

Reading Guide – Salimpoor, et al.

Bibliographic Information:

Salimpoor, Valorie N., Mitchel Benovoy, Kevin Larcher, Alain Dagher, and Robert J. Zatorre.
"Anatomically Distinct Dopamine Release during Anticipation and Experience of Peak Emotion to Music." *Nature Neuroscience* 14, no. 2 (2011): 257-62.

Reading Type/Profile: Journal article from *Nature Neuroscience*, a journal that publishes research on a wide variety of biomedical topics including but not limited to emotional memory, Parkinson's disease, and the mammalian brain in general. The journal is written with a focus on neuroscience but includes entries from topics as diverse as genomics, hormones, and the architecture of the brain. It is an excellent journal overall for learning about the human nervous system. This particular contribution was revised in 2011 after being submitted.

Author Background: The background of Dr. Valorie Salimpoor is quite expansive – she has contributed to numerous topics of our interest such as non-musical influences on the processing of music and how we interpret music as pleasurable within the brain. Aside from this article on dopamine release during the anticipation and experience of music, she has also written about strategy use, working memory, and the relationship between repetitive stimuli and mathematical performance. Some of the other authors focus on equally interesting topics – Benovoy on adaptive facial recognition with technology, Dagher on movement disorders and MRIs, and Zatorre on aspects of auditory processing ranging from the function and structure of the auditory cortex to brain imaging techniques – but as a primary contributor to this paper, Salimpoor provided contributions to all parts of the article including artistic design, experimentation, analysis, and the write-up.

Abstract/Summary: Although music is traditionally viewed as an abstraction – something that is not tangible – Valorie Salimpoor and others agree that music and tangible stimuli have similar properties. For instance, both involve the striatal dopaminergic system (which mediates beat perception via dopamine and is impaired in those with Parkinson's disease for example) and almost universally cause feelings of euphoria or craving. Using a method for imaging the brain that is called raclopride positron emission tomography scanning, Salimpoor et al. visualized dopamine release within the striatum and mesolimbic regions of the brain. The authors used fMRIs to see the temporal aspects of dopamine release and found that the caudate nucleus is involved in anticipation while the nucleus accumbens is involved in experiencing the peak emotional response. Their findings suggest more generally that the intense pleasure brought about from music leads to dopamine release in the striatal system. Importantly, the anticipation of music (an abstract reward) and the actual peak pleasure from music release dopamine in

distinct and different anatomical pathways, which corroborates the general consensus that music plays an essential role in life and human society.

Important Details:

Music is an *abstract* stimulus, the effects of which depend highly on different cultures and personal opinions. Yet empirical studies agree with the general consensus that music has a powerful capacity to impact pleasurable emotional status.

The reason that the authors used *ligand-based positron emission tomography scanning* (which uses radiotracers to examine different processes and test for diseases) is that endogenous dopamine and raclopride bind to the same receptors – the amount of dopamine that excludes the raclopride can be estimated via this process of scanning. The authors focused primarily on estimating dopamine release in the striatum region of the brain.

The *chill response* is an important and wide-spread metric of pleasure; it makes an ordinarily subjective and unquantifiable phenomenon into an effect that can be objectively observed and verified through numerous experiments. Salimpoor et al. use the patterns of autonomic nervous system arousal commonly known as the chill response in order to measure the subject's pleasure associated with listening to music. Before recruiting volunteers, Salimpoor et al. ensured that they had demonstrated objectively verifiable chills during peak emotional response to music of their choice. Psychophysiological measurements such as heart rate were collected during PET scans – this helped the authors verify that their autonomic nervous systems took on different states during conditions of music versus the absence of music.

Salimpoor et al. hypothesized that over time dopamine would increase in the mesolimbic regions from exposure to music. They indexed endogenous dopamine transmission by decreases in *raclopride binding potential*. The presence of substantial raclopride binding potential differences between neutral and pleasurable conditions in these regions (the percentage of potential change was highest in the right caudate and the right nucleus accumbens) show that the experience of pleasure while listening to music is indeed associated with the release of dopamine within the striatal systems.

Musical tones elicit *anticipatory responses* over time; thus, the components of the brain preceding the peak pleasurable response can be isolated. Combining the methods of fMRI and PET scans, the authors specified both the temporal and neurochemical elements of anticipation. They predicted that, for their group of participants, hemodynamic response measured in blood oxygenation level over time (BOLD) would increase the most during peak emotional experiences in regions that had previously showed dopamine release under PET scans.

PET (*Positron Emission Tomography*, which measures the rate of metabolism of glucose within the brain) scans took place over two sessions – in each session, participants listened to either pleasurable music or neutral music while various indicators of emotional arousal (subjective or objective) were collected. All objective measures of psychophysiological signals – heart rate, respiration rate, electrodermal response, temperature, blood volume pulse amplitude – indicating emotional arousal showed significantly ($\alpha = 0.05$) higher activity in the autonomic nervous system during the pleasurable music condition as compared to the neutral.

For each item of pleasurable music, the average number of chills was 3.7 with a standard deviation of 2.8. A paired-samples t-test confirmed that greater pleasure was very much likely to be experienced during the pleasurable music condition over the neutral music condition. These findings confirmed that *a very strong correlation between peak emotional arousal and the chills state exists*.

Participants indicated by button press whether they experienced chills – these responses were used to identify the time spans of the peak and anticipation experiences where each anticipation epoch was defined as the 15 seconds up to the peak experience. Integrating the BOLD hemodynamic responses for these epochs and data on the regions that had released dopamine according to the raclopride PET scan, Salimpoor et al. found that increased BOLD responses that were found during anticipation periods were largely confined to the right caudate.

The main findings of the authors are that the dorsal and ventral striatum have a distinct role in music perception. Activity in both the caudate nucleus (a part of the striatum) and the nucleus accumbens were increased during anticipation. However, larger increases occurred in the caudate and in fact, caudate activity decreased during the peak emotional response.

While the number of chills experienced is significantly associated with binding potential differences (and hence dopamine transmission) in the right caudate rather than the nucleus accumbens, the intensity of chills (the overall amount of pleasure experienced) was most significantly associated with binding potential differences in the right nucleus accumbens instead of the caudate.

Distinct anatomical regions (ex. the dorsal and ventral striatum) contribute in separate ways to dopamine release associated with music listening. The striatum is an essential part of the brain implicated in motor functions such as Parkinson's. As such, the association between representations of music, motor control, and auditory processing remains an open question in cognitive science. Further studies could examine whether increases in pleasure without chills continue to effect increases in hemodynamic responses in the same areas of the brain.

For Further Reading:

"Alain Dagher, MD." Alain Dagher, MD. December 06, 2017. Montreal Neurological Institute and Hospital. <https://www.mcgill.ca/neuro/research/researchers/dagher>.

Alem, Emad El. "Epilepsy Awareness Program - EEG vs MRI, FMRI and PET." Middle East Medical Information Center and Directory. 2014. Accessed June 04, 2018. http://www.biomedresearches.com/root/pages/researches/epilepsy/eeg_fmri_and_pet.html.

"Dr. Valorie Niloufar Salimpoor." Baycrest Research. 2016. University of Toronto. <http://research.baycrest.org/vsalimpoor>.

A listing that gives basic information about the main author such as research-based awards, topics of interest, and publications.

Grahn, Jessica A., and Matthew Brett. "Impairment of Beat-based Rhythm Discrimination in Parkinson's Disease." *CORTEXX*45 (October 30, 2008): 54-61. ScienceDirect.

This article, while it mainly focuses on decreased dopamine in the striatal regions of the brain for Parkinson's patients, is valuable in that it describes the role of the striatum in auditory processing. Furthermore, it underscores the importance of dopamine in normalizing activity in the basal ganglia and supplementary motor areas of the brain.

"Mitchel Benovoy's Scientific Contributions While Affiliated with McGill University (Montréal, Canada) and Other Places." ResearchGate | Share and Discover Research. 2018. https://www.researchgate.net/scientific-contributions/15311945_Mitchel_Benovoy.

"Nature Neuroscience - Journals - NCBI." Advances in Pediatrics. 2018. <https://www.ncbi.nlm.nih.gov/labs/journals/nat-neurosci/>.

A biomedical journal that gives information about different regions of the brain such as the hippocampus, the consequences of Parkinson's, and context-dependent emotional memory.

"PET/CT - Positron Emission Tomography/Computed Tomography." Radiology Info. 2018. <https://www.radiologyinfo.org/en/info.cfm?pg=pet>.

This article describes the fundamentals of positron emission tomography and how it is used to detect the transmission of neurotransmitters as a form of nuclear medicine. Using radiotracers that can be detected later on, researchers are able to examine processes in different regions of the body.

"Robert Zatorre, PhD." Montreal Neurological Institute and Hospital. March 13, 2018. <https://www.mcgill.ca/neuro/research/researchers/zatorre>.

More information about one of the cognitive neuroscientists who studies every aspect of auditory processing from structural properties of the auditory cortex to how the brain deals with missing sensory information.

Q3. What is the difference between an emotion, a feeling, and a mood, according to (a) Damasio, and (b) Prinz?

The fundamental distinctions that Damasio makes early on in his work *The feeling of what happens: body and motion in the making of consciousness* is that emotion and feeling are events that occur subconsciously. Damasio claims that emotion is something that results from knowledge that exists in the subconscious; as a result, emotion is integral to the decision-making process (Damasio supports this claim by citing numerous examples of individuals who had reduced decision-making capability – these were people who had had injury to specific regions of the brain affecting emotion only, or those who were simply unemotional to begin with). Damasio generally views emotion as a form of non-conscious preference; citing the difficulties that people have in playing poker or otherwise trying to suppress our emotions, he says that they are involuntarily triggered and thus non-conscious.

In Jesse Prinz's chapter of *The Cambridge Handbook of Cognitive Science*, similar opinions about emotion as a non-trivial, non-random entity are expressed; emotions are absolutely essential in survival-based decision-making, attention and memory, and human culture. However, Prinz also advocates for the cognitive approach to emotion generation – this means that thoughts and appraisals (judgments) about different events can affect our emotions greatly. Whether or not we follow the multiple dimensional appraisal theory that includes automatic or unconscious appraisals, Prinz cites cases in which cognition is always in some form needed for the creation of emotion.

According to Damasio there are six primary emotions, but among these are common traits. Emotions are not random occurrences but rather specific responses to sensory stimuli that

are biologically determined and laid down by the evolutionary path. Emotions are integrally related to body states as they occupy the same subcortical regions of the brain. People express emotions through the body and as a result these emotions play an integral impact with the cognitive process. Emotions, based on the research of Damasio, cannot be suppressed without suppressing consciousness itself. Their purpose lies not only in maintenance of homeostasis of the body but also in the induction of specific and sometimes necessary evolutionary responses to environmental stimuli.

Prinz likewise emphasizes the importance of emotion in making decisions; first, we must perceive something and understand it through cognition before it can elicit an emotional response (for example, works of art). Although there are other cases of emotional elicitation that do not involve cognition such as music, Prinz emphasizes the role of cognition albeit to a lesser degree. For example, he says that there are also numerous pathways to the amygdala (a very old relic of evolution) from the subcortical pathways that connect sensory information directly to the amygdala. None of these mentioned regions (the amygdala and thalamus) involve cognition and yet they can induce immediate responses to sensory input in its absence.

Thus, Damasio's emotions are integrally related to the sustenance of life itself; they consist of reflexes that help determine the body's status. The creation of feelings is simply forming images and other representations of our basic six emotions – pain, pleasure (which are distinct from emotions) as well as emotions are represented as images that we call feelings. As we gain conscious control over our feelings, we also have greater power to affect our mood which consists of our responses to our consciously generated images.

In contrast to Damasio's claim that the feelings are cognition-based (that they require us to create mental representations of our emotions), Prinz also gives credence to the impure cognitive theory of the mind. This theory states that there is a distinction and separation between emotional cognition and emotional feeling; appraisal judgments about the world cause the emotional state which then causes a feeling state that is not dependent on cognition. The feelings are the after-effects of the emotions. For Prinz who follows Gordon's view of emotion, emotions have thoughts as their antecedents but have no thoughts as components. Feeling is our sensation of emotion and can linger long after the appraisal judgment stops.

Generally, Damasio claims that emotion is an important part of our machinery and that we ascribe different emotional values to objects per our ingrained evolutionary tendencies. Emotions are in every part of reason from envisioning certain events; consciousness (and hence reason) is inseparable from emotion. Neurons from the thalamus, basal ganglia, and brain stem release chemical substances such as endorphins or oxytocin, which results in an impact on every brain circuit – emotions are involuntarily conducted through the bloodstream and neural circuits simultaneously, which affects every part of the organism. Furthermore, emotion does not include pain or pleasure because these are more indicative of the presence of imbalance and its resolution. In order to feel an emotion, an organism must first envision – create a mental representation – of the emotion and then decide which mood it should acquire.

Furthermore, there is an additional distinction that Prinz does not make. He does not distinguish between pleasure, pain, and emotion. He simply states that emotions cause a body state which then is felt by the organism. Prinz claims that emotions rest on a continuous spectrum with three main elements – arousal, valence, and cognitive interpretation of the

combination of arousal and valence. Arousal for Prinz is related to autonomic responses in the realm of excitation or inhibition, while valence refers to the pleasant/unpleasant, approach/avoid dichotomies. Thus, one could argue that Prinz's conception of emotion and feeling is more complex than that of Damasio because it includes within it infinite combinations of possible nervous system states.

References

- Damasio, A. (1999). *The feeling of what happens: body and emotion in the making of consciousness*. 1st ed. Orlando, Florida: Harcourt, Inc, pp.35-81.
- Prinz, J. (2012). Emotion. From Keith Frankish and William M. Ramsey's *Cambridge Handbook of Cognitive Science*. Pages 193-211. New York, NY: Cambridge University Press.

Q1. Describe and discuss a specific musical instrument—other than a guitar—as a cognitive extension. Consider the ways in which it enables musical thought and action, as well as how it constrains musical thought and action.

Due to the fact that the guitar is excluded as a possible musical instrument, I would like to take the piano as an example. Since its conception in the year 1700, the modern piano as we know it was constructed as a louder version of the harpsichord – this innovation was brought about by the use of hammers that immediately retract after striking the string so as to not dampen it, the use of thicker strings with higher levels of tension than could be withstood by the plucking action of the harpsichord, and a wider range of possible notes¹.

The ways in which the piano serves as a cognitive extension are manifold; the piano allows the composer to play almost anything that could be played on any other instrument in terms of melody. This is because the layout of the keyboard is such that it includes every note and half-note sequentially and can be played with both hands. Furthermore, as in the instruction of perfect pitch, the piano can be used as a means of entraining people to understand specific pitches and identify them with certain hand positions on the piano. Without the piano, the piano player could not produce music; thus, the piano serves as a way of extending one's physical capabilities to express music that can be shared among audiences.

The piano has multiple octaves, the ability to suspend dampening of the strings, and the intensity of the sound can be controlled both via the touch of the piano player and by the addition of a pedal that reduces the number of strings being struck. These all contribute to its utility as a form of musical representation. As Pitt says in *Mental Representation*, mental images are representative of something similar to what an actual picture would represent. Similarly, the

¹ Powers, W. *The Piano: The Pianofortes of Bartolomeo Cristofori (1655-1731)*.

piano represents what someone would hear within their mind. Although its parts are discrete and unchanging, the movement of the player allows the piano to function as an analog, continuous auditory process that represents the abstraction of music.

The piano is not merely an external object that serves its function only when the player is present. It is a good example of what the connectionist theory that Pitt talks about says – that through repeated exposure to different notes and rhythms on the piano, the player can learn statistically and classically how to play the piano. This learning does not diminish in the absence of a piano because the player knows to maintain an internal representation of the piano. As we talked about in class, neural imaging has showed that the actual presence of beat and pitch is not necessary for someone's brain to undergo the same changes as if music were actually playing.

The piano, unlike some other stringed instruments such as the guitar and violin, restricts musical expression through its percussive nature. As Magnusson notes in *Of Epistemic Tools*, use of the piano discards the value and importance of microtonality as the player cannot affect the frequency of each tone that is produced by each key. Thus in the construction of music such as Jazz or other music that requires continuous changes of tone ala Jimi Hendrix, the piano might not serve as an adequate representation of what one has in mind (Magnusson 171). From the work of Davis Baird in 2004, we know that instruments such as the piano do not express one's knowledge through argumentation, syntax, and rhetoric. They express knowledge by creating more opportunities for mental representations to be created and supplying the instrumental functions needed to employ these representations (Magnusson 171).

Furthermore, the piano constrains musical expression through its ease of use; because the inner workings of the piano do not need to be understood in order for performances to be had,

the composer may not be able to understand the original uses of the piano. As Magnusson says, the designers and the users of an instrument have a very different and distinct understanding of it – this divergence becomes greater when we progress to more complex instruments (Magnusson 171) such as the digital piano. Thus the lack of understanding of the player constraints his musical expression. It is not only the functional limitations of the piano – the heavier hammers, the lack of vibrato, the acoustic properties of the ivory, and the percussive nature that separates the player from the music – but also the difficulty in forming mental representations pertaining to the piano that limit the ability of musical thought and action.

Despite Magnusson's distinction between the electric and acoustic forms of instruments, I would like to say that they are quite similar in many respects for the piano. I do agree that the acoustic instrument is a channel for embodiment in the world (Magnusson 175). Aside from the different internal functionality of the instruments, however, I claim that their basic output is largely the same and both forms serve as an external representation and embodiment of one's musical thought. Furthermore, both are created by people with the intention to facilitate musical performances. Perhaps the addition of other instruments would remove the constraints imposed on the user by the piano, as the pianos of our age cannot be played with the same rapidity for which the older ones allow.

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