MPATC-GE 2042: Psychology of Music

Pitch and Psychoacoustics
Empirical Research
Thompson, Chapter 3: Musical building blocks

• The auditory system
• Periodic sounds
• Connection between acoustic structure of sound and music (dissonance)
• Models of pitch perception
• Timbre perception
The nature of sound

- Sound is a pressure wave that originates from a vibrating object.
- This movement of air molecules emanates outward from the vibrating source and eventually collides with the eardrum (outer ear).
- Vibrations of the eardrum lead to movement of the basilar membrane, a resonant structure that resides within the cochlea of the inner ear.
- The purpose of the cochlea is to convert the vibration of sound into nerve impulses.
- Hair cells are sensory receptors found on the basilar membrane in the cochlea
  - Movement of these hair cells leads to electrical signals that are relayed from the auditory nerve to the auditory brain stem, and eventually the cortex.
Periodicity in sound

- When you pluck a string, it moves back and forth regularly—it’s a periodic movement resulting in a periodic sound wave.
- Periodic waveforms are perceived as pitched sounds.
- Most natural pitched sounds (e.g., like an violin sound) consist of not just the fundamental frequency (e.g. the 440 Hz for the A above middle C) but harmonics as well.
- The harmonic complexes usually consist of harmonic overtones of the fundamental frequency.
  - Overtones (or harmonic series) are integer multiples of the fundamental frequency
  - Example: the first several or overtones (or harmonics) of a fundamental frequency of 100 Hz are 200, 300, 400, 500 Hz
- Overtones can be of different strengths (amplitudes).
- Fourier analysis takes a waveform and produces a breakdown of a complex sound according to its partials (individual sine waves/frequency components) and how strong each of those components are.
The overtone series and musical harmony

- It’s been noted by many that the overtone series, in which the first several harmonic sound in octave, fifth, and major third relationships to the fundamental eerily correspond to important interval/harmonic relationships in Western music (octaves and fifths appear to be universal across cultures).

Images taken from Wikipedia article on the harmonic series, slightly modified. +/- indicates deviations in cents from equal temperament.
Sensory consonance and dissonance

• Dissonance is caused by partials that are too close to each other.
• When two sinusoids excite patterns of vibration along the basilar membrane in the cochlea, they interact if those frequencies are not separated by a distance greater than a critical band.
• Above A5 (880 Hz), the critical bandwidth is between between a major second and minor third in size.
• If the two frequencies are closer than the critical bandwidth, the basilar membrane has difficulty “resolving” those frequencies, resulting in “sensory interactions.”
• We hear this as dissonant intervals or timbral roughness
• (Note on tuning: J. S. Bach didn’t actually use equal temperament).
Pitch perception

• The universal concept of pitch chroma: the octave equivalence of pitches.
• Changes in pitch chroma are always accompanied by changes in pitch height.
• However, in some cases direction (up or down) can be interpreted differently.
• Pitch hierarchies
  – In a tonal context: Krumhansl’s probe-tone work.
Absolute pitch

- Absolute pitch (also known as “perfect pitch”) is a uncommon ability.
- Nonetheless some forms of long-term memory for pitch level may be quite common.
- Traditional view: everyone is born with absolute pitch, but this ability typically disappears unless one receives musical training early in childhood (by age 6 or 7).
  - Those without musical training that reinforces absolute pitch shift to relative pitch.
Timbre

• Timbre is often described as the attribute that distinguishes sounds when they are otherwise identical in pitch, duration, and loudness.

• Timbre is dependent on the presence and amplitude of partials as well as how they change over time.

• The relative intensity of harmonics is an important factor that distinguishes musical instrument sounds.
  – For example clarinet sounds typically contain high-frequency harmonics sounded at relatively high amplitudes, resulting in a “bright” sounding tone.
  – Attack and sustain portions of a sound can be quite difference and are important for instrumental sounds.
Timbre continued

• Dimensions of timbre
  – Brightness appears important in almost all studies on timbre
    • This is defined by having a wide range of spectral energy (spectral centroid—which defines a “center of mass” or median for a spectrum—is a good predictor of the brightness of a sound).
  – The influence of onsets (attacks) and other temporal properties are important in some studies but not others, depending on the specific timbres and duration of sounds.

• Timbre is processed faster than pitch, which is dependent on the frequency.

• Although timbre and pitch are considered different dimensions of sound, some studies indicate there are interactions.
  – When subjects are asked to compare two tones, chords, or melodies, judgments are easier when timbre is the same.

• Timbre has an effect on auditory stream segregation.
Empirical research

• The following material is taken from lecture notes by David Huron
• You will read some of Huron’s work in the following weeks
Empirical knowledge

• Definition of “empirical”- knowledge gained through observation, experience, or experiment.

• At least three sources of knowledge can be identified:
  – (1) intuition (intuitive knowledge)
  – (2) deduction (deductive knowledge)
  – (3) observation (empirical knowledge)
Intuition

• In everyday life, the most important source of knowledge is *intuition*.

• Evolution has shaped many of our intuitions—most of which have been refined to save our lives. We become suspicious for reasons which elude us.

• Especially in matters related to music, the most important knowledge we have is probably intuitive knowledge. Without intuition, music would be impossible.
Deductive knowledge

• Deductive knowledge is also called rationality.
• Deductive knowledge arises from logical thought.
  – If all people are mortal, and Socrates is a person, then Socrates is mortal.
Empirical knowledge

• Empirical knowledge is knowledge gained through observation. Sometimes this definition is extended: Empirical knowledge is knowledge gained through observation, experience, or experiment.
  – We know that many birds are capable of flight because we see them fly.
  – I’ve observed that some musicians can always identify the names of pitches (“perfect pitch”) and others can’t.
Types of knowledge: Summary

• Intuitive, deductive and empirical forms of knowledge are all necessary for life.

• Each form of knowledge adds to the value of the others. That is, they are complementary forms of knowledge.

• In addition, each form of knowledge also has limitations.
Grandma’s intuition

• A common complaint about empirical research is that it demonstrates “what we already know.” ... “Your research doesn't tell us anything new. My grandmother could have told you that!”

• It’s true: perhaps 95% of research projects merely confirm people’s pre-existing intuitions. So why bother going through all the expense and effort of engaging in empirical research?

• Suppose for the moment that your grandmother really did have excellent intuitions. We design an experiment, and then instead of actually running the experiment, we visit grandma and ask her what she thinks will happen. In 95% of cases, she gets it right.

• As you might suppose, the problem is not that our intuitions are mostly right. The problem lies in the small percentage (say 5%) of our intuitions which are wrong. In some cases, our intuitions are truly misguided. The only way we can discover which intuitions are wrong is by carrying out the empirical research.

• Unfortunately, there is a price to pay for doing the research—and not just the cost of the research itself. We must also realize that 95% of our work might seem unnecessary to others.

• In doing empirical music research, be prepared for the fact that many musicians will regard your efforts as naive and useless. The longer you engage in research, however, the greater the likelihood that you will move beyond commonplace intuitions and assemble a story that people will find surprising, informative and useful.
Group Task: Audience with God

• You have been granted an audience with God. Your group will be allowed to ask Him three questions related to music.

• What questions would you ask? Discuss the possibilities in your group and settle on three questions. Write the questions down. Assign a different group member to present each question to the class. Introduce each question with a short preamble that sets the stage for your question.

• N.B. You are not allowed to ask “meta-questions” (such as “What is a good question about music?”)
Rationale

• Ideally, research should focus on questions of the highest importance. The conscientious researcher always tries to answer the most important questions first.

• Unfortunately, the most important questions cannot always be answered given our limited resources and limited understanding. Instead, we tend to focus on answering questions for which we have the skills and resources to answer. By themselves, these questions are often not very interesting or compelling.

• The best research endeavors to connect good “top-down” questions with good “bottom-up” research resources. Empirical research methods can provide helpful resources for answering questions about music, but these methods should not dictate our research agendas. In learning how to do empirical research, it is equally important to learn to ask creative questions about music. The purpose of this task is to get you thinking about the larger issues.
Discussion: Deutsch et al., 2006

• Discussion leaders: Tommy Peh and Jake Sandakly
Reading question: Method

• In the experiment conducted, “all intervals between successively presented notes were larger than one octave” in attempt to “minimize the use of relative pitch as a cue” (Deutsch, D., Henthorn, T., Marvin, E., & Xu, H. 720). Do you believe that this method was truly effective in preventing the use of relative pitch, or do you think that there are some musicians who, while they do not possess absolute pitch, possess a strong enough sense relative pitch to quickly identify even very large intervals between two tones? Is it also possible that a subject may have been able to identify the presented notes in relation to a specific internalized note which they have memorized? (Tyler)
The study sub-categorized the test subjects from each school by the age they began their *general* musical studies, but made no mention of specific instruments. For example, piano has fixed pitch when you press a key (as do wind instruments to an extent), however string instruments and the human voice have a more ambiguous and non-defined surface to produce pitches. Is it plausible that the instruments the students learned could have an effect on the development of tonal recognition? If it is plausible, could the fixed key instrumentalists be at an advantage or disadvantage to the development of tonal recognition when compared with the string instrumentalists and vocalists? (Shannon)
Reading question: AP for quarter tones?

• The results of the study indicate that more people are considered to have perfect pitch when they are granted a window of one semitone in identifying pitch. As someone without perfect pitch, I had assumed that those with it are "perfect" instantly able to hear a sound and gather its frequency on the nose, but these results seem to indicate that there is a range of skill level. Some are good enough to get really close. What accounts for this difference? What is the smallest range with which a person can identify a pitch? For example, can some even predict a pitch at the quarter tone level? (Willie)
Reading question: Subjects

• Why was the pool of musicians bigger at ESM than at CCOM? (Rebekah)
• 1. How was the 85% correct response criteria decided for this study? Would using a lower percentage threshold provide insight into differences in tone language v. nontone language speakers who don't have conservatory level music training?

   For a simple two answer choice, a chance level for correct answers would be 50%. Similarly, chance level for a 12 note chromatic scale would be 1/12 (8.33%). It seems like it is reasonable to assume that participants could have answered significantly above chance level but still not hit the 85% cutoff used in this study. What is the reasoning behind 85%? Why not 80%; why not 90%?

   Using a high cutoff of 85% does make sense when testing conservatory students, because they have so much exposure to the pitch stimuli presented. However, using a threshold lower than 85% would allow the researchers to investigate non-conservatory musicians as well! Since they are interested in how tone languages influence absolute pitch perception, there still could be significant differences between the two language groups without high level musical training in a conservatory setting if they use a lower cutoff. Doing this might provide interesting results supporting differences in tonal/nontonal languages overall, not just in highly trained musicians. (Henry)
Reading question

• How do the results of this experiment influence our understanding of the debate between whether or not musical ability is innate vs. learned? Should we lean more towards the belief that at least the tonal aspects of music are learned as a result of these findings? (Max)
In this study of absolute pitch, the authors explain that, "Vietnamese and Mandarin, exhibited a remarkably precise and stable form of absolute pitch in reciting lists of words. Given these findings, it was conjectured that absolute pitch evolved as a feature of speech, analogous to other features such as vowel quality" Could this also mean that the pitched aspects of music (melody and harmony) share the same origins as language? Do you believe that, while rhythm seems innate to human (as found through the experiments with beat perception that we have previously read) melody and harmony could be an adaptation of both language contour and social interactions? (Julian T.)
In this study the authors state that "it may alternatively be proposed that the differences between the two groups obtained in the present study were due to genetic factors". If this assumption was right, what results do you think we would get if we ran a similar experiment, trying to determine if the individuals possess or could develop absolute pitch, with non musically trained people? What could the experiment consist on? Apart from language, in what way could culture and the educational models be affecting the development of absolute pitch? (Julian T.)
Reading question: Training for AP?

- If there is a similar time frame for developing absolute pitch between nontone language and tone language speakers, is it possible to develop techniques or methods in perceptual or language training to increase the prevalence of absolute pitch for nontone language speakers? (Eugenio)
Reading questions: Timbre

• Would the results of the experiment in the Deutsch lab report be different if they used different instruments to convey the pitch. For example, if they used violins for C4 and Bassoons for F#3, etc.

• Why do different timbres take more/less time to register in the ear? (Jess)
Deutsch, D., Henthorn, T., Marvin, E., & Xu, H clearly demonstrate that speakers of two tone languages – such as Vietnamese and specifically Mandarin – exhibit higher percentages of perfect pitch than English speakers among trained musicians. Considering this observation, would English speakers with perfect pitch have an easier time learning to speak Mandarin or Vietnamese? And if so, how much more quickly would an English speaker with perfect be able to learn two tone languages versus an English speaker with relative pitch? (Johnny)
The article mentions that students who are of Asian descent, but were either born in America or had one or more parents that spoke English in the home, were excluded from the testing data. If they were omitted for the sake of control, that is understandable, however these students could play a part in further examining the extent of the role that language plays in development. Is there a way to set up an experiment that could yield clear results in the developmental process of Asian-American and bilingual students? What might be a limiting factor in the tonal recognition developmental process of these students, as opposed to those who either had no tonal language spoken in the home or those who only had a tonal language spoken in the home? (Shannon)
• Among music students who have absolute pitch, is there a significant difference between Chinese and American students in their ability to successfully determine pitches when accounting for pitch duration and overall difficulty within the test? (Julian C.)
Reading question: AP vs. non-AP errors

- 2. **Was there a difference in the type of incorrect answer made between the two language groups?**

The results and discussion only highlighted differences in *correct answer rates*. I'd be very interested to see how the two language groups differed in *incorrect answer type*.

My hunch would be that incorrect answers for the tone language group would reflect absolute pitch processing (incorrect answers are close to the right pitch in terms of absolute pitch: guessing D when correct answer is C).

Conversely, incorrect answers for the nontone language group may reflect relative pitch processing (incorrect answers are related to the right pitch in terms of relative pitch: guessing G when the correct answer is C).

It is possible that if tone isn't an important factor in a language, relative pitch may be more relied upon when guessing individual pitches. Since G is closely related to C in relative terms (perfect 5th) it is possible that this error could be more common for nontone language speakers, even though they are pretty separated in terms of absolute pitch. (Henry)