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Similarities and Difference in the Neural processing of Speech and Song in Religious Music

Brett Pielstick

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Honors Thesis

Similarities and Differences in the Neural Processing of Speech and Song in Religious Music

by

Brett Dagan Pielstick

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Mechanical Engineering Department
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Advisor: Francesca Lawson
Honors Coordinator: Steve Johnson
Abstract

Similarities and Differences in the Neural Processing of Speech and Song in Religious Music

B. Dagan Pielstick
Mechanical Engineering Department
Bachelor of Science

An fMRI study was performed to see the differences in the neurological processing between spoken and sung language in religious music. Students at Brigham Young University, who are members of the Church of Jesus Christ of Latter-day Saints, were exposed to alternating blocks of spoken and sung lyrics of religious and non-religious songs. There was no significant activation when contrasting speech and song, but there was significant activation in the right middle temporal gyrus and the posterior cingulate gyrus when listening to spoken and sung religious lyrics, suggesting an emotional reaction to religious stimuli. Contrasting spoken stimuli for both religious and non-religious examples, we also found increased activation in the right middle temporal gyrus, as well as activation in the left temporal sulcus, which suggests multi-sensory integration in the processing of lyrics when spoken.
Acknowledgments

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I. Introduction

Music captivates nearly everyone in some form, and, like language, is found in all cultures. This ubiquity piques the interest of evolutionary biologists, psychologists, musicologists, neuroscientists, and scholars in a variety of other disciplines. Each discipline proposes its own theories, but we can gain a greater understanding about the relationship between sung and spoken language by combining perspectives and methodologies from several disciplines. Based on some of the theories developed by scholars who study the evolutionary origins of music, an underlying connection between music and language remains significant. One of the empirical methods for researching this topic is through neuroscience. Brain activity is recorded, and groupings of neuron activation are studied to determine the cognitive similarities and differences between speech and song. This allows us to gain insight into the neurological functioning of and the evolutionary relationship between music and language.

One example of empirical research comparing music and language is an fMRI study conducted by Angulo-Perkins et al. (2014). In their analysis, they grouped human vocalizations and music together and compared them to non-vocal sounds (such as yawning and screams). They found that the anterior portion of the superior temporal gyrus (STG) was more active in responding to music and human vocalizations than to non-vocal sounds. A similar but narrower response was found in the anterior portion of the STG when comparing human vocalizations and music to monkey vocalizations. The researchers discovered that there was a key difference between music and human vocalizations. They found that the planum polare, a part of the somatosensory cortex, responded significantly more to music than to human vocalizations. There were other parts of the brain, mostly in the STG, that responded more to human vocalizations than to speech. These parts of the brain were in the posterior portion of the STG, comprising of Brodmann areas 41 and 42 which are part of the primary auditory cortex. Activation of the planum polare is an example of one area that is not tied to basic auditory processing but responded significantly to music. This study is limited as the music stimuli were limited to piano, synthetic piano, and violin. While these instruments cover a wide range of musical literature, they do not shed light on the possible connections between spoken and sung language, which would provide insight on the origins of music and language.

In an fMRI adaptation study by Armony et al. (2015), they found that the same neural networks that process acoustic signals are active in both language and music, but there are distinct ‘music-prefering’ and ‘voice preferring’ neurons in the STG (meaning they are more active under music or voice stimulation). The acoustical overlap is efficient in processing auditory signals through the same networks, but the distinct music and voice neurons pose an interesting question about the continuum of brain activation between music and language.
Schoen et al. (2010) conducted an fMRI experiment on the difference between speech, song, and vocalists. This was accomplished by having 10 non-musician subjects listen to different words that were spoken or sung and then discern if the words were the same or different, or if the melodies were the same or different. Schoen found activation in the superior temporal gyrus bilaterally, though more intense in the right hemisphere for song versus speech. The comparison of song versus vocalise (a singing exercise using individual syllables or vowels sounds rather than words) had a stronger contrast than song versus speech. The superior temporal gyrus was more activated in song than vocalise. These networks were all active, but to different extents depending upon the stimuli. They also noted that “the planum polare (BA38) was only activated in the Song versus Speech contrast (music-related activation) but not in the Song versus Vocalise contrast (language related activation)” (460). This builds upon the results of Auglo-Perkins et al. (2015) and corresponds to an interpretation proposed by Brown et al. (2004) and Griffiths et al. (1998) where they postulate that the planum polare may be involved with the processing of complex musical patterns. Schoen made the claim that the linguistic and musical portions of these stimuli were not processed independently, which contradicted what Besson (1998), Peretz (1994), Orellana (2014) and many other scholars have claimed through their research.

Peretz and Zatorre (2005) suggested an explanation for the conflicting results, theorizing that some processing components appear to be genuinely specialized for music, while others could be involved in the processing of both music and speech. They argue that “one important question for the future is to determine which other processing components are uniquely involved in music and which components are not. This would provide clues as to the roots of brain specialization for music processing and hence the roots of musicality in general” (pg. 106).

Peretz and Zatorre also suggested that emotional processing of music is neurally isolable. They explain, “although the study of music as a means to express and induce emotions is a recent endeavor in neurosciences, a few studies (Blood et al. 1999, Peretz et al. 1998, Schmidt & Trainor 2001) have already highlighted important facts about music, emotions, and the brain.” More specifically, they argue, “these studies have suggested that the system for the analysis of emotional expression is neurally isolable” (pg. 98).

The present study addresses both points raised by Peretz and Zatorre: the similarity and differences in the neural processing of music and the role of music to express and induce emotions.
II. Experimental Design

Subject Body

Focusing on the neurological differences in processing spoken or sung lyrics, we selected subjects from the Latter-day Saint (LDS) students at Brigham Young University. The students all share a common musical tradition as the lyrics and tunes from the Latter-day Saint hymnal are well known, and students are accustomed to hearing the lyrics sung during the weekly worship service and spoken in the context of religious talks. The students also have been exposed to the broader American musical tradition, so we selected two pieces of music that are musically similar, *I Need Thee Every Hour* from the LDS hymnal and *Oh, Shenandoah*, a traditional American folk song. Two verses of each of these songs were recorded by a solo female voice. The same person also recorded the spoken lyrics for the same two verses.

Subject Selection

Students who were right handed, had no professional or collegiate musical training, and did not self-identify as ‘tone deaf’ (to ensure they had the ability to process music) were selected. Students with professional music training were excluded as the differences between spoken and sung language are less pronounced with a strong music background, as noted by Anglo-Perkins (2014).

Experiment Design

The participants were scanned at BYU on site using the Siemens TIM-Trio 3.0T MRI scanner. The images were functional T2-weighted images with a 2s repetition time, dividing up the scanning area into 39 interleaved slices. The first 6 scans of each run were discarded. A structural scan (with a 1x1x1mm voxel size) was acquired for each subject and normalized to the TPM template. Functional images were spatially and temporally realigned, spatially normalized to the normalized anatomical image and smoothed using an 8x8x8 mm FWHM Gaussian kernel. The stimuli presentation was controlled using ePrime. A simple fixation cross was displayed on the screen to reduce motor movement of the eyes and processing differences. The auditory stimuli were administered using a magnet-compatible stereophonic audio system with active noise control. The auditory stimuli were divided up into alternating blocks of spoken and sung stimuli. Each block contained a randomly selected a stimulus from the pool of religious and non-religious stimuli for both spoken and sung lyrics. The starting block (spoken or sung) was also randomly selected. Each block contained a randomly selected stimulus from the pool of religious and non-religious stimuli, and the starting block was also randomly selected. During the presentation of the stimulus, the fMRI machine took scans every 2 seconds until the end of the stimuli. Each new stimulus only began after the completion of the most recent scan.
The two-factor block design allowed us to explore the neural processing differences between speech and song and between religious and non-religious lyrics. The statistical analysis was performed using SPM12. After linking the structural MRI scan with the fMRI scan, we contrasted different block groupings against the average effect of the fMRI scans, this removed the average effect of acoustical stimulation. Our main analysis effort was focused on comparing activation differences under different stimuli, such as religious and non-religious stimuli, for the entire group. The contrasts were used in a random effect analysis (t-test).

III. Results

Spoken versus Sung
In order to examine the overall difference between spoken and sung lyrics, we contrasted spoken versus sung lyrics. We saw no significant activation differences between the spoken and sung stimuli. This held true when we performed the inverse contrast as well, as Schoen et al. in their study (2010).

Religious versus Non-Religious
Examining the religious effects of the study, we contrasted the religious versus the non-religious stimuli. This comparison yielded several regions of interests (ROI). We
observed increased activation (p-value < 0.05) in the right middle temporal gyrus and the posterior cingulate gyrus (see Figure 2: Sung blocks contrasting religious versus non-religious stimuli). This activation suggests religious lyrics evoke a stronger emotional reaction than non-religious lyrics.

**Spoken Stimuli Contrast**

Isolating the analysis of religious versus non-religious stimuli to just to the spoken data, we found several ROIs. Figure 3 shows increased activation (p-value < 0.05) in the right middle temporal gyrus, as is expected in spoken language, as well as activation at the boundary between the left inferior portion of the superior temporal gyrus and the left superior portion of the middle temporal gyrus (adjacent to the left temporal sulcus). This suggests responsiveness to multi-sensory integration rather than to spoken language alone. This might indicate that the auditory perception of spoken song lyrics is different than the auditory perception of words without the attachment to song.

**Figure 3: Spoken blocks contrasting religious versus non-religious stimuli**

**Figure 4: Sung blocks contrasting religious versus non-religious stimuli**
**Sung Stimuli**
Isolating the religious versus non-religious contrast to the sung stimuli, we found increased activation (p-value <0.05) in the posterior cingulate gyrus, see Figure 4. This suggests a greater emotional response to religious song than to non-religious song.

From these results it seems that music is intimately connected with emotion. This confirms what Blood et al. (1994), Patel (1998), and Schmidt and Trainor (2001) explored about music, emotion, and the brain.

**IV. Conclusion**
Finding no significant activation differences between spoken and sung song lyrics suggests that the neural pathways in processing the lyrics had significant overlap. This supports Cross and Woodruff’s idea that speech and song appear to represent two complementary sides of a common communicative toolkit (2009). Otherwise there would be more pronounced difference in the neurological processing of these different stimuli. Contrasting the religious versus non-religious stimuli on the spoken lyrics, the increased activation we found in the boundary between the left inferior portion of the superior temporal gyrus and the left superior portion of the middle temporal gyrus (adjacent to the left temporal sulcus) indicates that the subjects had a multi-sensory experience. This suggests that the auditory perception of spoken lyrics is different than that of spoken language alone. We also saw an increased activation in the right middle temporal gyrus and the posterior cingulate gyrus, suggesting an increased emotional response to religious stimuli. While exploring the neurological process of speech and song, we saw evidence that the neural pathways overlap (hence no significant activation differences between spoken and sung language) and that the religious stimuli result in a stronger emotional response from the subjects.

The results from this preliminary study support the existing research that speaks to the similarities in the neurological processing of speech and song. Moreover, the results also point to the importance of conducting further studies regarding the role of emotion in the processing of musical stimuli—an area that Peretz and Zatorre (2005) have identified as important for future research into exploring some of the ways musical stimuli are processed uniquely from linguistic stimuli.
V. References


