantly in one's mind is part of the human existence, this seemingly trivial occurrence is reported as common experience in different occasions (Halpern and Bartlett, n.d.). On the other hand, the understanding of the reasons why certain tunes or sounds get "*stuck in our heads*", colloquially speaking, while others do not, remains a complex question, research has been showing that a melodic dictation exercise, which includes several layers of information that need to be analyzed across various domains, presents a significant cognitive challenge (Cornelius and Brown 2020). The overall impact of factors like these on working memory can be understood through ideas like Owens and Sweller (2008) cognitive load theory. This theory suggests that the demands a task places on working memory depend on the complexity of the information, how that information is presented, and the individual's capacity to effectively use relevant schemata to organize and manage the information (Cornelius and Brown 2020). The phenomenon of sound repetition is intricately linked to the mechanisms of working memory and primary auditory cortex that further will be explained along this study (Lees and Lawson 2024).

The phenomenon of the earworm, also known as Involuntary Musical Imagery (INMI) (Beaman 2018) or Stuck Song Syndrome (Beaman and Williams 2010a), occurs when a sound fragment repeatedly replays in one's mind, often becoming an unwelcome and intrusive presence (Beaman 2018). The term "earworm" was first introduced by psychiatrist Cornelius Eckert in 1979 (Silbersweig 2021) and has since become widely recognized in both popular and academic literature.

This article is a literature review study which aims to elucidate the neuro-mechanisms – brain mechanisms, responsible for the occurrence of earworms, discourse about the behaviors that cause prominence in cases of episode, and what are the profiles of people who tend to experience it. And seeks to bring suggestions in case of the experience is unpleasant, how to hand out or even reduce the effects on people's lives, in addition to citing the situations in which earworms cease to be a natural behavior and become a concern according to the literature.

The first section of this study provided an introduction of the phenomenon and a background history, synthesis the brain mechanisms processes involved since from when the sound is heard to where it is storage. The following section presents types of behaviors that tend to propel the occurrence of earworm and what are the profiles of people who usually experience it. Then, a highlight of the difference between memorizing textbooks versus sounds and why the experience of earworms with music is more likely to happen, and finally the article ends with medical conditions that maybe masked by earworms and conclusion.

LITERATURE REVIEW

Earworms

Earworms represent a particularly troublesome form of involuntary musical imagery, characterized by their persistence and the difficulty individuals face in controlling them. The mechanisms behind the phenomenon are complex and not fully understood, but they often involve repetitive and unforgettable musical elements that make the tunes more memorable and harder to dislodge from one's memory. These appealing elements are frequently employed by marketing and advertising professionals

to create memorable and engaging content, a study conducted by Eldritch Priest at all speculates that earworms are not merely neurological anomalies, but expressions of how contemporary capitalism increasingly colonizes unconscious mental activity, converting even passive, “useless” thinking into exploitable cognitive labor (Priest 2018). The historical evolution of listening technologies has trained our perception, embedding musical structures into our cognitive habits so deeply that earworms emerge as a kind of habitual, technologically conditioned thinking (Priest 2018). However, once an earworm takes hold, eliminating it can be hardly challenging.

Individuals who experience the event often try various strategies to rid themselves of these persistent melodies. Some people attempt to replace it with a different song, hoping that shifting their focus will disrupt the repetitive cycle, although earworm recurrence is relatively uncommon and unlikely to persist for longer than 24 h, the length of both the earworm and the earworm experience frequently exceed standard estimates of auditory memory capacity (Beaman and Williams 2010b). Others may try to resolve the situation by singing the repetitive song all the way through, believing that completing the song will provide closure and end the loop. Additionally, some individuals engage in activities that require intense concentration, hoping that focusing their mental efforts elsewhere will help dislodge the earworm (Pillay 2017).

The study conducted by Zaid Yusufi Rafin (Rafin 2016) has shown that the more forcefully individuals try to suppress an earworm, the more persistent it can become. This finding suggests that attempts to actively erase it out of consciousness might paradoxically make it more persistent. The phenomenon of earworms is not only a common issue among the general population but also frequently originates from exposure to television and radio advertisements, which are specifically designed to be memorable and engaging. These advertisements often feature memorable jingles or repetitive musical hooks that can easily become stuck in the listener’s mind (Rafin 2016).

Even with their prevalence, earworms can be more than just a minor annoyance; they can impact an individual's daily life and cognitive functioning (Hemming and Altenmüller, n.d.). The intrusive nature of the case can be distressing and distracting, particularly when they occur at inconvenient times.

Earworm Process: The Brain Mechanism

To understand how the earworm process occurs, first it is necessary to understand the brain mechanism that captures sounds and how it turns into a repetitive melody for a long period after it happens. When sound waves travel through the external auditory canal and middle ear, they cause movement in the fluids within the cochlea of the inner ear. This movement stimulates the hair cells in the organ of Corti, initiating the process of hearing (Appler and Goodrich 2011).

After sound waves travel through the outer ear and into the inner ear, they undergo a transformation into electrical signals by the delicate structures within the cochlea. These signals are then transmitted to the brain, commencing their journey at the primary auditory cortex, a crucial hub located in the temporal lobe. The primary auditory cortex is intricately designed to process the fundamental elements of sound. It discriminates between various frequencies, enabling us to perceive pitch, as well as assessing the loudness of sounds, which is critical for understanding volume. Within this region, neurons are tuned to respond to specific sound frequencies, creating a complex map of auditory information. This allows the brain to not only detect sounds but also to interpret them, paving the way for our appreciation of music, speech, and the myriad sounds that shape our daily experiences (Graham, Johnsrude, and Simons 2003).

Once auditory information is processed in the primary auditory cortex, it is transmitted to a network of cortical regions that further interpret these sounds, including those that govern our emotional responses. Among the key structures engaged in this intricate process is the amygdala. Recognized for its crucial role in emotional processing, the amygdala helps us associate sounds with specific feelings and memories, influencing how we react to what we hear. For instance, a familiar melody may evoke nostalgia, while a sudden loud noise might trigger fear. This interplay between auditory perception and emotional response illustrates how sounds can profoundly impact our feelings and behaviors. The collaboration between the auditory cortex and the amygdala not only enhances our awareness of our environment but

also enriches our emotional experiences, creating a deeper connection to the world around us (Concina et al. 2019).

The amygdala helps encode the emotional significance of sounds, including music, which explains why songs with emotional resonance are more likely to be retained in memory. Regardless of the specific emotion evoked, music with a strong emotional charge tends to make a lasting impression. The auditory cortex is intricately connected to the limbic system, a group of structures in the brain that plays a vital role in emotion, memory, and, importantly, the processing of sound and music. This region does more than simply analyze auditory stimuli; it actively engages with music during listening experiences, allowing us to appreciate melodies, harmonies, and rhythms. Moreover, the auditory cortex is instrumental in the formation and storage of musical memories. When we listen to a song, the emotional resonance and context of that music can create lasting associations, enabling us to recall not only the sounds but also the emotions and memories linked to them. This dynamic interplay between auditory perception and the limbic system helps explain why certain pieces of music can evoke powerful feelings or transport us back to specific moments in our lives, enriching our overall experience of sound and music (Sturgeon 2018).

Research from Dartmouth College indicates that the auditory cortex is activated not only when listening to music but also when merely imagining hearing a song. This finding supports the idea that the auditory cortex is involved in both processing and retaining musical memories throughout a person's life ("Your Brain on Music: Earworms," n.d.).

Music has a profound effect on both hemispheres of the brain, and this bilateral activation can enhance learning and memory (FNU 2019). The corpus callosum, a major commissural structure in the brain composed of white matter tracts, is crucial for connecting the left and right hemispheres of the cerebral cortex (Olszewska et al. 2021). A larger corpus callosum and thicker myelinated axons can enhance inter-hemispheric communication and improve cognitive functions, a study conducted by Gottfried Schlaug et al. employing in-vivo magnetic resonance morphometry to investigate the midsagittal area of the corpus callosum (CC) in 30 professional musicians compared to 30 age-, sex-, and handedness-matched controls. The findings revealed that the anterior half of the corpus callosum was significantly larger in musicians, especially those who began training before age 7. This suggests enhanced interhemispheric communication and potential asymmetries in sensorimotor areas. However, the results align with evidence of anatomical changes occurring during early development, indicating the brain's plasticity in response to musical experience (Schlaug et al. 1995). Given that music activates various brain regions, understanding how earworms, or involuntary musical imagery (INMI), persist could provide insights into the mechanisms of memory formation and retention.

The working memory, or operational memory, is a cognitive system responsible for holding and manipulating temporary information. This process is routinely accessed to manage information needed for tasks such as problem-solving or decision-making (Cowan 2014). Although working memory typically handles everyday information rather than specific songs or sounds, certain melodies or audio stimuli manage to intrude and persist in the thoughts. This leads to wonder why some sounds become so entrenched in the human minds.

One explanation involves the concept of the "speech therapy loop", a term used to describe how certain auditory stimuli, like unforgettable songs, engage more deeply with our working memory. According to neurologist Diogo Haddad from Hospital Oswaldo Cruz in São Paulo, Brazil, this looping effect occurs due to specific characteristics of the music, including simpler rhythms, repetitive structures, and shorter lyrics (Haddad 2021). These elements make it easier for the song to be encoded and replayed in our minds.

The phenomenon of earworms can be attributed to these cognitive and sensory mechanisms. Earworms are often characterized by their captive nature – melodies that are easy to remember and recite. The looping process is facilitated by the brain's working memory, which tends to favor stimuli that are repeated frequently and are relatively simple in structure (Cowan 2014).

It is worth noting that not all auditory stimuli become earworms. Factors such as individual differences in memory capacity, musical preference, and even emotional state play a role in whether a particular song or sound adheres in one's head (Priest 2018). For instance, people might find themselves with a memorable commercial jingle replaying in their intellect more often than a complex classical

composition. The jingle's repetitive nature and simple melody make it more likely to engage the working memory loop, whereas the complex structure of classical music might not facilitate the same degree of repetition.

Songs and sounds that possess simpler rhythms, repetitive elements, and shorter lyrics are more likely to become earworms due to their ease of processing and memorability. While this phenomenon is widespread and familiar to many, the cognitive processes behind why certain sounds become persistent in the brainpower offer a fascinating glimpse into how brains process and retain auditory information.

The mnemonic power of music is well-documented (Werner 2018);(Thaut et al. 2014);(Ratovohery et al. 2019); melodies, rhythms, and lyrics can aid in memory retention and recall. For instance, educational songs like the ABC Song, set to the tune of "Twinkle, Twinkle, Little Star", help people, especially children, learn and remember information more effectively ("Your Brain on Music: Earworms," n.d.). Even though the vast literature tends to agree with this narrative, there are some studies who disagree with the power of memory retention due memorable songs. The article Folk pedagogy? Investigating how and why UK early years and primary teachers use song with young learners was written by Catherine Hamilton and Victoria (Hamilton and Murphy 2024) with a strong criticism of the association of music in early education, stating that what we find today in the literature, for the most part, concerns a tendency of the method preferred by the teacher and not a true scientific proof of the effectiveness of making an association with folk pedagogy and the use of music.

The author also criticized the validity and reliability of famous studies that are used as support for literature reviews like she said: "It is surprisingly difficult to find reliable empirical evidence for what songs specially contribute to learning outcomes outside music, so-called transfer benefits from one cognitive or academic domain to another." In another sentence she also said: "Cultural beliefs that music training makes you more intelligent persist, nevertheless. There is a mismatch between teachers' intuition for using songs in a cross-curricular manner and the dearth of reliable empirical evidence about music's extrinsic cognitive and academic benefits." One point to highlight of this study was the failure to consider the neurological aspects and psychic processes that are related to the use of music in early education.

Earworm Process: Tendence Behaviour

Research into earworms often focuses on understanding the conditions under which they occur. A study by McCullough Campbell and Margulis (2015) explored whether overt motor involvement – such as humming, singing, or tapping – or imagined motor involvement, such as envisioning a continuation of an interrupted melody, leads to more frequent occurrences of INMI compared to passive listening. The findings suggested that active engagement with music, either physically or mentally, increases the likelihood of experiencing an earworm. However, the interruption of a melody alone did not appear to significantly impact the frequency of earworms.

Further analysis into the characteristics of earworms reveals that these tunes often exhibit certain global melodic contours and less common average gradients between melodic turning points compared to non-earworm songs. Jakubowski et al. (2017) conducted a study on a large pop music corpus and found that earworms typically have simpler and more repetitive melodic structures, making them more likely to become trapped in people's mind.

Earworm Process: People

Everyone can or will experience earworm at least one time in life, and this is not a statistical statement but a matter of causality, because we are often exposed to countless advertisements, songs, commercials, movies, shows and so on that make us more likely to at least one time have it. But some studies (McCullough Campbell and Margulis 2015) have proved that some people are more likely to experience earworms than another.

Sounds vs. Textbooks or Conversations

The inquiry about why people have easiness assimilating music instead of texts or spoken information is also present in the literature. Furthermore, the question about why people only have earworms with music and sounds, and not with phrases, is also an interest interrogation for researchers. Eric A. Havelock explains in the book *Preface to Plato* (Vaiano 2019) that the content of everyday conversations (and, by extension, the plain text of textbooks) is vulnerable to the *wireless telephone phenomenon*, which means, the information that humans read or listen to during a conversation is storage in the brain through a process of reformulating the sentences instead of transmitting them exactly how was said to our working memory. This happens because for the brain what matter is the message, not the words, the brain chooses to convey that message to save energy, and this message compression process gradually causes information to be lost. Music, jingles or advertisements, on the other hand, does not allow space for brain reformulation because the words matter as much as the meanings themselves. The number of syllables, the tone and accentuation, and the choice of rhymes determine the information that has to be kept (Vaiano 2019).

Also, the rhythm of the music or sound will create patterns that will allow faster memorization (Brower 1993). The human brain tends to seek out patterns to facilitate comprehension, retention, and processing of information, making it more accessible when presented in an illustrative manner (Berl et al. 2010). This cognitive phenomenon bears resemblance to the employment of a hook, referred to as an earworm or generally a *catchy bit*, by music producers within their compositions. Coincidentally, this method also functions as a means of enhancing memory retention, which elucidates why certain language courses are structured around melodious and captivating musical arrangements. Some even suggest (*The Atlanta Journal-Constitution* 2021) that the benefits don't necessarily depend on the kind of music that is listened to, but rather on how effectively they internalize the song's pattern.

Indicatives of Underlying Medical Condition

Music therapists already use music's ability to trigger a range of emotional states in their patients. According to Brittany Meyer (*The Atlanta Journal-Constitution* 2021), a neurologic music therapist at UPMC Children's Hospital of Pittsburgh, music's ability to activate multiple parts of the brain simultaneously makes it a useful tool for rebuilding and strengthening pathways in the brain. Earworms are considered intrusions: unwelcome involuntary thoughts, they are a subtype of obsessions. People experiencing earworms as terribly annoying and stressful are more likely to express typical OCD symptoms (such as mysophobia – fear of germs, dirt, and contamination) (Euser, Oosterhoff, and van Balkom 2016).

Persistent tunes, colloquially referred to as “stuck songs”, should be discerned from auditory hallucinations wherein individuals are convinced that the source of the sound is external. Within the context of “release hallucinations”, individuals with no history of mental illness compensate for diminished auditory stimuli following hearing impairment. On rare occasions, instances of persistent tunes have been reported in association with migraine, atypical manifestations of complex epilepsy, or palinacousis (the continued perception of a sound after its physical cessation), often manifesting alongside concurrent severe neurological symptoms (Euser, Oosterhoff, and van Balkom 2016).

Earworms are generally viewed as neutral or enjoyable, although certain individuals may find them distressing. To differentiate between typical physiological experiences and potential pathological manifestations, it is essential to evaluate the degree of distress caused, the extent of efforts to avoid or alleviate the earworms, and to inquire about the presence of other symptoms associated with obsessive-compulsive disorder (Hemming and Altenmüller, n.d.).

CONCLUSION

The experience of earworms constitutes an appearing occurrence in human life, as individuals are likely to encounter them at some point. Despite its widespread nature, the understanding of earworms remains a relatively unexplored topic in academic literature.

Earworms, or involuntary musical imagery (INMI), refer to the spontaneous replay of music or fragments of songs in our minds. They can range from a few bars of a memorable tune to entire songs, often surfacing without any conscious effort or intention. This phenomenon is remarkably common, affecting people from all walks of life. Research suggests that nearly everyone experiences earworms at some time, with some experiencing them more frequently than others.

The appeal of earworms is partly due to their “catchy nature”. Certain musical elements, such as repetitive melodies, rhythmic patterns, or distinctive hooks, are more likely to become earworms. However, the specific reasons why certain tunes become earworms and others do not are fully understood.

Despite their prevalence, academic research on earworms is relatively sparse. While there have been some studies investigating the cognitive mechanisms behind earworms, the field remains in its infancy. Researchers have begun to explore potential explanations for why earworms occur, including the role of memory, attention, and emotional responses. Some theories suggest that earworms may be related to how our brains process and store musical information, while others propose that they might be linked to psychological factors such as stress or boredom.

One aspect that complicates the study of earworms is their subjective nature. The experience of having a song stuck can vary widely among individuals. Factors such as personal musical preferences, current emotional state, and the context in which the earworm occurs all play a role in shaping the experience. This variability makes it challenging to establish a one-size-fits-all explanation or solution for earworms.

There are some strategies that individuals use to manage or alleviate earworms. These include listening to the full version of the song, engaging in distracting activities, or even trying to replace the earworm with a different tune. While these methods may provide temporary relief, they do not address the underlying cognitive processes responsible for earworms.

In summary, earworms are a widespread phenomenon, affecting many people at various points in their lives. While they are a common experience, our understanding of why and how they occur remains incomplete. The topic presents an interesting area for further research, particularly in exploring the cognitive and psychological mechanisms behind earworms. As our knowledge in this area grows, we may gain a deeper understanding of this intriguing aspect of human experience and develop more effective strategies for managing these persistent musical intrusions.

For future studies, efforts would benefit from additional investigations and a comprehensive delve deeper into this subject through clinical studies. This will help in establishing effective measures for preventing earworms, especially in clinical settings where the impact of persistent musical intrusions can be particularly disruptive. Understanding the cognitive and psychological mechanisms behind earworms can provide valuable insights into how musical memory works and how to better manage these persistent auditory intrusions.

SUMMARY

Earworms, commonly referred to as Stuck Song Syndrome or Involuntary Musical Imagery (INMI), are the phenomenon of catchy tunes replaying involuntarily in one's mind. This intriguing aspect of human cognition invites exploration into the neurological mechanisms at play. Recent studies reveal that earworms engage several crucial brain regions, notably the primary auditory cortex and the amygdala. The primary auditory cortex is responsible for processing basic auditory features like pitch and volume, while the amygdala plays a vital role in emotional processing and memory formation. Together, these areas facilitate the encoding and retrieval of musical information, linking emotional significance to the

persistently replayed tunes. Moreover, behavioural aspects of earworms highlight how repetitive exposure to specific melodies can trigger these mental repetitions.

Factors such as emotional responses and contextual elements—like stress or boredom—also contribute significantly to why certain songs become lodged in our thoughts. By analysing these elements, researchers seek to understand the specific reasons behind the creation of earworms and the various stimuli that contribute to their prevalence. This research not only enhances our understanding of the cognitive and emotional dimensions of earworms but also sheds light on the underlying processes of auditory perception and memory. It clarifies why some melodies linger in our minds while others quickly fade away. Ultimately, the goal is to provide a broader understanding of how earworms occur, exploring potential strategies for managing these persistent musical intrusions. Such insights carry implications for both cognitive science and everyday life, illuminating the intricate relationship between music, memory, and emotion. Understanding earworms may lead to greater awareness of our cognitive processes and offer practical approaches to cope with these catchy mental echoes.

REFERENCES

- Appler, Jessica M., and Lisa V. Goodrich. 2011. "Connecting the Ear to the Brain: Molecular Mechanisms of Auditory Circuit Assembly." *Progress in Neurobiology* 93 (4): 488–508. <https://doi.org/10.1016/j.pneurobio.2011.01.004>.
- Beaman, C. Philip. 2018. "The Literary and Recent Scientific History of the Earworm: A Review and Theoretical Framework." *Auditory Perception & Cognition* 1 (1–2): 42–65. <https://doi.org/10.1080/25742442.2018.1533735>.
- Beaman, C. Philip, and Tim I. Williams. 2010a. "Earworms (Stuck Song Syndrome): Towards a Natural History of Intrusive Thoughts." *British Journal of Psychology* 101 (4): 637–53. <https://doi.org/10.1348/000712609X479636>.
- Beaman, C. Philip, and Tim I. Williams. 2010b. "Earworms (Stuck Song Syndrome): Towards a Natural History of Intrusive Thoughts." *British Journal of Psychology* 101 (4): 637–53. <https://doi.org/10.1348/000712609X479636>.
- Berl, Madison M., Elizabeth S. Duke, Jessica Mayo, Lisa R. Rosenberger, Erin N. Moore, John VanMeter, Nan Bernstein Ratner, Chandan J. Vaidya, and William Davis Gaillard. 2010. "Functional Anatomy of Listening and Reading Comprehension during Development." *Brain and Language* 114 (2): 115–25. <https://doi.org/10.1016/j.bandl.2010.06.002>.
- Brower, Candace. 1993. "Memory and the Perception of Rhythm." *Music Theory Spectrum* 15 (1): 19–35. <https://doi.org/10.2307/745907>.
- Concina, Giulia, Annamaria Renna, Anna Grosso, and Benedetto Sacchetti. 2019. "The Auditory Cortex and the Emotional Valence of Sounds." *Neuroscience and Biobehavioral Reviews* 98 (March):256–64. <https://doi.org/10.1016/j.neubiorev.2019.01.018>.
- Cornelius, Nathan, and Jenine L Brown. 2020. "The Interaction of Repetition and Difficulty for Working Memory in Melodic Dictation Tasks." *Research Studies in Music Education* 42 (3): 368–82. <https://doi.org/10.1177/1321103X18821194>.

- Cowan, Nelson. 2014. "Working Memory Underpins Cognitive Development, Learning, and Education." *Educational Psychology Review* 26 (2): 197–223. <https://doi.org/10.1007/s10648-013-9246-y>.
- Euser, Anne Margriet, Menno Oosterhoff, and Ingrid van Balkom. 2016. "Stuck Song Syndrome: Musical Obsessions - When to Look for OCD." *The British Journal of General Practice: The Journal of the Royal College of General Practitioners* 66 (643): 90. <https://doi.org/10.3399/bjgp16X683629>.
- FNU. 2019. "The Benefits of Studying with Music." Florida National University (FNU) (blog). August 13, 2019. <https://www.fnu.edu/benefits-studying-music/>.
- Graham, Kim S., Ingrid S. Johnsrude, and Jon S. Simons. 2003. "Temporal Lobe." In *Encyclopedia of the Neurological Sciences*, edited by Michael J. Aminoff and Robert B. Daroff, 486–95. New York: Academic Press. <https://doi.org/10.1016/B0-12-226870-9/00779-6>.
- Haddad, Diogo. 2021. "Entenda como as músicas-chiclete grudam na cabeça por vários dias." *Noticias R7*. July 26, 2021. <https://noticias.r7.com/tecnologia-e-ciencia/entenda-como-as-musicas-chiclete-grudam-na-cabeca-por-varios-dias-26072021/>.
- Halpern, Andrea R., and James C. Bartlett. n.d. "The Persistence of Musical Memories: A Descriptive Study of Earworms." Accessed May 11, 2025. <https://online.ucpress.edu/mp/article/28/4/425/62495/The-Persistence-of-Musical-Memories-A-Descriptive>.
- Hamilton, Catherine, and Victoria A. and Murphy. 2024. "Folk Pedagogy? Investigating How and Why UK Early Years and Primary Teachers Use Songs with Young Learners." *Education 3-13* 52 (8): 1488–1509. <https://doi.org/10.1080/03004279.2023.2168132>.
- Hemming, Jan, and Eckart Altenmüller. n.d. "When an Everyday-Phenomenon Becomes Clinical: The Case of Long-Term 'Earworms.'"
- Jakubowski, Kelly, Sebastian Finkel, Lauren Stewart, and Daniel Müllensiefen. 2017. "Dissecting an Earworm: Melodic Features and Song Popularity Predict Involuntary Musical Imagery." *Psychology of Aesthetics, Creativity, and the Arts* 11 (2): 122–35. <https://doi.org/10.1037/aca0000090>.
- Lees, A.J., and Sarah Lawson. 2024. "Earworms—A Narrative Review of Infectious Music." *JAMA* 331 (13): 1075–76. <https://doi.org/10.1001/jama.2024.2780>.
- McCullough Campbell, Stephanie, and Elizabeth Hellmuth Margulis. 2015. "Catching an Earworm Through Movement." *Journal of New Music Research* 44 (4): 347–58. <https://doi.org/10.1080/09298215.2015.1084331>.
- Olszewska, Alicja M., Maciej Gaca, Aleksandra M. Herman, Katarzyna Jednoróg, and Artur Marchewka. 2021. "How Musical Training Shapes the Adult Brain: Predispositions and Neuroplasticity." *Frontiers in Neuroscience* 15:630829. <https://doi.org/10.3389/fnins.2021.630829>.
- Owens, Paul, and John and Sweller. 2008. "Cognitive Load Theory and Music Instruction." *Educational Psychology* 28 (1): 29–45. <https://doi.org/10.1080/01443410701369146>.
- Pillay, Srin. 2017. "Why You Can't Get a Song out of Your Head and What to Do about It." *Harvard Health*. October 4, 2017. <https://www.health.harvard.edu/blog/why-you-cant-get-a-song-out-of-your-head-and-what-to-do-about-it-2017100412490>.

- Priest, Eldritch. 2018. "Earworms, Daydreams and Cognitive Capitalism." *Theory, Culture & Society* 35 (1): 141–62. <https://doi.org/10.1177/0263276416667200>.
- Rafin, Zaid Yusufi. 2016. "A 19-Year-Old with Intrusive Loops of Music in His Mind." *Psychiatric Annals* 46 (12): 671–73. <https://doi.org/10.3928/00485713-20161020-01>.
- Ratovohery, Stéphanie, Baudouin, Alexia, Palisson, Juliette, Maillet, Didier, Bailon, Olivier, Belin, Catherine, and Pauline and Narme. 2019. "Music as a Mnemonic Strategy to Mitigate Verbal Episodic Memory in Alzheimer's Disease: Does Musical Valence Matter?" *Journal of Clinical and Experimental Neuropsychology* 41 (10): 1060–73. <https://doi.org/10.1080/13803395.2019.1650897>.
- Schlaug, Gottfried, Lutz Jäncke, Yanxiong Huang, Jochen F. Staiger, and Helmuth Steinmetz. 1995. "Increased Corpus Callosum Size in Musicians." *Neuropsychologia, Neuropsychological And Developmental Studies Of The Corpus Callosum*, 33 (8): 1047–55. [https://doi.org/10.1016/0028-3932\(95\)00045-5](https://doi.org/10.1016/0028-3932(95)00045-5).
- Silbersweig, David. 2021. "Harvard Scientist on Why That Song Is Stuck in Your Head." *Harvard Gazette*. December 14, 2021. <https://news.harvard.edu/gazette/story/2021/12/harvard-scientist-on-why-that-song-is-stuck-in-your-head/>.
- Sturgeon, David. 2018. *Introduction to Anatomy and Physiology for Healthcare Students*. London: Routledge. <https://doi.org/10.4324/9781315544298>.
- Thaut, Michael H., David A. Peterson, Gerald C. McIntosh, and Volker Hoemberg. 2014. "Music Mnemonics Aid Verbal Memory and Induce Learning – Related Brain Plasticity in Multiple Sclerosis." *Frontiers in Human Neuroscience* 8 (June). <https://doi.org/10.3389/fnhum.2014.00395>.
- The Atlanta Journal-Constitution. 2021. "Although Annoying, Earworms May Help You Process Memories," July 22, 2021, sec. Pulse.
- Vaiano, Bruno. 2019. "Por que é mais fácil lembrar letra de música que conteúdo de uma prova? | Oráculo." *Super*. 2019. <https://super.abril.com.br/coluna/oraculo/por-que-e-mais-facil-lembrar-letra-de-musica-que-conteudo-de-uma-prova/>.
- "Your Brain on Music: Earworms." n.d. The Kennedy Center. Accessed March 10, 2025. <https://www.kennedy-center.org/education/resources-for-educators/classroom-resources/media-and-interactives/media/music/your-brain-on-music/your-brain-on-music/your-brain-on-music-earworms/>.
- Werner, Riah. 2018. "Music, Movement and Memory: Pedagogical Songs as Mnemonic Aids." *TESOL Journal* 9 (4): e00387. <https://doi.org/10.1002/tesj.387>.
- Grammarly. (n.d.). *Grammarly: Writing assistant for spelling and academic tone improvement. * Retrieved from [<https://www.grammarly.com>] (<https://www.grammarly.com>)

Submitted: 12/09/2025

Approved:

Editor section:

AUTHORS' CONTRIBUTION

Author 1 - Design and development of the project, data collection, data analysis, writing of the text and review of the final version of the article.

DECLARATION OF CONFLICT OF INTEREST

The author declare that there is no conflict of interest with this article.

DECLARATION OF AVAILABILITY OF RESEARCH DATA

The entire dataset supporting the results of this study is available on OECD.org and can be accessed at <https://www.oecd.org/en/data/datasets/pisa-2022-database.html>.

DECLARAÇÃO DE DISPONIBILIDADE DE DADOS DA PESQUISA

Todo o conjunto de dados de apoio aos resultados deste estudo foi disponibilizado em OECD.Org e pode ser acessado em <https://www.oecd.org/en/data/datasets/pisa-2022-database.html>.

This preprint was submitted under the following conditions:

- The authors declare that the necessary Terms of Free and Informed Consent of participants or patients in the research were obtained and are described in the manuscript, when applicable.
- The authors declare that the preparation of the manuscript followed the ethical norms of scientific communication.
- The authors declare that they are aware that they are solely responsible for the content of the preprint and that the deposit in SciELO Preprints does not mean any commitment on the part of SciELO, except its preservation and dissemination.
- The authors declare that the data, applications, and other content underlying the manuscript are referenced.
- The deposited manuscript is in PDF format.
- The authors declare that the research that originated the manuscript followed good ethical practices and that the necessary approvals from research ethics committees, when applicable, are described in the manuscript.
- The authors declare that once a manuscript is posted on the SciELO Preprints server, it can only be taken down on request to the SciELO Preprints server Editorial Secretariat, who will post a retraction notice in its place.
- The authors agree that the approved manuscript will be made available under a [Creative Commons CC-BY](#) license.
- The submitting author declares that the contributions of all authors and conflict of interest statement are included explicitly and in specific sections of the manuscript.
- The authors declare that the manuscript was not deposited and/or previously made available on another preprint server or published by a journal.
- If the manuscript is being reviewed or being prepared for publishing but not yet published by a journal, the authors declare that they have received authorization from the journal to make this deposit.
- The submitting author declares that all authors of the manuscript agree with the submission to SciELO Preprints.