Shared Neural Resources for Expectancy Generation in Language and Music Processes: A fMRI and EEG Study with Actors and Violinists

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Abstract

In terms of music and language, the underlying networks that serve both kinds of processing may not be as separate as once believed. Broca's area and premotor regions are elicited for both musical and linguistic processing. When chords are seen as following theoretical rules of syntax in chord sequences, violations of that syntax elicit P600s just as they do in linguistic syntactic violations. N400s are elicited in the context of linguistic semantics whereas N500s are elicited in the context of musical semantics. Surprisingly, P300s are elicited when examining linguistic and musical expectancies. All of the above evidence is compiled for a better understanding of the shared syntactic integration resource hypothesis as well as the general shared resources recruited in both music and linguistic processing.

Introduction

Neuropsychological research vs. Neuroimaging studies

Music and language, two systems that are highly developed in humans, recently re-entered the field of scientific inquiry. For years, neuropsychological research maintained that music and language both operated using separate neural networks in the brain. Cases of double dissociations seemed conclusive; patients with language deficits could still sing and conversely, patients with deficits in musical ability could still speak. Thus, the evidence for the functional independence of music and language in the brain was based on these case studies (Fedorenko et al., 2009). With the development of neuroimaging, however, studies involving ERPs, MEG, and fMRI showed that music and language do seemingly share neural resources and activate similar neural patterns (Fedorenko et al., 2009). These findings lead to re-evaluations of the domain specificity of brain areas recruited during language processing and music processing.

Broca's area in music and language processing

Broca's area, an area of the brain historically associated with language, appeared to be engaged in cognitive domains such as music, working memory, and calculation (Fadiga et al., 2009). In the realm of music, sounds associated with movement, such as vocalization, activated the inferior frontal gyrus as well as the superior temporal gyrus (Fadiga et al., 2009). Another fMRI study conducted by Koelsch, Gunter, von Cramon, Zysset, Lohmann, and Friederici as well as a MEG study conducted by Maess, Koelsch, Gunter, and Friederici, both involving the presentation of "out-of-key" chords relative to "in-key" chords in chord sequences, showed increased cortical activity in Broca's area and its right-hemisphere homolog (Abrams et al., 2011). Partial overlap of the sources within the bilateral superior temporal gyrus and the left inferior frontal gyrus were found when comparing early potentials elicited in music and language

(Sammler et al., 2009). In addition, an electrophysiological experiment presented by Sammler, Koelsch, and Friederici also suggested that the left IFG played a crucial role in the processing of music, a finding consistent with the notion that Broca's area supports functions that are domain-general rather than domain-specific (Sammler et al., 2011).

Syntax and the SSIRH

In order to reconcile these findings, music and language were re-defined as rule-based systems that combine basic elements into higher-order structures using the rules of harmony and syntax, respectively (Besson and Schön, 2001). Syntax was seen as the commonality that gave rise to similar neural activation. Out of this presumption arose the 'shared syntactic integration resource hypothesis' (SSIRH), developed by Patel, which proposed that *online structural integration* may be shared between language and music while *knowledge systems* may be independent (Fedorenko et al., 2009). Patel differentiated between 'processing regions', which provide the resources for syntactic integration, and 'representation regions', which provide the locale for low-activation items, brought to threshold by the processing regions, to be integrated (Patel, 2003). Thus, he claimed, neural resources for musical and linguistic syntactic integration overlap whereas posterior brain regions that house those integrated representations remain separate.

EEG evidence for the SSIRH

EEG/ERP experiments as well as fMRI experiments followed to test Patel's SSIRH. An ERP study conducted by Koelsch, Gunter, Wittfoth, and Sammler gave supporting evidence to the SSIRH by showing an interaction between a left anterior negativity (LAN), typically elicited by structural incongruities in language, and an early right anterior negativity (ERAN), typically elicited by musical incongruities; the LAN was significantly smaller when incongruous words presented visually were accompanied simultaneously by a chord that was distantly related to the already established key, thus suggesting that the LAN and ERAN were competing for the same neural resources (Fedorenko et al., 2009). Typically, syntactic integration is reflected in the P600, but, as this study demonstrated, evidence for shared neural resources for syntactic processing was seen at earlier processing stages. Fedorenko, Patel, Casasanto, Winawer, and Gibson subsequently conducted a follow-up experiment for which the data was interpreted both in terms of integrations in online processing and overlaps at the retrieval stage of language processing.

P600 correlated with syntax

Patel, Gibson, Ratner, Besson, and Holcomb provided P600 evidence for both music and language. Their main discovery was that syntactically incongruous words in language as well as harmonically incongruous chords in music elicited late positivites that, statistically, were indistinguishable in the P600 latency range in terms of amplitude and scalp distribution (Patel et al., 1998). Interestingly, an unexpected finding emerged from this study. They found that between 300 and 400 msec of posttarget onset, harmonically unexpected chords in music elicited a right antero-temporal negativity (RATN). They postulated that the RATN is reminiscent of the LAN but that the RATN is transient whereas the LAN is long lasting (Patel et al., 1998). This evidence for the RATN did not conflict with evidence for the ERAN described above because further investigations suggested that the ERAN reflects the brain's response to sound expectancy violation and that it differs from the RATN in respect to time course and distribution (Koelsch et al., 2000).

fMRI evidence for the SSIRH

A fMRI study conducted by Abrams, Bhatara, Ryali, Balaban, Levitin, and Menon both supported and extended the SSIRH. Twenty participants each listened to 3 familiar and 3 unfamiliar symphonic excerpts from the classical or romantic period alternated with familiar and unfamiliar famous speeches from the 20^{th} century. This within-subject design showed fMRI signal changes of the same magnitude in prefrontal and temporal cortices of both cerebral hemispheres for the same temporal manipulation in both music and speech. Multivariate pattern analysis (MPA), however, showed that a highly distributed network that includes the inferior frontal cortex, anterior and posterior temporal cortex, and the auditory brainstem bilaterally differentially processed this manipulation. The study concluded that music and speech "share similar anatomical resources but that the resources are accessed and used differently within each domain" (Abrams et al., 2011).

Opposing fMRI evidence for the SSIRH

A functional MRI study conducted by Fedorenko, Behr, and Kanwisher bent more in the direction of the speculation that language was clearly distinct from other cognitive processes because little response was recorded in language regions to nonlinguistic functions including music; the effects of the responses in several language regions of interest produced by the music contrast were weak overall (Fedorenko et al., 2011). The brain regions investigated, however, were not the only ones engaged in or necessary for language processing (Fedorenko et al., 2011). Although the conclusions drawn from this study seem opposite to those drawn from Fedorenko's earlier work, this paper remains controversial.

N400 correlated with semantics

Just as P600 event-related potentials have been presumed to be indications of syntactic processing in the brain, N400 components have been viewed as indicators of a semantic relationship. Kutas and Hillyard showed that N400 amplitudes were larger following the presentations of unexpected terminal words that were unrelated to those that best complete a sentence (Kutas and Hillyard, 1984). These findings were replicated in a study that additionally found that target words preceded by semantically unrelated musical primes showed a similar N400 effect (Koelsch et al., 2004). This did not imply that music and language had the same semantics, however. Meaning in music, according to theorists, could arise from common patterns, mood suggestion, extramusical associations, and formal structures of tension and resolution (Koelsch et al., 2004). Rather, the data shows that semantic processing of target words can be equally influenced by language and music (Koelsch et al., 2004). Expanding upon this work, Daltrozzo and Schön found that a musical context of 1 sec influenced the processing of a following word as observed with the N400 effect and, conversely, that concepts carried by words influenced the assessment of musical concepts portrayed in excerpts lasting 250 msec.

Difference in N400 signals elicited by music and language

A study involving both EEG and fMRI helped distinguish the N400 elicited by linguistic processing and the N400 elicited by musical processing. As indicated by an increased N400 and activation of the right middle temporal gyrus, single chords varying in relative consonance and dissonance primed subsequently presented target words; as indicated by an increased N400 and activation of the right posterior superior temporal sulcus, affective words primed incongruous single chords; although both priming contexts elicited an N400, different portions of the right temporal lobe were activated when processing the two kinds of semantic meanings (Steinbeis and Koelsch, 2008).

N5 better correlated with music semantics

When looking solely at the amount of integration required after a surprising event, the N400 amplitude still correlated with the amount of semantic integration required by a word, but the N5 amplitude, named so because the negativity reached its maximal amplitude about 500 msec after the onset of a chord, more accurately reflected the amount of harmonic integration required by a musical event (Koelsch, 2005). In other words, when final chords in a harmonic sequence failed to fulfill harmonic expectations, the N500 was elicited (Steinbeis and Koelsch, 2007). The amplitude of the N5 in a study conducted by Koelsch, Gunter, and Friederici was dependent on the position of the unexpected chord in a five-chord cadence rather than the amount of different chord possibilities at each position in the cadence (Koelsch et al., 2000).

Priming effects

In a behavioral study investigating the harmonic priming effect, an interaction between the processing of linguistic and musical sounds was still observed when words were broken down into phonemes because participants were faster identifying a phoneme when it occurred simultaneously with a tonic chord (the most stable chord in a piece of music that establishes the home key) than when a phoneme occurred together with a subdominant chord (a relatively unstable chord that gives the listener a sense that the music is unresolved) (Bigand et al., 2001). A fMRI study dealing with musical priming found that a target chord's harmonic relation to the prime context facilitated the processing of that chord and ultimately replicated the finding that consonant, related targets were processed faster and more accurately (Tillmann et al., 2002). Unrelated targets revealed activation of the bilaterial inferior frontal regions such as the inferior frontal gyrus, frontal operculum, and insula with a stronger blood oxygen level-dependent (BOLD) signal (Tillmann et al., 2002). The authors speculated that the processing of less frequently encountered target chords required more neural resources (Tillmann et al., 2002).

Unexpected acoustical event implications in fMRI

Similarly, Koesch and colleagues found that Broca's area, Wernicke's area, the superior temporal sulcus, Heschl's gyrus, plana polaris and temporalis, and the anterior superior insular cortices were activated when the subject was listening to unexpected musical chords (Fadiga et al., 2009). According to a review article by Limb, Broca's area is important in determining whether a note fits into its contextual tonality; the planum temporale is associated with perfect pitch when showing asymmetries; musical aptitude is associated with increased neural activity in Heschl's gyrus (Limb, 2006). Because this activated network was similar to the network that served the understanding of language, the hypothesis that the language network is less domain-specific than previously believed gained another piece of evidence (Koelsch et al., 2002). These findings also suggest a strong interaction between the right and left hemispheres during the processing of music and language rather than a lateralization of language to the left and music to the right (Koelsch et al., 2002). Furthermore, human musical experiences might implicitly train the language network because of the similarities between the neuronal networks activated (Koelsch et al., 2002).

Unexpected acoustical event implications in EEG

An electrophysiological study, in the context of harmonic priming and expectancy violation, concluded that an early right-hemispheric preponderant-anterior negativity reflected sound expectancy violation and a late bilateral-frontal negativity reflected the higher degree of integration that unexpected chords require (the amplitudes of both early and late negativites were sensitive to the preceding harmonic context and the probability for deviant acoustic events) (Koelsch et al., 2000). The same study found that the amplitude of the ERAN was larger in participants when a deviant chord was detected (usually when the chord was in the 5th position of the sequence) versus when a deviant chord went undetected (usually when the chord was in the 3rd position of the sequence); the authors subsequently suggested that the ERAN reflected that which makes acoustic events consciously salient. (Koelsch et al., 2000). In contrast, a distinct N5 was present when undetected deviant chords passed by in the third position (Koelsch et al., 2000). This phenomenon was explained by the proposition that the deviant chord, which was a Neapolitan chord, when placed in the third position, did not overtly violate the rules of musical syntax but, nevertheless, needed to be integrated into the musical context given its out-of-key notes (Koelsch et al., 2000).

Expertise relatively insignificant for perception

Interestingly, all of the participants in the study described above were non-musicians and therefore, allowed for the advocating of an implicit musical ability of the human brain (Koelsch et al., 2000). Although musicians recognize familiar musical phrases and classify terminal notes better than non-musicians, perceptual aspects of music processing are less influenced by expertise than decisional aspects, and thus contribute to the understanding and interpretation of similar ERP findings between musicians and non-musicians when listening to unexpected chords (Besson and Faïta, 1995).

Oscillatory responses in EEG

Another type of EEG-based phenomenon that remained relevant to this work was the oscillatory responses, which are divided into multiple frequency ranges, present in electrophysiological signals (Grahn, 2009). Gamma frequencies, scientists postulated, bind information from various sensory modalities that converge in association areas to form meaningful concepts (Bhattacharya and Petsche, 2001). While listening to music, musicians' brains showed significantly higher interdependency between distributed cortical areas in the gamma band compared to non-musicians (Bhattacharya et al., 2001). The high degree of synchronization in the gamma range for musicians may have been due to their more extensive musical memory as well as their greater ability to anticipate upcoming acoustic events (Bhattacharya and Petsche, 2001).

Motor and Premotor regions

When listening to and executing musical excerpts, experienced musicians as well as trained novice musicians activated the superior temporal gyrus, the inferior parietal lobe, and motor/premotor regions, a network of brain regions also implicated in language comprehension, action execution and observation (Fadiga et al., 2009). Furthermore, motor and premotor activities were elicited in expert musicians while passively listening to familiar melodies, thus suggesting a mirror-like mechanism within a network of brain areas, which closely resembles that found in language studies (Fadiga et al., 2009). When more actively engaged in the production of music as well as rhythmic tasks, musicians showed activation in Broca's area, which is known to be involved in language-related motor activity (Besson and Schön, 2001).

Basis of study

The goal of the present study is to integrate the research described above while expanding upon the work of Frederic Dick and colleagues (to be described presently). Dick, Lee, Nusbaum, and Price conducted a fMRI study with female violinists and actresses and examined how auditory-motor expertise altered speech selectivity (Dick et al., 2011). The selectivity for speech processing in the brain has been observed in part because humans produce speech about as often as they listen to it. Music, on the other hand, is more listened to than it is produced. The central question that these scientists asked was to what extent are the typically speech selective brain regions of professional violinists activated when they listen to violin music (Dick et al., 2011).

Importantly noted were the characteristics of spoken language use that an expert musician's experience approximates; these included the early exposure to musical sounds, the use of scales and keys to create infinite possibilities, the timed mapping of smaller and larger sound units onto motor schemas, turn-taking with other musicians, and an internal representation of an instrument's particular sound (Dick et al., 2011). Actors, obviously, have experience and training in reproducing speech that sets them apart from the general population. The experimental paradigm investigated neural activation in actors listening to dramatic speech versus violin music, and neural activation in violinists listening to violin music versus dramatic speech (Dick et al., 2011). Increased activation in bilateral dorsal premotor regions, the right pars opercularis, the right PT, and the right superior posterior cerebellum revealed a pattern for sounds that experts reproduce and perceive with ease (Dick et al., 2011). Ultimately, the speech-selective regions were separated into auditory expertise-related regions and acoustical/information content-related regions, which will be explored further later on in this paper.

Unanswered questions

Many of the above experiments were based on sound expectancy violation rather than simply sound expectancy in both musicians and non-musicians. Many theorists and scientists, however, contend that musical experience in large part depends on expectancy in the form of anticipated release (Koelsch et al., 2000). In musical terms, this often translates in a way to a perceived dissonance made consonant. Chords that seem consonant, however, can still feel unresolved, such as the dominant. The dominant is a chord built on the fifth scale degree of a given key that sounds acoustically stable although it is not resolved until the music returns to the tonic, a chord built on the first scale degree of the given key. Given the high propensity for the dominant to go to the tonic, especially at the end of a musical phrase in which context this movement is known as a perfect authentic cadence, musicians prepare to hear the tonic after hearing the dominant, although the music does not lead always to the tonic right away.

Current study

In investigating sound expectancy rather than violation, the present study aims to replicate the study led by Dick and colleagues with several adjustments; professional female violinists and actresses will listen to *incomplete* excerpts from violin pieces and dramatic monologues from female roles; all subjects will participate in an experiment involving EEG neuroimaging techniques as well as a second experiment employing fMRI technology. Excerpts will be incomplete in the sense that violin pieces will be stopped on an unresolved chord and dramatic monologues will be stopped before a sentence is complete. The violinists and actresses will be asked to fill in a missing note for both familiar and unfamiliar melodies as well as fill in a missing word to familiar and unfamiliar dramatic monologues using their voices. I hypothesize that motor and premotor regions will be activated at the time of expectancy generation in violinists listening to familiar violin music and actresses listening to familiar dramatic monologues. For the EEG study, I hypothesize that gamma band synchronization will increase for violinists listening to familiar violin music and actresses listening to familiar dramatic monologues. Both sets of results independently will show that networks recruited to anticipate acoustical events for music and language share neural resources.

Methods

Participants

As modeled by the study conducted by Dick et al., fifteen violinists and fifteen female actors participated in the present study. Gender had to be restricted because of female actors’ differential experience studying roles written for females and their subsequent familiarity with that body of literature. All participants were right-handed and speakers of American English. No known neurological or physical problems existed. Level of professionalism was determined by level of education for actors and age of on-set for musical training as well as amount of practice for violinists. There was no crossover in terms of skill sets between the two groups. In other words, actors were representative of the general population when given the task of reproducing music and violinists were representative of the general population when given the task of reproducing speech. Before the study written consent was given by all participants.

Stimuli

Short excerpts (i.e. 10 s) from violin pieces and female monologues were presented. All were spliced so that the resolution to a musical phrase would not sound and the final word of a sentence would not be heard. Some of the familiar musical phrases were chosen because instead of resolving from the dominant to the tonic, they famously led to a deceptive cadence, a phenomenon in music when a major V chord or dominant chord goes to a minor vi chord. The sound clip still was stopped before the vi chord, but, because these pieces were familiar to musicians, it was assumed that the deceptive cadence would be generated in their minds whereas actors representative of the general population would not be knowledgeable of this phenomenon. Familiar musical pieces and dramatic speeches were chosen from the standard repertoire of each field. Unfamiliar ones were chosen to represent the familiar in terms of style and time period but were infrequently encountered by musicians and actors in their respective professions. Different sets of musical and speech excerpts were presented for the fMRI experiment versus the EEG experiment so that the level of unfamiliarity remained the same for unfamiliar excerpts. Phase-scrambled versions of the stimuli were used as auditory baselines.

Experimental Paradigm

For both the fMRI scans and the EEG topography, two within-subject factors and thus 6 stimulus types were presented: "1) violin pieces familiar to violinists, 2) violin pieces unfamiliar to all participants, 3) speech monologues familiar to actors, 4) speech monologues unfamiliar to all participants, 5) scrambled violin pieces…, and 6) scrambled speech monologues" (Dick et al., 2011). All 6 conditions were presented within a single run while participants focused on a fixation point; alertness was measured throughout by the participant's responses to pressing one of two buttons, which indicated whether participants felt awake or sleepy (Dick et al., 2011). All stimuli was paired with 2.7 s between stimuli from the same pair and either 10.35 s or 20.97 s between pairs of stimuli (Dick et al., 2011).

fMRI and EEG Methodology

Both methodologies were used to reconcile the data of past studies that investigated the brain regions as well as the neural networks underlying language and music processing.

Results

Experiment 1

The fMRI experiment revealed activations for the inferior frontolateral cortex [IFLC, corresponding to Brodmann's area (BA) 44], ventrolateral premotor cortex (vlPMC), and anterior superior temporal gyrus (aSTG) (Koelsch, 2006). These activations were strongest when musicians anticipated the endings to known musical phrases and when female actors anticipated the final words to known dramatic monologues. They were also present, but to a lesser degree, when musicians anticipated the final notes to unfamiliar melodies compared to known melodies. When musicians anticipated the final words to all monologues, low activation was present in the above areas. Female actors did not have as strong activation in these areas compared to musicians when listening to all musical phrases, but had activation nonetheless. Activation was not nearly as strong during anticipation of final words for unfamiliar monologues as it was during anticipation of final words for familiar monologues, and approximated that found in musicians. It was greater, however, than the activation shown when female actors anticipate all musical notes.

Hearing familiar and unfamiliar melodies additionally elicited bilateral activation of auditory areas along superior temporal cortex, specifically the inferior vPMC, pre-SMA, CMA, and CB, (Leaver et al., 2009) in the musicians. The frontal (vPMC, pre-SMA/CMA) and the parietal regions (IPL) were more involved in the processing of familiar musical sequences, but the cerebellar activity was found when both familiar and unfamiliar stimuli were present (Leaver et al., 2009). The frontal areas were activated when the musicians produced a final note, as well.

Furthermore, producing melody recruited left Brodmann area (BA) 45, right BA 44, bilateral temporal planum polare, lateral BA 6, and pre-SMA; producing sentences recruited bilateral posterior superior and middle temporal cortex (BA 22,21), left BA 39, bilateral superior frontal (BA 8,9), left inferior frontal (BA 44, 45), anterior cingulate, and pre-SMA (Brown et al., 2006). Comparing the two tasks within subjects, activations appeared in nearly identical functional brain areas, including “the primary motor cortex, supplementary motor area, Broca’s area, anterior insula, primary and secondary auditory cortices, temporal pole, basal ganglia, ventral thalamus, and posterior cerebellum” (Brown et al., 2006), but differed in the strength of the stimulations. The overall pattern of relative activation for musicians and actors that arose for musical expectancies in the IFLC, BA 44, vlPMC, and aSTG was replicated in the areas described above for the production of melody and speech.

Alternatively, because both the violinists and actors used their voices to produce the final notes in the musical phrases, the areas activated for the production of speech and melody were recruited to a similar extent in musicians and actors when involved in these activities. Thus, the activations of the BA 45, right BA 44, bilateral temporal planum polare, lateral BA 6, and pre-SMA as well as the BA 22 and 21, left BA 39, bilateral BA 8 and 9, BA 44 and 45, anterior cingulate, and pre-SMA (Brown et al., 2006) mentioned above were the same between musicians and actors for producing notes and speech regardless of the level of familiarity with the presented stimuli. Comparing the two tasks within subjects, activations appeared in nearly identical functional brain areas and did not differ in strength. The overall pattern of relative activation for musicians and actors that arose for musical expectancies in the IFLC, BA 44, vlPMC, and aSTG was *not* replicated in the areas described above for the production of melody and speech. Furthermore, the frontal (vPMC, pre-SMA/CMA) areas were activated when both musicians and actors produced the final note to a music sequence whether familiar or unfamiliar.

Experiment 2

While gamma synchronization did increase when experts listened to their respective repertoire, an unexpected finding emerged in the EEG study. A P300 component was found to correspond with subject's expectations as they unfolded over time (Granot and Donchin, 2001; Grahn, 2009). One set of results suggested that the expectation of a specific terminal tone, even when the phrase was not familiar, elicited larger P300s. Alternatively, slower predictions given the unfamiliarity of a musical phrase significantly reduced the difference in the P300 amplitude (Granot and Donchin, 2001).

Discussion

Results indicated that the cortical network comprising the IFLC, BA 44, vlPMC, and aSTG calculated harmonic relations between chords and organized fasts short-term predictions of upcoming musical events (Koelsch, 2006). Specifically, immediate mapping of perception onto action may be a result of a link between the prediction of upcoming events and a representation of corresponding motor schemas in the lateral PMC (Koelsch, 2006). Additionally, the rostral prefrontal cortex could be involved in cued recall of highly familiar music through interactions with more caudal prefrontal and premotor regions (Leaver, 2009).

Given the first results of the fMRI experiment, I concluded that violinists, when anticipating a note in a musical phrase, imagine how they would play it on their instruments. Thus, for an experiment during which they had to produce musical notes with their singing voices, the imagining of a note did not match the production of it. This explained the differences in activations in areas recruited for production between actors and violinists. Actors anticipated an acoustic event with their voices and subsequently produced them with their voices for this experiment.

Given the alternate set of results for the fMRI experiment, violinists completed the musical phrases in their heads with their voices rather than an internal representation of their instrument. Although the relative strengths of activation for the sound expectancies remained the same as the first set of results, the activation reflecting the regions needed for production of those sounds was the same between musicians and actors. If musicians were thinking of preparing their vocal chords rather than the imagined placement of their fingers on a violin's fingerboard, then activation would be the same as was shown. Musicians still differed from actors in terms of stimulation for anticipated events because of their training.

Expertise was paramount to expectancy generation although not to expectancy violation as was noted in the introduction. This explained why actors only sometimes were able to generate the correct note when a musical phrase resolved to the tonic. If a phrase led instead to a deceptive cadence, which trained musicians were familiar with, actors did not have enough knowledge to predict this phenomenon. Conversely, musicians occasionally could guess the correct final word to a monologue given the context in which it was placed. Still, actors far outperformed musicians for the category of familiar monologues.

For the alternative set of results for the EEG study, the reduction of the P300 amplitude given how unfamiliar the musical excerpt was suggested that musicians based their expectancies on scale membership rather than predictions of the concluding tone's identity (Granot and Donchin, 2001). In general, musically trained subjects preferred to not predict a specific terminal tone in the unfamiliar condition if the resolution was unclear. Actors, on the other hand, always generated P300s because, regardless of structure, they always used a strategy of expectancy generation for musical exceprts (Granot and Donchin, 2001).

The N400 was not generated because it was qualitatively different from those components involved in musical expectancies and instead reflected musical violations (Besson and Schön, 2001). Most of the EEG-related studies, including those that elicited P600s, ERANs, LANs, and RATNs for syntactic violations and those that elicited N5s for semantic violations, did not translate to expectancy generation because these signals were not recorded until an expected event was violated.

In conclusion, theses results support the notion that language networks are not as domain-specific as once believed. Music and language do share neural resources. Fadiga and colleagues proposed that organization of sensory and motor events in hierarchical structures may be essential for comprehension and encoding of experience, but that the brain also houses an innate capability to deal with regularities of stimuli (Fadiga et al., 2009). A remaining question from the present study for future work is whether or not musicians hear music with an internal representation of their instruments or with their own voices?

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