

TO WHAT EXTENT CAN
NORTHEASTERN STUDENTS PERCEIVE
PITCH FROM PERCUSSIVE TIMBRE?

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Abstract

Timbre is one of the most perplexing aspects of music and sound due to its incredibly complex nature, and due to the fact that it is tied to many abstract qualities which are difficult to quantify. The relationship between timbre, pitch and frequency is a frequent topic in music psychology. One aspect of this that is not as frequently discussed is the analysis of pitch in percussion instruments. In music, drums and percussion play the very specific and prescriptive role of rhythm and tempo. However, as all sounds have frequency, drums and percussion, when played, have a specific frequency that is not perceived. Therefore, percussive instruments are never considered melodic or having pitch. The purpose of this study is to investigate why this is, and what role timbre plays in this phenomenon.

Introduction

In music, the timbre of an instrument determines its unique tone and texture, and this is determined by a multitude of factors, such as attack (how “punchy” the initial onset of an instrument is), harmonics, loudness, and others. This means that a tuba, piano, and guitar all can play the same note but sound entirely different sonically and tonally. Thus, timbre is an integral part, if not the most important factor, in musical perception psychologically. Despite this, the subject of timbre is still an enigma to most researchers. Acoustical Society of America defined timbre in 1960s as “the attribute of auditory sensation which enables a listener to judge that two nonidentical sounds, similarly presented and having the same loudness and pitch, are dissimilar.” (asastandards.org) This definition implies that timbre is one of the most important attributes of sound, yet it still remains an enigma.

The realm of music and auditory processing in general is a very nuanced field due to the fact that, as humans, our ability to hear and perceive the world around us is incredibly advanced. Despite this, many of the different factors that determine how we perceive sounds and music are quantifiable, such as the decibel scale for loudness/amplitude, and the note scale for pitch classes. In terms of timbre, however, there is no such tangible scale that can quantify it. For that past 50 years, researchers have attempted to do just that, with very skewed results. Despite this, researchers have associated certain perceptual qualities with timbre, such as brightness, richness, attack, and more (Handell 1995).

One key study that investigates the role of timbre in our perception of music is “Music in Our Ears: The Biological Bases of Musical Timbre” by Patil et. al. In this study, researchers examine the neural processing of timbre to better define the role of timbre in perception. They specifically focus on the how processing of spectro-temporal changes contributes to the recognition of musical instruments. They found that specific neurons in the brain are sensitive to specific frequencies as well as spectral attributes such as spectral symmetry and bandwidth of frequencies (Patil 2012). This demonstrates that timbral and spectral changes sonically elicit a unique neurological response in a localized part of the brain, and thus must account for a significant amount of auditory perception and processing (Patil 2012).

When it comes to percussion, timbre is a very interesting topic. As a drummer myself, I have had the opportunity to hear and perceive drum sounds for quite a while, and one question that I have always had is why we as humans don't register pitch in drums. Every sound in existence has a pitch because pitch is essentially the manifestation of frequency, and sounds emanate in air at a certain frequency. Furthermore, Pitch and timbre are inherently related due to the fact that frequency content, when plotted onto a spectrum, determines the specific timbral

texture of a sound. Based off of previous research timbre may play a significant factor in why humans don't perceive pitch in drums. This is what this experiment will set out to investigate.

One study that investigates timbre in the realm of percussion is William Brent's dissertation "Physical and Perceptual Aspects of Percussive Timbre," in which Brent builds on previously established conventions and principles, including the technique of multidimensional scaling and the use of the algorithm "timbreID" to spectrally analyze the percussive timbres that

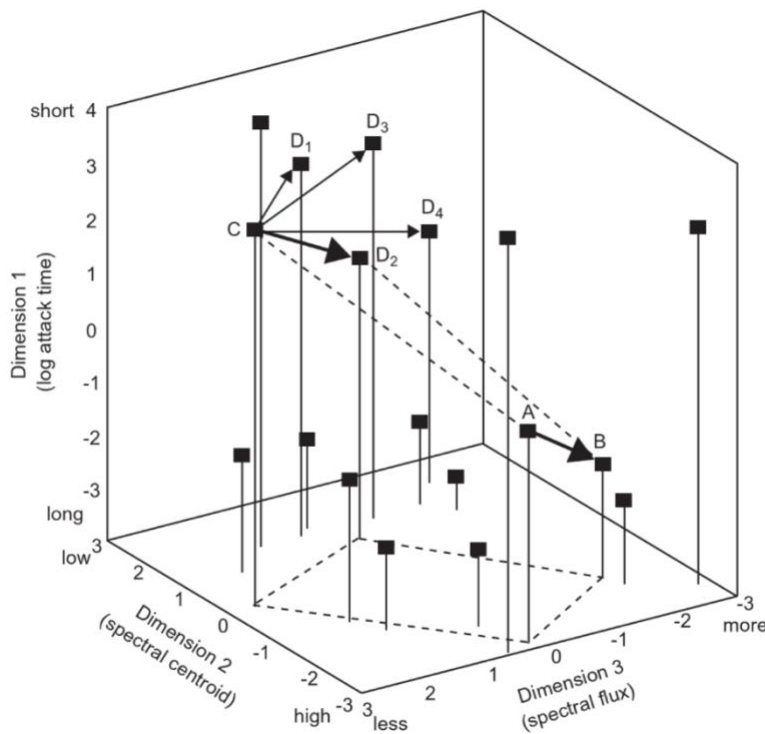
Sharp	Rough	Deep
Dry	Pure	Rich
Bright	Round	Noisy
Shrill	Warm	Dull
Dead	Brilliant	Thin

he had chosen. In his experiment, Brent took 6 participants from the University of California in San Diego, 5 of which were percussion performance majors. These participants were presented with 30 unique percussion sounds and were instructed to rate them using

a certain set of 15 adjectives as can be seen in the table above. These sounds were rate through algorithmic software called Pure Data patches. With these data points, the most used adjectives were "deep," "sharp," "bright," and "noisy." Brent also found correlations between certain pairs of adjectives, like "noisy" and "rough," and "round" and "warm." These are words not typically used for sound. However, they do, when put into context of the sounds used, make sense. For example, "noisy" implies that there are many frequencies clashing with each other in a certain

sound, which could also be used as an explanation of the adjective “rough.” Brent came to many conclusions and very deeply analyzed the results that he had accrued.

Another work that investigates timbre is Stephen McAdams’s “Musical Timbre Perception” in the book *Psychology of Music*. In his study, McAdams focuses more on the psychophysics of timbre and its implications in quantifying timbre. McAdams, like Brent, discusses the multidimensional scale and how it can be used with spectral centroid, flux, and attack time. like Brent and many other researchers, McAdams concludes that attack time and



frequency are major contributors to the spectral content, and thus the timbre of an instrument.

For this study, I will be attempting to answer the question of how well can students from Northeastern University perceive pitch from percussive timbres.

This is a question that I have frequently had because all sounds have some level of pitch and

frequency, but many sounds, such as drums and other percussion, do not elicit the perception of pitch. This is what I will investigate in my study.

Methods

Subjects

For my study, I polled Northeastern University students between the ages of 19 and 22. This study consists of 10 students, four of which identify as female, and 6 of which identify as male. Most of these participants are friends of mine, with some being friends of these friends. I gathered these participants via text and email. In terms of the demographics of the participants, there has been a fair mix of ages and majors, with a grouping of both engineering students and music technology students. Part of the reason for this is the fact that I primarily polled my peers, and most of my peers are engineers and music technology students. Originally, I had stated that I intended to primarily poll students in the Music Perception and Cognition class but have found it easier to gather participants in my own circle and will continue to until I have received an ample number of responses.

Stimuli

For this study, participants were be presented with 3 short audio samples consisting of different percussive hits, each varying in timbre and tone. The percussion samples are a snare drum hit, tom hit, and a triangle. In this experiment, the triangle serves as a control due to the fact that it has low spectral content and has a clear pitch. These sounds were chosen due their short attack and quick release. One aspect that will be monitored is how an audio file's release affects the participant's perception of pitch, because the longer the sound is, the longer the participant has to perceive a pitch. Another factor that could skew results that will be monitored is listening fatigue, as well as anchoring bias. The participants may anchor to any of the audio files and may base their answers to subsequent audio files on previous audio files.

Procedures

The main data point that is intended to be measured is to what extent the participants can perceive a pitch from these audio samples. To play these sounds, each participant will be sent a Google Form, as well as a folder containing each file, all of which being sent via email. Ideally, I would like to conduct this study in person, but for the sake of efficiency and the fact that everybody has different schedules, it will be conducted on the participants' terms. One downside to this is the fact that this method doesn't ensure that each participant is in the same headspace, which may skew results.

Each audio file will have an associated question on the Google form, on which they will be instructed to respond with a number from 1 to 10, with 1 designating no perceived pitch, and 10 designating a high perception of pitch. The participants will be instructed to listen to these audio files in order, one at a time, with headphones in order to fully hear the audio files, ensuring valid test results.

Results

Data Analysis

Once the participants have finished listening to and rating the audio files, they will submit the Google Form, from which I will plot the data into a spreadsheet for further data analysis. Alongside the responses from the participants, I will input all three audio files into the program called Audacity, in which I will create a spectrogram for each audio sample. The spectrogram of each audio file will be essential in visualizing the harmonics of a sound and will give clues as to at what point a percussive hit elicits a reaction to pitch. With this spectrogram,

alongside the responses from participants, I will determine the results and the answer to the research question of “How well can Northeastern students perceive pitch.”

In this study, I chose to use a Google Form to receive responses. Initially, I had wanted to incorporate the audio samples into the Google Form, but could not due to its limits. Instead, I put together a folder with each of the sounds and sent it to my participants after they had agreed to participate.

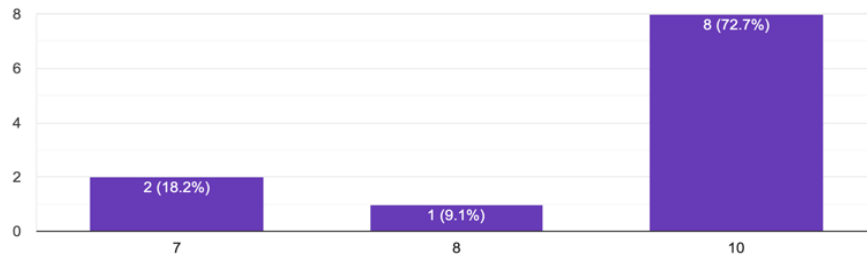
For the sounds, initially I had wanted to use a total of 10 separate sounds to achieve a wide variety of responses to different types of percussive timbres, but after receiving feedback I decided to consolidate and simplify the process by only using 3 sounds including a control. The three instruments that I used were a triangle, a snare drum, and a tom drum. The triangle serves as a control because it has a very clear pitch, while the other two serve as data points off of which to analyze. On the Google Form, the participants are asked to rank from 1-10 how easily they can perceive a pitch in each of the three audio samples. My hypothesis for this experiment was that the tom would be more easily perceived as pitch than the snare drum, and that, unsurprisingly, the triangle would be perceived the easiest.



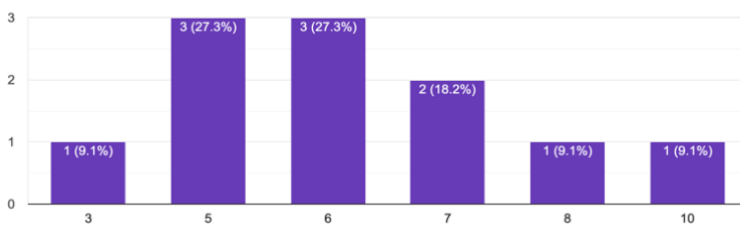
The results of this study were highly unexpected and not consistent. Overall, the only consistent result was in the control, with almost all the participants ranking it a 10. In terms of the other two, there were very mixed results from every participant, with some ranking the snare

drum highly, some ranking the tom highly, some ranking both lowly, and even some ranking both highly. Overall, the control sample scored highly with participants, unsurprisingly, with an average of 9.5 out of 10, with only 2 people answering lower than a 10. The snare drum and tom were nearly identical in average, with the snare drum averaging a 5.8, and the tom averaging a 5.5.

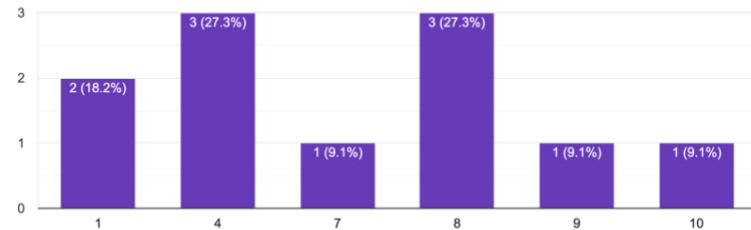
From 1-10, how much can you hear the pitch of audio sample 1? (1 being no pitch, 10 being you can distinctly hear a pitch)
11 responses



From 1-10, how much can you hear the pitch of audio sample 2? (1 being no pitch, 10 being you can distinctly hear a pitch)
11 responses



From 1-10, how much can you hear the pitch of audio sample 3? (1 being no pitch, 10 being you can distinctly hear a pitch)
11 responses

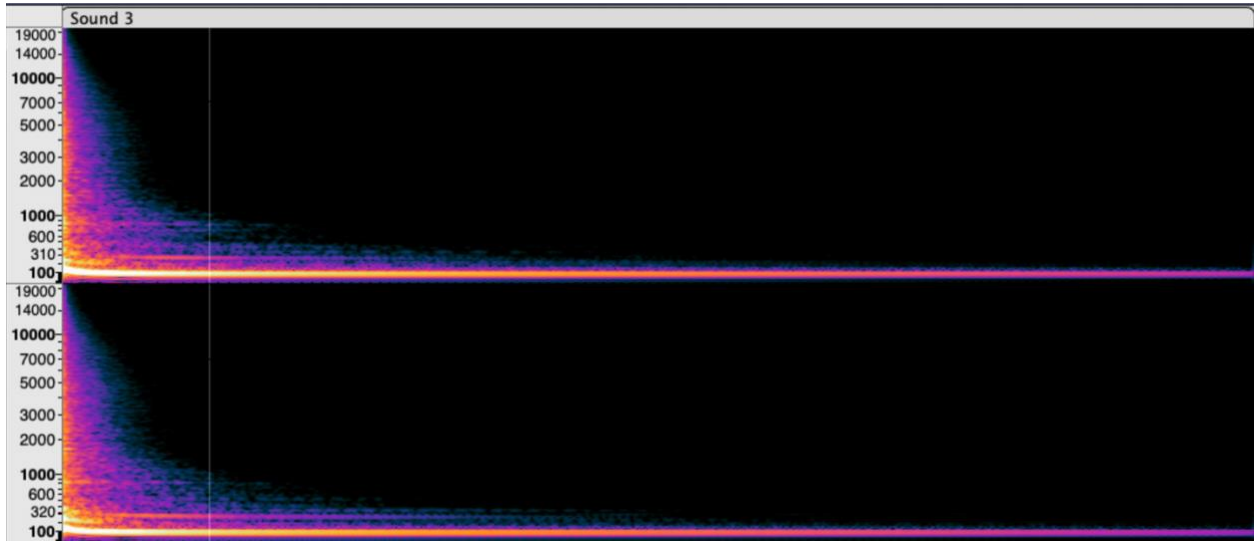
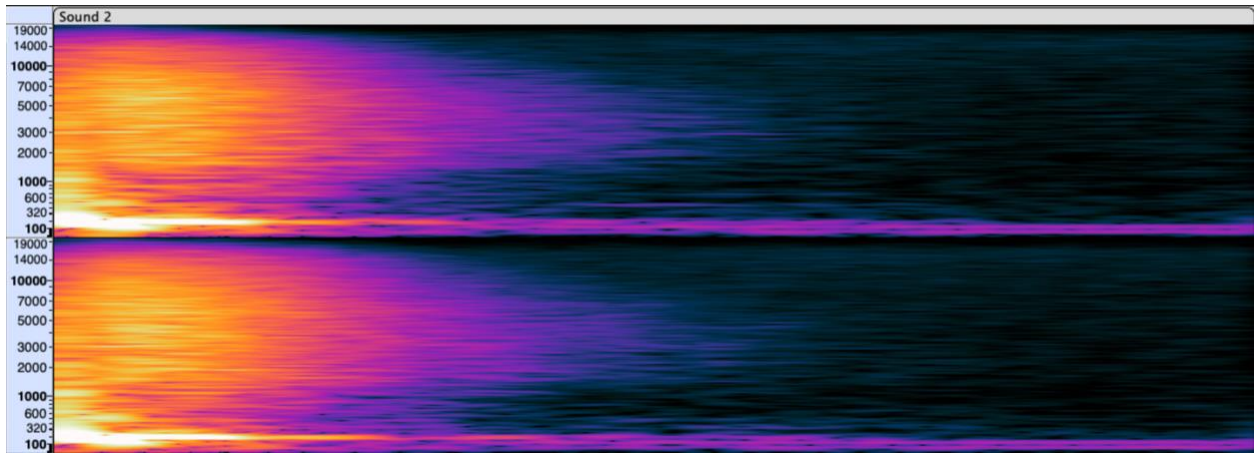
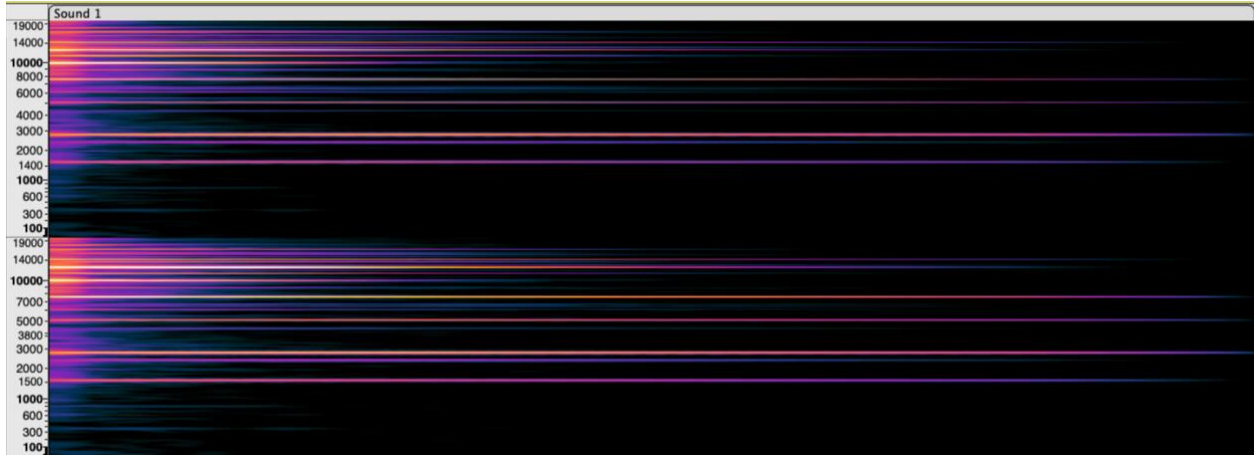


One aspect that might have played a factor was the length of the audio file of the tom versus the snare. The snare drum was a quick, punchy sound while the tom drum was a slightly longer sound that very slightly detunes very quickly. Normally, in a standard procedure for an experiment of this topic, every aspect of the samples would be controlled. In McAdams's study,

all of the parameters were controlled and standardized throughout the procedure. This includes loudness, duration, and number of times the participants are allowed to listen to the samples. For 9 of the 10 participants, I was not present when they were participating in the study, so I have no information or data on how many times they listened to each audio sample. For one of the participants, I was in their presence when they were listening to the audio samples, and they listened to each sample more than one time and went back to some of them after answering to presumably check their answers. In the future, this would very likely have to be restricted because that undoubtedly had an effect on their response.

I suspect that some other participants may have undergone the same process, with one participant reaching out to me for clarification, and once I gave clarification, they communicated that they changed their answers. This is very likely to have played at a major factor in the results of the study.

Other factors may have affected the results, such as time of day that the participants took the survey, whether or not there was music playing, and if they were preoccupied with something else at the same time. The participants could have also listened to the audio samples multiple times until they heard a pitch, which could account for higher rankings. Hence why in the future, I would like to conduct this study in a more controlled environment in person with the participants.



Once all of the data had been collected from participants, I inputted the audio files of the three tested instruments into the audio program Audacity, which has a feature that allows the user to see the frequency spectrograph. Unsurprisingly, the triangle showcases a very clear fundamental frequency, as well as clear overtones and harmonics above it. This directly correlates with the high rankings by the participants and justifies the use of the triangle as a control in this experiment. The spectrograms of the snare and tom demonstrate a positive correlation to my hypothesis that the pitch of the tom would be more easily perceived than the snare, but due to the high level of variability of the environments of the participants, this proved to not be the case.

Despite the invalidity of the results of this experiment, the spectrograms of these samples still provide evidence of the relationship of frequency and timbre. The spectrogram of the snare drum (Sound 2) is highly dense, showing that there are many frequencies clashing with each other, as well as the fact that there is a wide range of fundamental frequencies, shown by the bright white line between 200Hz and 300Hz. One essential structural factor of this range of frequencies is that snare drums have a set of wires on the bottom head. This creates the unique snare sound when the top head is struck and the wires on the bottom vibrate. This is what induces the wide range of frequencies that make the pitch of the overall instrument much less clear.

On the other hand, the spectrogram of the tom sample (Sound 3) shows a clear fundamental frequency around 100Hz, as well as less frequencies serving as overtones. Another factor unique to toms that affects the tone, and therefore timbre, of the instrument is whether the top drumhead is coated or clear. Clear drumheads result in a longer decay time and clearer sound than coated drumheads, which provide a slightly more muted tone and shorter decay time. In this

experiment, a tom with a clear top drumhead was used. In future experiments, this may be a factor that should be investigated.

Discussion

Conclusion and Future Improvements

Overall, this experiment proved to be a sufficient test of how timbre and pitch in percussive instruments should be examined and investigated, but extenuating circumstances that were not accounted for made it such that the results proved invalid and inconsistent. Multiple factors played a part in disrupting the experiment:

- (1) The environment of the experiment was not standardized, which allowed for much more variability in results. Factors such as preoccupation, distraction, and improper test-taking techniques due to lack of parameters played a significant part in this. In the future, this experiment should be carried out in person with the participants, so that parameters can more easily be put in place, and so that participants do not listen to the audio samples more than once.
- (2) In terms of the audio samples used, in the future, more instruments should be utilized and tested in order to account for a wider range of timbral qualities. Unique instruments such as bongos, cymbals, and other cultural percussion instruments may provide more evidence for the role of timbre in the perception of pitch in these types of instruments. In this experiment, only three instruments were used due to the amount of time allotted for data acquisition, which severely limited results and allowed for more variability in data collection. In studies such as Brent 2010, many more instruments were used, which resulted in much more diverse data points, as well as more predictable and reliable results

(I am aware that there are other circumstances and precautions taken that result in more reliable data, which must be taken into account in future iterations of this study).

(3) Restrictions on the tools that could be used to conduct this experiment may have played a factor in the lack of validity of results. Other more reputable researchers were able to utilize brain scans and algorithmic programs to analyze their results and achieve much more diverse data points. The multidimensional scaling system was a tool used in many previous studies that proved immensely helpful in achieving unique results. This is a valid idea to consider in subsequent iterations of this study.

Overall, this study proved helpful in introducing the current techniques of measuring timbre, and, despite skewed results, still provided useful information on the timbral attributes of percussive instruments.

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