# Understanding the Reception of Schoenberg's Music From a Neuroscientist's Perspective

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When Arnold Schoenberg adopted an atonal compositional style in the early twentieth century he met a series of unprecedented negative criticism and violent events at premieres of his works. While scholars have attributed the negative reception of Schoenberg's music to a variety of social reasons, such as the possibility that listeners attended his performances wanting to provoke a controversy, this article reexamines these events using neuroscience and establishes a difference in perception of tonal and atonal works. I hypothesize that the resistance to atonal music was due to the audience's predisposition to tonal music and that this predisposition influenced the expectations of listeners. According to the scientific literature, the pleasure experienced by listening to music is derived from a positive reinforcement of expectations. Based upon research into song acquisition in birds, there is a critical period during early childhood where we are able to internalize scale degree statistics without formal education. In western cultures, these internalizations are governed by tonality. Therefore, the internalized sense of tonality contributed to the harsh reception of Schoenberg's music.

## Introduction

As is well known, when Arnold Schoenberg (1874-1951) gave up the use of traditional harmony in his compositions in the early twentieth century in favor of what became known as "atonal" compositions, he encountered a series of scandalous events at premieres of his works. Several concerts between 1908 and 1920 had such unprecedented reactions that included even physical violence. Although scholars have examined these events extensively, the scholarship on musical modernism has typically focused on two approaches: formalist theoretical analysis or social and political interpretations.[1] By reviewing recent neuroscience studies examining the perception of music, this study explores an alternative approach to explain the reactions to musical modernism and to establish a difference in perception of tonal and atonal pieces. By looking at the basic science and psychology of music perception, science provides an alternative and perhaps informative means of understanding musical modernism.

The root cause of the aversion to Schoenberg's music is arguably related to a violation of the audience's implicit expectations. It has been argued that one of the main contributors to our so called "pleasure" in music is derived from our ability to predict sequences of events that are about to occur within a musical composition.[2] We are "rewarded" when our predictions are correct. In this sense, individuals listening experience shape their musical perception.[3] In music of the common practice period in the western world, these predictions are based on certain harmonic progressions and cadences. Of course, this predictability is lost within the framework of atonal music.

## The Reception of Atonal Music

The increasing use of dissonance in music at the turn of the twentieth century posed difficulties for composers working within the constraints of traditional harmony, namely composing within an organized key center. After considering the compositional challenges in this fast changing environment, particularly the intelligibility of the new music, Schoenberg pronounced the "emancipation of dissonance" as a solution. He recounted the moment of change to atonality in these terms:

> Such a change became necessary when there occurred simultaneously a development which ended in what I call the *emancipation of the dissonance*. The ear had gradually become acquainted with a great number of dissonances,

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[1] David Huron, Sweet Anticipation: Music and the Psychology of Expectation (Cambridge: MIT Press, 2006), 353.

[2] See Stephen McAdams and Daniel Matzkin, "Similarity, Invariance, and Musical Variation," *Annals of the New York Academy of Sciences* 930 (2001): 1. Also see Huron, *Sweet Anticipation*.

[3] Elizabeth Hellmuth Margulis et al., "Selective Neurophysiologic Responses to Music in Instrumentalists with Different Listening Biographies," *Human Brain Mapping* 30, no. 1 (2009): 6.

> and so had lost the fear of their 'sense-interrupting' effect. One no longer expected preparations of Wagner's dissonances or resolutions of Strauss' discords; one was not disturbed by Debussy's non-functional harmonies, or by the harsh counterpoint of later composers. This state of affairs led to a freer use of dissonances comparable to classic composers' treatment of diminished seventh chords, which could precede and follow any other harmony, consonant or dissonant, as if there were no dissonance at all.[4]

On another occasion Schoenberg discussed how dissonant chords were frequently used so liberally throughout a piece that listeners came not to expect preparations of dissonances or resolution of dissonant chords. This happened in part because composers at that time had been progressively using dissonant chords more freely, many times without proper preparations and resolutions. Rather than using "unstable" chords, Schoenberg wished to fully emancipate the use of dissonant chords, so that they were no longer considered unstable within the framework of the piece.[5] As Schoenberg argues "this premise treats dissonances like consonances and renounces a tonal centre."[6] In effect, he believed that dissonant chords no longer required special treatments, such as preparation and resolutions.[7] In the absence of a tonal center, Schoenberg began to compose based primarily on motivic organization.

His audiences were not so quick to approve of his new atonal style, however. Most of the premieres are remembered for being scandalous, even violent. The performances of his First String Quartet (Op. 7) in 1907 and his Second String Quartet (Op. 10) in 1908, were met with intense outrage and protest amongst critics.[8] During the 1908 premiere of his Second String Quartet, shouting broke out between two critics.[9] His performance of Pierrot lunaire in 1914 was met with similar reception of hissing and disruptions.[10] People in the audience were booing in the middle of the performance and whistling; a sign of harsh disapproval in Europe.[11] Alma Mahler recounts a concert including pieces by Schoenberg in 1905 where "the audience kept leaving in droves and slamming the doors behind them while the music was being played."[12]

A few first-hand descriptions of several of Schoenberg's performances give adequate light on how the audience perceived the music. A review published in the Viennese paper Musikblätter des Anbruch recounts the events at an early performance of Kammersymphonie (Op. 9):

> After the second orchestral piece a storm of laughter went through the hall, which was overpowered by the admirers of this nerve-racking and provocative music with thunderous applause. . . . After Schoenberg's Op. 9, his Kammersymphonie . . . one could hear the shrill sound of door keys among the violent clapping and in the second gallery the first fight of the evening began . . . when Schoenberg knocked on the desk in the middle of the song and shouted to the public that anyone disturbing the peace would be removed by the police, insults, fisticuffs and challenges broke out again. Herr von Webern shouted from his box that the whole lot should be pushed out, and the public answered immediately that the admirers of this misguided kind of music should be sent off to Steinhof [the local lunatic asylum]. It was not an unusual occurrence when one of the public with breathless haste and with ape-like agility climbed over several rows of seats in order to box the object of his anger on the ears. . . . Finally the president of the Academic Society went onto the conductor's stand and asked that Mahler's memory should be honoured and his 'Kindertotenlieder' listened to. This request only led to a general series of insults, which the President again replied to with ear-boxing. All the public now stormed on to the platform, in front of the musicians, who were pale with fear and trembling, determined to clear the platform and end the concert. However, it still took

[4] Arnold Schoenberg, *Style and Idea: Selected Writings of Arnold Schoenberg*, ed. Leonard Stein, trans. Leo Black (Berkeley: University of California Press, 1985), 111.
[5] Bryan R. Simms, *The Atonal Music of Arnold Schoenberg, 1908-1923* (New York: Oxford University Press, 2000), 15.
[6] Schoenberg, *Style and Idea*, 217.
[7] Simms, *The Atonal Music of Arnold Schoenberg*, 15.
[8] Avior Byron, "Schoenberg as Performer: An Aesthetics in Practice" (Ph.D. Diss., University of London, 2007), 28.
[9] Leon Botstein, "Music and Its Public: Habits of Listening and the Crisis of Musical Modernism in Vienna, 1870-1914" (Ph.D. Diss., Harvard University, 1985), 1208.
[10] Byron, "Schoenberg as Performer," 5.
[11] Joan Allen Smith, *Schoenberg and His Circle: A Viennese Portrait* (New York: Schirmer, 1986), 72.
[12] Alma Mahler, *Gustav Mahler* (London: John Murrary, 1946), 77.

> another half hour, till the last brawlers left the hall in a fury.[13]

Similar receptions were met at performances of atonal works by Alban Berg, who was one of Schoenberg's pupils. In a performance of Berg's Seven Early Songs, one of his performers, Marcel Dick, recounts what happened in the audience to Josef Polnauer, a government official who was sitting next to Gustav Mahler:

> Mahler was very disturbed by the shouting invectives of a person behind him in the audience . . . so Mahler turned around and said, "You are not supposed to hiss when I applaud." To which he answered back quite brazenly, "I hiss also at your unprintable symphonies!" Whereupon, Polnauer let it fly -- he gave it to him -- whereupon, the attacked person brought out a knife and sliced Polnauer's face open, and he carried the scar with great pride to the end of his days."[14]

Schoenberg's most unpleasant criticisms came from professional music critics. The early twentieth century was marked by increasing attendance by the listener without developed musical understanding. During this time, the critic became the indispensable guide to the listener. Through reviews, the critic transposed their own interpretation and opinion into the minds of the listener.[15] These reviews were consistently negative toward Schoenberg and arguably led to further negative reception of his music. Critic James Huneker, for instance, recounts his experience of a performance of Schoenberg's Pierrot lunaire in 1912:

> What did I hear? At first, the sound of delicate china shivering into a thousand luminous fragments. In the welter of tonalities that bruised each other as they passed and repassed, in the preliminary grip of enharmonics that almost made the ears bleed, the eyes water, the scalp to freeze, I could not get a central grip on myself. It was new music (or new exquisitely horrible sounds) with a vengeance. The very ecstasy of the hideous! I say "exquisitely horrible," for pain can be at once exquisite and horrible; consider toothache and its first cousin, neuralagia. And the border-land between pain and pleasure is a territory hitherto unexplored by musical composers. Wagner suggests poetic anguish; Schoenberg not only arouses the image of anguish, but he brings it home to his auditory in the most subjective way. You suffer the anguish with the fictitious character in the poem. Your nerves -- and remember the porches of the ears are the gateways to the brain and ganglionic centres -- are literally pinched and scraped.[16]

These first-hand accounts of several performances of atonal works depict the unusually violent reactions of the audience. Significantly, these reactions occurred during a time where the Viennese enthusiasts wanted new modern music.[17] As Leon Botstein contends, Schoenberg's music represented a new form of modernism from the one previously experienced by the Viennese public because it forced the listener to concentrate on the musical elements and form.[18] But as Alban Berg explains, rather than using musical materials and forms in traditional ways, such as the ones used in the music of Mahler and Strauss, Schoenberg's music forced the listeners to understand the internal dimensions of musical logic.[19]

During a time of high emphasis on progression towards modernism, why would people have such extreme reactions to Schoenberg's music? Although other composers, such as Debussy, had used unstable keys and dissonance, Schoenberg was the first composer to completely abandon tonality. Although many scholars have suggested a variety of social reasons for the scandalous receptions,[20] such as the possibility that people went to the performances wanting to cause disturbance, I suggest that the negative perceptions may have had to do with the way our brains perceive music.

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[13] Hans Stuckenschmidt, *Arnold Schoenberg: His Life, World, and Work*, trans. Humphrey Searle (New York: Schirmer, 1978), 184-87.
[14] Smith, *Schoenberg and His Circle*, 70.
[15] Botstein, "Music and Its Public," 1000.
[16] James Huneker, *Ivory, Apes, and Peacocks* (New York: Charles Scribner's Sons, 1915), 93-94.
[17] Botstein, "Music and Its Public," 1188.
[18] Ibid., 1203.
[19] Alban Berg, "Why Is Schoenberg's Music So Difficult to Understand?," in *Alban Berg*, ed. Willi Reich (New York: Harcourt, 1965).
[20] Leon Botstein examines in detail the social issues during that time, with special emphasis on Semitism in Botstein, "Music and Its Public."

## The Development of Tonal Predispositions

Recent developments in the science of neuronal plasticity might help explain the processes involved in learning tonality as well as how the brain reacts to changes. The doctrine of neuronal plasticity has changed considerably since the pioneering days of Santiago Ramon y Cajal and Camillo Golgi around the turn of the twentieth century. For most of the twentieth century science has generally regarded the brain as a fixed entity that cannot change after early childhood. Only in the past few decades, in parallel with new technological advances that have advanced our understanding of the brain, has this paradigm shifted to the current school of thought that the brain regularly participates in plastic changes throughout a person's lifetime. Donald Hebb, one of the first proponents of the theory of synaptic plasticity as it relates to learning and memory, famously coined the phrase, "Neurons that fire together, wire together."[21] He contended that an increase in synaptic efficiency between two different neurons occurs after repeated and persistent stimulation of a presynaptic and postsynaptic cell.[22] This theory explains the associative learning that arises when simultaneous activation of multiple neurons increases synaptic strength. This strengthening of synaptic connection is a way to explain a biological theory of how memory can be stored in the brain through the morphological or chemical modification of brain tissue as a result of external stimuli.

One of the major factors involved in this paradigm shift toward synaptic plasticity was the study of birdsong, as it demonstrates a development similar to the one that occurs in language acquisition in human infants.[23] Since birdsong is one example of temporally restricted learning, it provides a model for studying how early experience sculpts neural and behavior organization.[24]

Understanding birdsong is important because birds are not born with a preset repertoire of songs; they must learn it from other birds. Additionally, some species of birds have the ability to change their repertoire throughout their lives, while other species cannot. The majority of imitative learning is confined to a small period after birth called the critical period; any substantial learning outside of this period is almost impossible. Birdsong learning and acquisition is of particular interest to scientists because it provides a good model for the study of vocal learning and plasticity.[25] There are three ways in which molecular changes can confine learning to the sensitive period and regulate plasticity: upstream events, synaptic changes, and downstream events. Upstream events are composed of circuitry related to learning, such as inhibitory and excitatory inputs and neuromodulator pathways. Examples of synaptic changes include modulation of receptors, intracellular signaling, and trophic factors. Downstream events are involved in expression of the plasticity cascades, and include gene expression, synapse formation, and synapse elimination.[26] Although this present article will not discuss the specific molecular mechanisms behind neuronal plasticity,[27] the findings mentioned above suggest that there are biological mechanisms in the brain that mediate neuronal reorganization as a result of learning.

One critical finding from the birdsong research, which has also been replicated in other species, is that there are several neurobehavioral stages in learning. Birdsong learning is divided into several stages of learning and repetition. Upon hatching, birds enter a stage called subsong, where the birds first begin to experiment with sound production. After growing more, the bird enters a plastic song stage where the first learning and imitation of song begins to occur. After the plastic stage, the bird enters a crystallized song stage, where the songs are committed to

[21] Donald O. Hebb, *The Organization of Behavior: a Neuropsychological Theory* (New York: Wiley, 1949).
[22] Richard E. Brown and Peter M. Milner, "The Legacy of Donald O. Hebb: More Than the Hebb Synapse," *Nature Reviews Neuroscience* 4, no. 12 (2003).
[23] Johan J. Bolhuis and Manfred Gahr, "Neural Mechanisms of Birdsong Memory," *Nature Reviews Neuroscience* 7, no. 5 (2006). Note that bird vocalizations can be split into two different types: songs and calls. Birdcalls are seen in every species of birds, and function mostly as a means of communication or alarm. Birdsong, however, is not present in all bird types, and song is longer and more complex than calls. Song serves an important function in courtship and mating.
[24] Kathy W. Nordeen and Ernest J. Nordeen, "Synaptic and Molecular Mechanisms Regulating Plasticity During Early Learning," *Annals of the New York Academy of Sciences* 1016 (2004).
[25] Heather Williams, "Birdsong and Singing Behavior," *Annals of the New York Academy of Sciences* 1016 (2004).
[26] Nordeen and Nordeen, "Synaptic and Molecular Mechanisms."
[27] For a very good review of the specific mechanisms behind plasticity as it relates to birdsong, see Bolhuis and Gahr, "Neural Mechanisms of Birdsong Memory." Specifically, the molecular mechanisms behind neuronal and synaptic plasticity in general are mediated by the N-methyl-D-aspartate (NMDA) receptor. For information on the NMDA receptor as it relates to the plasticity of learning, see Nordeen and Nordeen, "Synaptic and Molecular Mechanisms." The NMDA receptor's long term potentiation is mediated by $Ca^{2+}$/calmodulin-dependent protein kinase II (CaM kinase II). A detailed review about the role of CaM kinase II as it relates to long term potentiation is offered by John Lisman, Howard Schulman, and Hollis Cline, "The Molecular Basis of CaMKII Function in Synaptic and Behavioural Memory," *Nature Reviews Neuroscience* 3, no. 3 (2002). See also Gary A. Wayman et al., "Calmodulin-Kinases: Modulators of Neuronal Development and Plasticity," *Neuron* 59, no. 6 (2008). For a more historical review of CaM kinase II and its implications for learning and memory, see Takashi Yamauchi, "Neuronal Ca2+/Calmodulin-Dependent Protein Kinase II - Discovery, Progress in a Quarter of a Century, and Perspective: Implication for Learning and Memory," *Biological & Pharmaceutical Bulletin* 28, no. 8 (2005).

memory.[28] These stages involve other learning phases. The bird is able to learn new songs only during a "critical period," when it must be exposed to songs being produced by other members. The critical period closes toward the end of the sensory phase, which is when the bird commits songs to memory. After the sensory phase, the bird enters a sensorimotor phase, when the bird engages in practice of the learned songs. The subsong and plastic stages occur during the sensorimotor phase. At the end of the sensorimotor phase, the bird enters a crystallized phase, where the song is committed to memory and is able to be reproduced later in life.[29]

Although humans have a different purpose of learning music (birdsong has an evolutionary function of courtship for reproduction), the most important feature of the previous results suggests that there is indeed a "critical period" in infancy where we internalize a language system.[30] In most instances, there is a limited period of time where a person internalizes their main language system. This is why it is more difficult to learn a second language during adulthood. A person's first language, that is the language that they use when they think, is most often learned during a critical period during early childhood.[31] Since musical acquisition has many parallels to language acquisition,[32] I suggest that it is within a critical period that infants implicitly learn the rules of tonality. This early auditory exposure creates an inclination of musical preference.

In the early months of life, infants engage in processing pitch and temporal patterns.[33] Much of this processing occurs as a result of maternal singing, as mothers often sing common lullabies to their infants. In western cultures, these lullabies are usually governed by a tonal language. The act of the infant processing these lullabies on multiple occasions ("cells that fire together wire together") predisposes them to a particular musical style.[34] Further early exposure to specific musical styles may also contribute to an individual's predisposition toward a musical preference. Musically inexperienced learners are constantly exposed to music in everyday life that allows them to implicitly learn certain regularities. This knowledge consists of the functions of tones and chords within a key and its relation to other keys. These internalized "rules" further influence future musical memory and musical expectancies.[35] Preliminary evidence shows that this also occurs cross-culturally, where members of a particular culture internalize their own culture's set of rules, regardless of whether or not it is governed by western tonality.[36] Musical styles are very diverse across cultures, but all cultures share the phenomenon of organizing music into a system of probability relationships.[37]

## Musical Expectation in the Brain

Several scholars have demonstrated the relationship between learned grammatical and syntactical elements in music and their role in the listening process. While using Gestalt theory, musicologist Leonard Meyer describes the importance of expectation to the listener's experience of music. He argues that the emotional content of music arises through the composer's ability to "play" with our expectations.[38] Psychologist Carol Krumhansl suggests the theory that tonality may be viewed as a set of statistically learned schemas arising from sustained exposure to the music of some culture.[39] Krumhansl suggests zeroth-order probabilities (individual scale tones) are internalized by listeners. David Huron further suggests that in addition to

[28] Georg F. Striedter, "The Development of Learning in Songbirds," in *Principles of Brain Evolution* (Sunderland: Sinauser Associates, 2005).
[29] Ibid.
[30] Thomas F. Munte, Eckart Altenmuller, and Lutz Jancke, "The Musician's Brain as a Model of Neuroplasticity," *Nature Reviews Neuroscience* 3, no. 6 (2002).
[31] John T. Lamendella, "General Principles of Neurofunctional Organization and Their Manifestation in Primary and Nonprimary Language Acquisition," *Language Learning* 27, no. 1 (1977).
[32] It is important to note that the neuroanatomy of music perception is a highly contested topic in the neuroscience community. Many scientists consider that music and language processes occur in separate brain circuits. However, several studies have found that some of the circuits responsible for musical processing share the same brain regions for language processing, particularly a region called Broca's area, the superior temporal sulcus, the superior temporal gyrus (contains the primary auditory cortex), and the insular cortex: Stefan Koelsch et al., "Bach Speaks: A Cortical 'Language-Network' Serves the Processing of Music," *NeuroImage* 17, no. 2 (2002). For an overview of the issues involved in the neuroanatomy of musical perception, see Isabelle Peretz, "The Nature of Music from a Biological Perspective," *Cognition* 100, no. 1 (2006).
[33] Sandra E. Trehub, "Musical Predispositions in Infancy," *Annals of the New York Academy of Sciences* 930, no. 1 (2001): 1.
[34] Ibid.: 7.
[35] Barbara Tillman, Jamshed J. Bharucha, and Emmanuel Bigand, "Implicit Learning of Tonality: A Self-Organizing Approach.," *Psychological Review* 107, no. 4 (2000): 887. See also Lauren Stewart and Vincent Walsh, "Infant Learning: Music and the Baby Brain," *Current Biology* 15, no. 21 (2005). For a good review about musical predispositions see also Peretz, "The Nature of Music."
[36] Huron, *Sweet Anticipation*, 174.
[37] Leonard B. Meyer, *Emotion and Meaning in Music* (Chicago: University of Chicago Press, 1956), 63.
[38] Ibid.
[39] Huron, *Sweet Anticipation*, 172.

zeroth-order probabilities, there are higher-order probabilities (succession of tones) that are also internalized.[40]

David Huron delves into the emotional experiences, or what he calls "qualia" of different tones. By qualia, he refers to specific subjective psychological feelings that particular tones evoke. For example, subjects often give the following descriptions for the dominant tone within a diatonic scale: strong, muscular, balance, possibility, and pleasant. For the lowered supertonic tone, the following descriptions are commonly evoked: surprise, abruptness, and pause.[41] Most of these qualia relate to the amount of consonance or dissonance in a given chord. However, while musical consonance or dissonance is culturally determined, sensory consonance or dissonance is culturally invariant and independent of musical training.[42] For example, a minor 2nd is highly dissonant in isolation. Since dissonance is generally perceived as "harsh" sounding, it is easy to attach a negative connotation to an isolated minor 2nd. But within a contextual framework, such as a large musical piece, a minor 2nd may sound beautiful. Inside a contextual framework, however, the delineation of consonance/dissonance depends on musical training.[43] Interestingly, it has been shown that infants prefer to listen to consonance over dissonance.[44]

David Huron also argues that learning is a strict biological process. Whether a behavior is learned or innate depends on whether or not the behavior promotes the adaptive fitness of an organism in its environment.[45] Expectations in music are learned from previous musical exposure; they are derived from past experience. The coding of past experiences is referred to as memory, so expectations are related to memory. Although memory seems to function as an aesthetical process for us to enjoy our past successes, from a biological standpoint, memory exists only as a means to repeat our success and to avoid future failures.[46] From an evolutionary perspective, memory serves as a means for determining whether or not a particular stimulus is a danger to the organism. By anticipating future events, organisms can take steps to avoid the possibility of a negative outcome. If we cannot avoid a negative outcome, expectation allows us to prepare ourselves by adopting a certain state of arousal.[47] When a listener's prediction is confirmed to be correct, their prediction is positively reinforced. Tension in music is created by prolonging the positive reinforcement.[48]

Since pleasure in music is derived from the positive reinforcement of successful predictions, then it is quite possible that the aversion to atonal music was due to a violation of predictions. As mentioned previously, the prediction effect is dependent on the listener's musical experience. In 1908, everyone was still operating within a tonal framework. It is therefore not surprising that pitch predictions would fail if a listener applied a key-related schema to the listening experience of atonal music. Expectations require instinctive mental responses; it is not enough to consciously know that a particular chord will suggest a certain cadence.[49] Rather, in order to be effective, this must occur subconsciously without relying on any formal music theory education.

Around 1920, Schoenberg devised his compositional style of twelve-tone technique. This serial method of composition used all twelve notes of the chromatic scale equally within a given musical piece. Each piece used a set of different series, which dictated the order in which the tones appear so no tones would be repeated before the entire set is presented.[50] One of his reasons for developing the twelve tone method was to avoid tone rows that might suggest a tonal center. An often quoted passage by Schoenberg describes his logic behind developing twelve-tone compositions:

> I have stated in my *Harmonielehre* that the emphasis given to a tone by a premature repetition is capable of heightening it to the rank of a tonic. But the regular application of a set of twelve tones emphasizes all the other tones in the same manner, thus depriving one single tone of the privilege of supremacy. It seemed in the first stages immensely important to avoid a similarity with tonality.[51]

[40] Ibid.
[41] Ibid., 145.
[42] EW Burns and WD Ward, "Intervals, Scales, and Tuning," in *The Psychology of Music*, ed. Diana Deutsch (New York: Academic, 1982); JW Butler and PG Daston, "Musical Consonance as Musical Preference: A Cross Cultural Study," *Journal of Experimental Psychology* 79 (1968); Yonatan I. Fishman et al., "Consonance and Dissonance of Musical Chords: Neural Correlates in Auditory Cortex of Monkeys and Humans," *Journal of Neurophysiology* 86, no. 6 (2001): 1.
[43] Yonatan I. Fishman et al., "Consonance and Dissonance of Musical Chords: Neural Correlates in Auditory Cortex of Monkeys and Humans," *Journal of Neurophysiology* 86, no. 6 (2001).
[44] Laurel J. Trainor and Becky M. Heinmiller, "The Development of Evaluative Responses to Music: Infants Prefer to Listen to Consonance over Dissonance," *Infant Behavior and Development* 21, no. 1 (1998).
[45] Huron, *Sweet Anticipation*, 59-64.
[46] Ibid., 219.
[47] Ibid., 109.
[48] Ibid., 305.
[49] Meyer, *Emotion and Meaning in Music*, 61.
[50] Carol L. Krumhansl, *Cognitive Foundations of Musical Pitch* (Oxford: Oxford University Press, 1990), 241. For detailed information on Schoenberg's twelve-tone method see Ethan Haimo, *Schoenberg's Serial Odyssey: The Evolution of His Twelve-Tone Method, 1914-1928* (Oxford: Clarendon Press, 1990).
[51] Schoenberg, *Style and Idea*, 246.

This quote suggests that Schoenberg was well aware that his audiences were trying to understand his music based on previous tonal experiences and that he actively sought to minimize tonal implications with his tone rows. David Huron conducted a study comparing random twelve-tone rows to twelve-tone rows composed by Schoenberg. His results showed that Schoenberg's tone rows had significantly lower tonal concentrations than random tone rows. Since the random tone rows tended to evoke a sense of a tonal area, these findings further show that Schoenberg sought to purposely avoid people's natural tendency to attach a key center to his musical work.[52]

In light of the above, Schoenberg's music presents a dichotomy between sensory and culturally accepted dissonances. Although it may not be fair to call Schoenberg's music "ugly" from an aesthetic standpoint, one may evoke qualia to describe the music, especially when expectations are based on a tonal framework. The audiences at the premieres would have had all their predictions betrayed, which in essence would be contrary to the positive feedback they had been experiencing throughout their lives. Listening within the framework of tonality would evoke a sense of confusion and discomfort, even if these feelings were misattributed. No successful prediction effect is possible without accurate expectations. Indeed, expectancies generated by a harmonic context reflect the innate or learned mental representation of tonality. Further, the harmonic context of a chord sequence primes the processing of chords related to the context and induces expectations by activating tonal representations in the mind of the listener.[53]

I am not suggesting that it is impossible to enjoy atonal music. But I believe it is impossible to enjoy it unless one internalizes a specific atonal schema that allows them to predict patterns. A study by Krumhansl et al. confirms this claim.[54] This study, which addressed the perception of atonal pitch sequences on groups of people experimentally, found that listeners were divided into two groups. One of the groups heard the sequence based upon classic tonal schema. However, a second group had internalized the atonal schema and used this schema to reinforce their expectation effects. The members of this group ended up being more musically trained than the other group.[55] In essence, this group had engaged in neural plasticity throughout their musical training.

Schoenberg's writings hint that he may have anticipated the hallmarks of neural plasticity. In 1918, Schoenberg conducted ten open rehearsals of his Chamber Symphony, Op. 9. In order to increase understanding of the music, these rehearsals created a context for which the audience could gradually become familiar with the music (or "internalize" it as I previously discussed). During each rehearsal, he would only have a few voices play first, and then would gradually add more voices together; then he would focus on individual phrases. Finally, he would rehearse the final piece as a whole uninterrupted.[56] As the announcement brochure described,

> Rather than giving a single performance, Arnold Schoenberg plans to hold a series of ten open rehearsals. In the final rehearsal, the work will be played in its entirety at least once without interruption. In this way the listener is offered the opportunity to hear the work often enough to grasp it in detail as well as in its entirety. It will also be of interest to the audience, and especially to musicians, to be able to follow the performance preparation of such a difficult work from the very beginning.[57]

The results were apparently a success. The organizer, Erwin Ratz, wrote that "the effect was truly as I expected. Even the people who at first couldn't get anything out of it said after three or four rehearsals, 'That sounds like Mozart.'"[58]

Still frustrated with the opposition he was receiving at premieres, Schoenberg and his pupils later organized the Society for Private Musical Performances in 1918. This society was created in order to perform new twelve-tone works in a highly controlled environment. In the prospectus for the society, Alban Berg writes that "the attitude of the public toward modern music is affected to an immense degree by the circumstance that the impression it receives from that music is inevitably one of obscurity."[59] The prospectus lays down three principles that are necessary for someone to understand new music, which are:

[52] Huron, *Sweet Anticipation*, 342.
[53] Sakari Leino et al., "Representation of Harmony Rules in the Human Brain: Further Evidence from Event-Related Potentials," *Brain Research* 1142 (2007).
[54] Krumhansl, *Cognitive Foundations of Musical Pitch*.
[55] Huron, *Sweet Anticipation*, 348; Krumhansl, *Cognitive Foundations of Musical Pitch*.
[56] Smith, *Schoenberg and His Circle*, 73-75.
[57] Ibid., 74.
[58] Ibid., 75.
[59] Ibid., 245.

1. Clear, well-rehearsed performances.
2. Frequent repetitions.
3. The performances must be removed from the corrupting influence of publicity; that is, they must not be directed toward the winning of competitions and must be unaccompanied by applause, or demonstrations of disapproval.[60]

These principles are in line with the requirements for behavioral neural plasticity to work. For the first time, Schoenberg began to perform his works in front of audiences that did not riot.

## Discussion

The findings of this article have many implications for both the fields of musicology and neuroscience. From a scientific standpoint, the negative receptions of atonal works provide an example for the study behind a complex behavior. Although music clearly evokes various emotions, the evolutionary and functional reasons are still unknown. With all the technical advances involved in studying the brain, the science behind music perception still eludes scientists. As neuroscientist Daniel J. Levitin eloquently puts it, "many people who love music profess to know nothing about it. I've found that many of my colleagues who study difficult, intricate topics such as neurochemistry or psychopharmacology feel unprepared to deal with research in the neuroscience of music. And who can blame them?"[61]

Part of the reason why we don't know more about the science of music relates to its inherent complexity. Music perception involves a complex interaction of many regions of the brain. Studies have come far in attempting to study the functional neuroanatomy behind music perception. However, most neuroanatomical studies have used simple isolated musical passages or chords. Once complex musical works are considered, it is difficult to remove subject bias or prejudice, and it is difficult to attribute a certain response to a particular reason. It is not obvious how the complexity of music translates to brain organization, and it is also unlikely that there is a single region that processes all aspects of music. Studies of patients with brain damage that lead to musical impairment but leave other functions intact are extremely informative, but patients with these deficits are relatively rare. Since music processing involves complex cognitive functions, it is also difficult to study the science of music in most other species.

Thus, the complexity of both music and the brain requires the use of interdisciplinary methods. The receptions of Schoenberg's music reveal important information about how the brain organizes tonality based upon expectation. In this case, one of the main contributing factors was the deviation from the listener's subconscious musical expectations, which were implicitly developed from a young age. From a musicological perspective, this study provided an alternative explanation for the reactions to atonal works. Perhaps the true reasons behind the controversial receptions were multifaceted, but few people have attempted to explain the receptions from a scientific perspective. The solution to understanding this historical problem comes from a systematic approach using musical-historical and scientific methods.

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