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As easy as it would be to begin this essay with a succinct “music is” statement (e.g. “music is life” or “music is power”), it would be akin to encapsulating the boundless expanse of the cosmos in a single photograph. It would fail to honor the immeasurable richness and complexity of the force which has transformed humanity from a group of disparate apes into a symphony of interconnected souls. For all of history, music has served as a means for humans to tap into and express the very things that make them human—their emotions, culture, and individual identities. Its profound impact was particularly evident during the Holocaust, where it provided victims and survivors with an indelible connection to their humanity and cultural roots when faced with the Nazis' systematic efforts to eradicate the Jewish people and culture. Take, for instance, Terezin, a concentration camp situated in present-day Czechia. Originally created as a holding place for Jews bound for the Eastern extermination camps, Terezin evolved into an unexpected artistic nexus—a place where Jews could, in the words of survivor Zdenka Fantlova, “dance under the gallows”, celebrating their lives and culture in what felt like the final hours of Judaism (The Guardian 2013). Hosting regular concerts and operas, it was one of the few places in WWII-era Europe where Jewish music could be performed, Nazi overseers only tolerating this

practice because of the grim certainty surrounding the fate of Terezin Jews. According to another survivor, Anka Berman, the presence of music in the camp “connected us to the lives we had lived, and lost. Looking back, it's amazing to think how much pleasure [it] gave to so many people, under the most horrific of circumstances” (The Guardian 2013). This testimony is one of many which speak to the profound impact of music as a source of solace and shared humanity in the face of unimaginable horrors. However, in order to more comprehensively understand the significance of music for Holocaust victims and survivors, we must take an interdisciplinary approach—this essay delves into the neuroscientific underpinnings of music and its remarkable ability to embody culture and conjure memories, two crucial aspects of cultural preservation.

It goes without saying that music has a unique effect on people. Its power to make us feel, think, and move is unparalleled by all other forms of expression and stimulus. That being so, the act of trying to scientifically characterize the power of music, especially for Holocaust victims, can feel almost sacrilegious. While acknowledging that scientific reasoning alone may not ever be able to fully expound the significance of music for Holocaust survivors, it *can* provide worthwhile insight into the value of music as a facet of culture. For instance, research suggests that the cerebellum (a brain structure nestled in the back of the skull) may be responsible for the “transcendental” feeling we get when listening to music—that sublime sense of total immersion that seemingly weaves us into the metaphysical fabric of everything that is and ever was. For most of the history of neuroscience, researchers have understood the cerebellum to be the primary structure which coordinates motor control and balance. It achieves this through a process called forward modeling, which refers to the brain’s ability to generate predictions or internal models of the sensory consequences of motor commands before executing a movement. An example of this process in action is the disorienting sensation we feel when reaching the base of

a stairwell after erroneously anticipating another step—the cerebellum’s prediction of what “should” happen manifests as a physical sensation in the body. Recent research, however, suggests that the cerebellum and its forward modeling process serve a much broader spectrum of purposes. A 2021 study by Gallea et al. proposes a new model (based on fMRI findings) for the cerebellar loops involved in forward modeling; it suggests that the cerebellum’s forward model feedback loop engages not only the motor areas of the brain, but also the areas involved in sensory processing. This may explain why we can “feel” music—with its use of steady beat patterns, iterative melodies, and repetitive rhythms, music keeps the cerebellum engaged in a constant loop of prediction and sensory feedback, its responses to change manifesting as unique physical sensations. This intricate sensorimotor dance, engaging both the physical and mental realms, likely underlies the holistically and indescribably immersive experience that music provides. With every culture having its own characteristic musical patterns (and, therefore, its own characteristic patterns of music-related cerebellar feedback), music is not just a series of auditory sensations, but a conduit for shared feelings and experiences that words are incapable of eliciting. The cerebellum's ability to render music into a tangible cultural experience provides important context as to why music was such an important aspect of Jewish life during the Holocaust. Stripped of all physical connections to Jewish culture, music became the vehicle through which Jews could once again *feel* its essence, further thwarting the Nazis' attempts to erase it from existence.

Music possesses another inherent power—the ability to evoke vivid memories. This holds profound significance for Holocaust survivors, the majority of whom have endured unimaginable loss. For them, memories take on a new dimension of significance, serving as not just recollections, but instruments of empowerment and resistance. Through the recall of even the

minutest details about their loved ones, survivors pay homage to the complexity and wholeness of victims whom the Nazis sought to reduce to mere yellow badges and numbers on a list. The preservation of these memories also serves to ensure that we, as a collective, do not forget the horrific consequences of hatred and bigotry. In terms of music's ability to conjure these memories, Alzheimer's patients are living testaments to the legitimacy of this phenomenon. Even in the advanced stages of the disease, they can often recall elaborate details of music-related memories, while basic semantic memories, such as their birthday or the fact that they have kids, fade into permanent oblivion (Paul 2022). This phenomenon is yet again tied to the cerebellum—its special way of encoding music-associated memories is what makes these memories so incredibly potent. For context, the formation of memories occurs as a result of the brain's innate ability to link stimuli that occur simultaneously—hence the neuroscience adage, “cells that fire together wire together”. Music, being a stimulus which engages nearly every area of the brain, becomes very powerfully associated with (and therefore, physically connected to) a wide variety of other sights, sounds, and sensations happening concurrently. This is why memories associated with music tend to be more vivid and engrossing than memories associated with, for instance, pictures or nonmusical sounds (Belfi et al. 2016). These music-associated memories are then encoded as *implicit* memories in the cerebellum, allowing them to remain fully intact and accessible for much longer than the *explicit* memories encoded in the midbrain structures. This is because, while explicit memories fade in the absence of recall, implicit memories persist independently of conscious recollection. For example, consider a person who, at five years old, had a picnic with their family while listening to Paul McCartney. In their adulthood, upon hearing McCartney's music again, they may recall nuanced details of that picnic—the weather, the taste of a particular food, their mom's haircut at the time—despite

having no conscious memory of ever attending a picnic at five years old, let alone any conscious memory of these fine details. While this is a universally powerful experience, it is especially valuable for survivors of any event so dehumanizing, isolating, and traumatic as the Holocaust. For these survivors, music-associated memories serve as a catalyst for unlocking the special moments steeped in cultural profusion and connection with lost loved ones, as well as the haunting moments necessary for passing on the imperative of “never again” to future generations, ensuring that it resonates throughout the rest of human existence.

Echoing through the oppressive walls of Terezin and far beyond, music is the ultimate embodiment of our shared humanity. While its impact can be explained by neuroscience, it cannot be reduced to it—a full understanding of the power of music would require a full understanding of the deepest depths of suffering, the highest peaks of joy, and the full human capacity for both cruelty and compassion. As we confront the legacy of the Holocaust, let us not only bear witness to its harrowing lessons, but actively exercise them in every moment of our lives. Let us choose empathy over apathy, enlightenment over ignorance, and love over hate.

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