Intersect, Vol 15, No 2 (2022)

Differences in Brain Activation Between Musicians and Non-Musicians

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Abstract

Right temporoparietal junction differences between musicians and non-musicians is evident. However, studying Berknowitz & Ansari's 2009 paper "Expertise-related deactivation of the right temporoparietal junction during musical improvisation," the conclusions that they made as to why may be incomplete.

In the paper "Expertise-related deactivation of the right temporoparietal junction during musical improvisation" (Berkowitz & Ansari, 2009), researchers examined differences in functional brain activity between musicians and non-musicians during musical improvisation. They then identified neural correlates activated when musicians use spontaneous, novel motor sequences. Most music cognition research compares the degree of activation between musicians and non-musicians, but differences in brain activation between musicians and non-musicians when using creativity and improvisation had not been thoroughly studied at the time. Berkowitz and Ansari (2009) explained that most of the research prior to this has used pitch memory or rhythmic performance measures when studying perceptual and motor tasks in musicians versus non-musicians. (Berkowitz & Ansari, 2009; Chen et al., 2008; Gaab et al., 2006). Berkowitz and Ansari based this study on the frontal brain areas identified in their earlier paper—the inferior frontal gyrus, ventral area of the anterior cingulate cortex, and the dorsal premotor cortex (Berkowitz & Ansari, 2008). These brain areas are responsible for the planning, selection, and generation of novel motor sequences. Previous research has used improvisation to study the correlation between brain activation and novel motor sequences in musicians, but the degree to which this activation differs from non-musicians has not been thoroughly explored (Brown et al., 2006; Bengtsson et al., 2007; Limb and Braun, 2008; Berkowitz & Ansari, 2008).

For instance, in another more recent study, the focus was on musicians, and thus did not have the comparison of a non-musical group (Tachibana et al., 2019). The study looked at improvisation and brain activation, and used fMRIS technology to observe musical improvisation more naturalistically, as there were not the same restraints as the fMRI (i.e. no metal, confinement of device, etc.). Study participants, which consisted of twenty healthy professional or amateur male musicians, participated in several blocks which each consisted of first improvising a melody, and then moving to remembering and playing a previously learned melody (Tachibana et al., 2019). In the formulaic block, participants played previously learned blues or jazz riffs and in the improvisation condition participants were asked to improvise their own melodies; however, in both conditions, the participants were asked to match their tempo to the background track being listened to (2019). This study found that the PCF and DLPFC were activated to a higher degree in improvisation (2019). However, it is important to note that differences between amateur and professional musicians was not measured (2019), so we see no activation in the rTPJ, as was expected in the musician group, and do not have a further explanation into the activation in the non-musician group.

Berkowitz and Ansari had a narrow hypothesis focusing only on the inferior frontal gyrus, ventral area of the anterior cingulate cortex, and the dorsal premotor cortex; they hypothesized that the degree of musical training a person has should correlate with the degree of brain activity elicited in these areas—and that the areas more active than others during a musically creative task should differ based on the participant's level of musical experience. In other words, the *degree* of activation should differ based on their musical training, but the activated brain areas should remain the same as noted above (Berkowitz & Ansari, 2009).

This study was a block design study, one in which all participants took part in each of the four conditions. Subjects had to either (1) play a series of pre-established note sequences or (2) improvise their own set of note sequences. Each of these conditions also had two sub-conditions where there was either (i) a metronome present or (ii) no metronome present. When the metronome was playing, participants were asked to match the rhythm of their note sequences (either pre-established or improvised) to the rhythm of the metronome. Each of these measures were conducted on both the musical and non-musical participant groups.

Participants were shown a series of pre-established note sequences, which consisted of playing one key five times in a row or playing all five keys in either ascending or descending order. During the testing, participants wore MRI-safe headphones allowing them to hear the notes played in real time. They were instructed by seeing visual instructions that read either "play patterns," where they played as many of the pre-learned patterns as they could within the time period, or "make up melodies," where they had to make up as many novel sequences as possible within the time frame. The headphones not only allowed participants to hear the notes they played in real time, but also played a metronome—or no metronome, depending on the condition—to which subjects had to match the pace of their note.

Structural images of the brain were obtained using a full-body T3 MRI. Functional images of the brain were also obtained for all participants in all conditions using fMRI blood oxygenation level-dependent (BOLD) contrast. fMRI measures the level of oxygenation within the brain, with the higher oxygenation level correlating with a higher degree of activation. This is often done by using a subtraction method, where level of activation is shown over and above a control level of activation during the same test. The oxygenation levels positively correlate with brain activity because greater levels of activation of the brain requires greater levels of oxygen, which can be measured by fMRI. Researchers then compared the level of activation between all four conditions using t-tests. They also observed the number of novel sequences played by each group by quantifying how many musical sequences had not been played before by each participant and averaging this by musician and non-musician groups; in other words, they measured the number of new patterns played by each person. The researchers also measured the rhythmic freedom present by measuring how close to the metronome each participant hit each note within their musical sequences. Surprisingly, researchers found no significant differences between the groups in the inferior frontal gyrus, ventral area of the anterior cingulate cortex, and the dorsal premotor cortex—which is not in line with their initial hypothesis. They also were unable to find differences in the amount of novel note sequences between groups (Berkowitz & Ansani, 2009).

The researchers then went back to the data, using post-hoc analysis, and found that the brain region called the rolandic temporoparietal junction (rTPJ) was deactivated to a greater degree in both the improvisation and rhythmic freedom conditions, but only for the group of trained musicians. This deactivation was found in both conditions (improvisation and rhythmic freedom) but was only statistically significant in the improvisation condition. Berkowitz and Ansari (2009) concluded, after analyzing other studies about the rTPJ, that this deactivation is because musicians could tune out any distractions or noise to better concentrate on playing their instrument. It is relevant to note that top-down factors depend on skills acquired throughout a person's life. Once they become more innate, these skills become more hardwired and occur more automatically; whereas bottom-up processing is based on a constant attenuation to surrounding stimuli and then acting based on your perception. This means that non-musical participants were picking up things one by one and not drawing from previously acquired information (Thompson, 2015). Berkowitz and Ansari (2009) claim that musicians use top-down processing because of their experience; oppositely, non-musicians use bottom-up processing because they rely on the notes previously played to decide the next note they will play.

In one of the papers cited by Berkowitz and Ansari (2009), researchers looked at several papers that examined the role of the temporoparietal junction and found evidence of less activation in the rTPJ when using goal-driven attention (Corbetta et al., 2008). In Corbetta's review, they explain that the rTPJ is a part of the ventral frontoparietal attention network. This brain network helps us reorient our attention to a salient or important stimulus, and the activation of this network greatly depends on the relevance and importance of the stimuli to the viewer (Corbetta et al, 2008). In other words, this paper suggests that focused attention on a task lessens rTPJ activity and prevents reorientation to outside stimuli. However, if the relevance of the stimulus activates the ventral network—which includes the rTPJ, this would mean that it is not the level of musical skill that is the factor causing the rTPJ to deactivate; in fact, one would think that this area would be more activated in musicians because music is relevant in their lives (2008).

It is important to note that, although Berkowitz and Ansari focus on musical creativity being a large factor in this phenomenon (2009), the memory load of musicians' could be what leads to this deactivation. Because musicians have extensive musical knowledge and practice in musical application, many are used to often tuning out outside distractions. While they have procured this ability, non-musicians rely on external cues to create their sequence of notes. The studies included in the Corbetta et al. (2008) paper also used visual stimuli and focused on this domain. However, the paper specifically states that the distinction between task and attentional orientation may not be applicable to other neural systems (2008). In fact, the conclusion drawn by Berkowitz and Ansari (2009) cannot generalize completely to the auditory system because Corbetta et al., (2008) focused entirely on the visual neural network. This is one of the drawbacks mentioned in their study (Berkowitz & Ansari, 2009).

Corbetta et al. (2009) mention in their paper that the rTPJ is seen to be deactivated when one has a high memory-load. They explain this phenomenon below, as well as how it relates to Theory of Mind (ToM):

> Because greater memory loads produce stronger TPJ deactivations (Todd et al., 2005), differential TPJ activity in experimental and control conditions of ToM paradigms could reflect overall differences in memory load or task complexity (Corbetta et al., 2008).

In more recent papers, the rTPJ was found to be activated when participants were using imitation (Sowden & Catmur, 2016; Kubit & Jack, 2013). ToM is the ability to understand the mindset of other individuals' and is a prime function of the rTPJ. Because non-musicians do not play music, they may be thinking about how someone else would respond, and thus the brain areas used in ToM are activated. However, musicians already have this knowledge and therefore do not need to use ToM.

Sowden and Catmur (2016) found that during a task requiring participants to switch between representations of their own actions and others' actions, the rTPJ was more active when representing others' actions. Sowden and Catmur (2016) elaborate by saying:

> For example, when taking another person's perspective, switching between 'self' and 'other' representations is required in order to inhibit the representation of one's own perspective and to enhance the representation of the other's perspective. Similarly, in theory-of-mind tasks, one needs to represent the beliefs, desires, or intentions of another person, rather than one's own beliefs, desires, and intentions. (Sowden & Catmur, 2016, p. 1108)

It is possible that participants in the non-musical group put themselves in a position where they had to act like a musician or act in a way that is not normal to them, and, because their knowledge of music is limited, may have had to use the same brain mechanisms responsible for thinking like a musician and imitating their behavior.

As stated earlier, the ventral network is used to redirect attention to novel information. Because musicians are knowledgeable about music and how notes should sound, there is less new information that their brain is picking up, and thus the ventral network is less active; whereas, in non-musicians there may be a breach of expectation, as they are not as familiar. Both reorientation of attention and ToM activate the rTPJ and ventral network, so the combination of these in non-musicians may more accurately explain the differences in brain activation. Therefore, non-musicians may be more active in this area because they are unfamiliar with music.

The combination of both studies may show that there are reasons for not only a deactivation of the rTPJ in musicians, but also a higher activation in non-musicians. The deactivation of this area in musicians could be due to task-shifting and blocking out distractions, as mentioned by Berkowitz and Ansari (2009); however, it is more likely due to the memory-load that musicians have regarding musical tasks and extensive knowledge on the subject (Corbetta et al., 2008). There is also evidence that non-musicians may have a more active rTPJ than musicians because of their need to represent the desires or intentions of someone else as they have little prior musical knowledge or ability (Sowden & Catmur, 2016). Another explanation for the activation could be that a non-musician's ventral system is activated because the musical notes are viewed as a novel stimulus (Corbetta et al., 2009)

There are quite a few drawbacks to Berkowitz and Ansari's paper. The two had conducted an earlier study focusing only on musicians; they used these participants as the musical condition for this experiment as well, and only selected new participants for non-musical conditions. Therefore, participants from the musical condition had undergone a similar experiment already, which may have influenced their behavior in the current study. Another drawback is that a lot of the data was excluded from their analysis, meaning that there was a smaller sample size used. Thirteen music subjects were originally recruited, and fifteen non-musical participants. Three participants from the non-musician group were excluded and one from the musician group due to head motion causing unclear imaging. There was already a very small sample size; the data excluded may have changed the results of the study. While the exact values were not given, the final—and likely most salient—drawback is that much of their conclusions were based on non-corrected statistics and the data became non-significant after using the Bonferroni Correction. The correction is used when looking at post-hoc data, or analysis done after the research is complete, which is not related to or included in the initial hypothesis. This is a method of controlling data to avoid type I errors, as well as implementing a stricter alpha value, meaning that, by not using this correction, the data used to make their conclusion is more likely to have a false-positive or erroneously show a greater statistical significance. However, despite the limitations to their research, the paper by Berkowitz and Ansari (2009) does give insight into areas of possible future research.

In essence, Berkowits and Ansari (2009)'s originally hypothesized that the inferior frontal gyrus, ventral area of the anterior cingulate cortex, and the dorsal premotor cortex—which are responsible for selection and generation of novel motor sequences—would differ between musicians and non-musicians. However, their findings showed no differences between groups in these brain regions. Researchers conducted a post-hoc analysis which found that the rolandic temporoparietal junction (rTPJ) to be more active in non-musicians and less active, or "deactivated" in musicians. They concluded, based on research focused on the visual domain, that this deactivation is a result of musicians tuning out external distractions when focusing on creative musical activity. Their research has many drawbacks, including the fact that they included participants who had previously completed a similar study, that the researchers excluded data, and that they made conclusions based on non-corrected data. Another factor that could skew their results is that they used a series of t-tests, which would yield a lower significance threshold than performing an ANOVA, and thus leads to a higher probability of a type I error; finding significance when there is no significance.

After examining sources used in their paper, and outside studies, there are other possibilities for their findings. The reason behind the deactivation of the rTPJ in musicians is an area of future research, but also studying why there is a higher activation in non-musicians. My thoughts are that the deactivation of the rTPJ in musicians could be due a high memory-load, or the musicians' previously established familiarity with the notes (Corbetta et al., 2008). Non-musicians also show a more active rTPJ than musicians. These findings could be because non-musicians need to imitate musicians as an attempt to represent their desires or intentions due to the non-musicians' lack of prior musical knowledge or ability (Sowden & Catmur, 2016). This area may also be more active because non-musicians may hear these notes as a more "novel" stimulus, which activates the ventral system. While Berkowitz and Ansari's 2009 study brought about several significant findings in the area of musical decision-making and related brain activation, further study is needed to explore alternative explanations for their conclusions.

References

Bengtsson, S.L., Csíkszentmihályi, M., Ullén, F., 2007. Cortical regions involved in the generation of musical structures during improvisation in pianists. J. Cogn. *Neurosci*. 19 (5), 830–842.

Berkowitz, A. L., & Ansari, D., (2008). Generation of novel motor sequences: The neural correlates of musical improvisation. *Neuroimage, 41*, 535–543.

Berkowitz, A. L., & Ansari, D., (2009). Expertise-related deactivation of the right temporoparietal junction during musical improvisation. *Neuroimage*, *49*, 712-719.

Brown, S., Martinez, M.J., Parsons, L.M., 2006. Music and language side by side in the brain: a PET study of the generation of melodies and sentences. *European Journal of Neuroscience,* 23(10):2791-803.

Chen, J.L., Penhune, V.B., Zatorre, R.J., 2008. Listening to musical rhythms recruits motor regions of the brain. Cereb. *Cortex* 12, 2844–2854

Corbetta, M., Patel, G., Schulman, G.L., (2008). The reorientation system of the human brain: from environment to theory of mind. *Neuron, 58*(3), 306-324.

Gaab, N., Gaser, C., Schlaug, G., 2006. Improvement-related functional plasticity following pitch memory training. *NeuroImage,* 31 (1), 255–263.

Kubit, B., & Jack, A. I. (2013). Rethinking the role of the rtpj in attention and social cognition in light of the opposing domains hypothesis: Findings from an ale-based meta-analysis and resting-state functional connectivity. *Frontiers in Human Neuroscience,* 7. https://doi.org/10.3389/fnhum.2013.00323

Limb, C.J., Braun, A.R., 2008. Neural substrates of spontaneous musical performance: an fMRI study of jazz improvisation. *PLoS ONE,* 3 (2), e1679.

Sowden, S., Catmur, C., (2015). The Role of the Right Temporoparietal Junction in the Control of Imitation. *Cerebral Cortex*, *25*(4), 1107–1113.

Tachibana, A., Noah, J. A., Ono, Y., Taguchi, D., & Ueda, S. (2019). Prefrontal activation related to spontaneous creativity with rock music improvisation: A functional near-infrared spectroscopy study. Scientific Reports, 9(1). https://doi.org/10.1038/s41598-019-52348-6

Thompson, W.F., (2015). *Music, Thought, and Feeling: Understanding the psychology of music, 2*.