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 itspartials (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 bypartials that are too close to each other.
- When two sinusoids excitepatterns of vibration along the basilar membrane in the cochlea, they interact if those frequencies are not separated by a distance greater than acritical band.
- Above A5 (880 Hz), the critical bandwidth 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 different 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 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 will 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.
Empirical research: Types of studies

• Many of the things music scholars do is empirical: deciphering manuscripts, studying a score, and listening to a performance. That is, much music scholarship is empirical.

• A distinction can be made between *formal* and *informal* observation.

• What makes something Empirical Research is that the observations are planned in advance.

• At least seven types of empirical studies can be distinguished: (1) exploratory study, (2) descriptive study, (3) correlational study, (4) pilot study, (5) experimental study, (6) meta-study, and (7) modeling study.
Types of studies:  
1. Exploratory study

- An exploratory study is intended to help the researcher gain familiarity with a new field or phenomenon. When Charles Darwin sailed on the Beagle in 1831-6, the purpose was exploratory. The goal was to see what plants and animals existed in different parts of the world.
- An ethnomusicologist might go to the island of Yap, simply to expose him/herself to the culture and music. A historical musicologist might poke around in a dusty archive, simply to see what is there. A music psychologist might attach a heart-rate monitor to a listener, simply to see if the music has any measurable effect.
- Exploratory studies are not hypothesis-driven. They are common when a researcher enters a new field or encounters a new phenomenon.
- The principal purpose of the exploratory study is to alert the researcher to new possibilities.
- It is usually difficult to get exploratory studies published although this sometimes occurs in the field of ethnomusicology.
Types of studies:
2. Descriptive study

• Like the exploratory study, the descriptive study is not hypothesis-driven.

• It differs from the exploratory study in that usually some measurements are made.

• When an anthropologist discovers the skull of a long dead human ancestor, the first order of business is to describe the skull. This typically involves reporting a series of detailed measurements.

• Publishing a detailed description is useful, even if the anthropologist has no theory or hypothesis to test.
Types of studies:  
3. Correlational study

- A correlational study is hypothesis-driven.
- It involves collecting at least two different sets of measurements, and determining whether there is any relationship between the two sets.
- Note that it cannot identify causation.
- A common type of correlational study is the survey.
Types of studies:  
4. Pilot study

• A pilot study is a form of experimental study (next category).

• It is carried out simply as a way of testing the experimental procedure.

• The goal is to determine whether the full-fledged experiment is feasible.

• The difference between a pilot study and an experimental study is typically the number of participants.
Types of studies:
5. Experimental study

• Measure. Hypothesis-driven.
• Can say something about causation. Dependent and independent variables.
• Manipulate independent variables, observe dependent variables.
• Of all the different kinds of empirical studies, the experimental study is the most highly regarded by researchers. There is a reason for this: the experimental study is the only type of study that allows the research to say something about causation.
• “No causation without manipulation.”
Types of studies:
6. Meta study

- A meta-study is a “study of studies.”
- It is typically done when a large number of studies have been carried out related to some problem.
- For example, many studies have been carried out related to whether television violence promotes violent behavior in viewers.
- Some of the studies seem to show a link, whereas other studies seem to show no link.
- In a meta-analysis, the researchers identify all of the pertinent studies. They then evaluate the quality of each study, including the quality of the samples used, the number of participants, the quality of the stimuli, the extensiveness of the controls, and other factors.
- Poor studies are simply discarded if they fail to achieve the minimum quality criteria established by the researchers.
- Then the researchers combine together all of the good studies, and do a statistical analysis on the aggregate data. The aim is to see if all of the studies ultimately tell a coherent story.
Types of studies: 
7. Modeling study

• Theories can often be implemented as models.
• An example of a physical model is a large model of San Francisco Bay built by the U.S. Army corps of Engineers. The actual bay is 100 km long.
• The model is 1 km in length so the scale is 1 meter = 100 meters.
• Models are useful for testing hypotheses that are impossible (or unethical) to test in reality.
• For example, how long will it take an oil spill in Oakland to reach the mouth of the Sacramento River?
• More commonly, models are rendered as computer programs.
Empirical research: Six big ideas

1. We never prove anything

- Only logicians and mathematicians can talk about “proof.” Any set of observations can be interpreted in more than one way.

- Conclusions should be expressed as follows:
  - The results *are consistent* with the view that …
  - The observations *indicate* that the theory …

- Avoid words like “establish,” “confirm,” or “prove.” Use words like “suggest” or “imply.”
  - Our study *suggests* that …
  - The results from our experiment *imply* that …

- Just because we can’t prove anything doesn’t mean we aren’t interested in truth. In fact, the pursuit of truth is one of the main motivations for people who engage in research.

- Our slogan reminds us of the motivation, and simultaneously tells us that the truth is not accessible to us:

  - **Slogan:** *Motivated by truth, with no hope of proof.*
Empirical research: Six big ideas

2. Research invites failure

• Suppose you were trying to convince someone that your idea is right. Which of the following strategies provides a more compelling argument?
  – Identify lots of existing evidence that fits with your theory.
  – Identify lots of the ways in which your theory might be wrong—and show that your theory survives all of these challenges.
• Any set of observations is consistent with innumerable theories. So showing that the evidence is consistent with your theory doesn’t make the most compelling argument.
• In formal empiricism, researchers follow the second rhetorical strategy: Instead of trying to “prove” your theory, try to make your theory fail. Your audience will be more impressed.
• It’s not research if you don’t allow failure. Good research seeks opportunities to refute your own ideas.
• Good research does not involve collecting evidence that supports an idea. Instead, good research involves collecting evidence that tests an idea.
• Research is often motivated by our intuitions, hopes, and (sometimes) secret beliefs. Without these motivations, we wouldn’t have the energy to do all the work involved in research.
• Even if you have no ulterior motive, other researchers may think that you have an ulterior motive. You will convince your most skeptical critic by persistently testing your own ideas.
• **Slogan:** It’s not research if you don’t invite failure.
Empirical research: Six big ideas
3. Make a prediction

• What is a test? If a theory is good, then you should be able to make a prediction about the future.

• An empirical test is a prediction. You predict what as-yet unobserved data should look like.
  – Biblical Adage: You can recognize a false prophet by his/her false prophecies.
  – Empirical Test: You can recognize a false theory by its false predictions.

• Slogan: We invite failure by making predictions.
  (We invite failure by testing hypotheses)
Empirical research: Six big ideas

4. Refutation is easier than confirmation

• The statement “All swans are white” can never be confirmed because you could never be sure that you have observed all swans (David Hume, 18th century).

• However, the statement “All swans are white” can fail by observing a single nonwhite swan. Refutation is easier than confirmation (Karl Popper, 1934).

• The essence of modern science: Tempt failure by trying to show that a set of observations is not consistent with your hypothesis. If this test fails, then you can say that “the observations are consistent with the hypothesis.”

• Aim not to be right, but to be not wrong. Or, expressed as our slogan:

Slogan: Aim not to be right, but to be not not right.
Empirical research: Six big ideas

5. Abstractions can be tested only by making them concrete

• If an abstract idea correctly describes the world, then we should see evidence of the idea in the concrete organization of the world.

• While theories are abstract ideas, theories can be tested only by making predictions that have observable consequences.

• Predicting things that can’t be observed won’t allow you to test your theory. In order to test an idea, we need to predict things that can be observed.

• Transforming abstract ideas into concrete observations is called operationalizing.

• **Slogan:** Test hypotheses by operationalizing terms.
Empirical research: Six big ideas

6. Compare actual observations with control observations

• Most people who catch a cold feel better in three or four days. Suppose you catch a cold and take a drug. You feel better in three or four days. Did the drug contribute to your recovery?
• If you always took this drug whenever you caught a cold, how would you ever know whether it was useful or useless?
• When making observations, ask yourself, “What would one normally see without this change or intervention?”
• In order to determine whether a drug helps you recover from a cold, you must compare the effect of taking the drug with what would happen if you didn’t take the drug.
• Each time you get a cold, count the number of days before you recover. Take the drug only every second illness. If the drug is effective for you, then it should, on average, shorten the duration of the colds when you took the drug compared with the colds when you didn’t take the drug. In this research, you will compare the results for the treatment condition against the control condition.
• We learn things only by comparison. All empirical research involves comparing two or more situations, measurements, or conditions.

Slogan: Compare, compare, compare.
Discussion: Deutsch et al., 2006

- Discussion leaders: Blake Allen and Kyle Tieman-Strauss
In this experiment, the researchers believe that the only difference between the students at CCOM and ESM is their native language. However, isn’t there any possibility that culture factor also influenced the results of this experiment? Since in some of the Asian cultures, parents often send their children to take various kinds of lessons to acquire skills that are usually left free to develop in western cultures. For example, some of my friends back in Taiwan not only learned how to play certain classical instruments but also took classes focus on training perfect pitch when they are little. (Natalie)

It's interesting, but understandably necessary for the experiment, that the ESM students from families that spoke an Asian languages had to be removed from the test group. However, could there have some insights to gain from considering this category of student as well? For example, what is the comparative effect on absolute pitch between simply speaking a tone language, and being immersed in a tone language-speaking society? (Jason S.)

Even though the authors included both Asian and American music students, wouldn’t a study of absolute pitch and speech offer more transferability and external validity if it were conducted on a more diverse subject group than music conservatory students? (John)
Reading questions: Subject background

- Considering the two student groups, I would like to know if certain variables that may or may not have to do with perfect pitch acquisition have been given consideration and controlled throughout the test? For example, do both student groups have the similar proportion of pianists, violinists, brass/wind players, percussionists, vocalists, etc.? Also, do both groups have a similar proportion of students who started off learning the fixed-do system versus the moveable-do system (which may affect the way brain matches pitches with solfege)? (Alison)

- Why were the authors concerned about instrumental background? As far as I know from my friends, people who learned piano as their first instrument are more likely to have perfect pitch than other instruments. (Vincent)

- There are some unanswered questions, or what appear leaps from evidence to conclusions, in the article by Deutsch et al that seem like they could be easily answered by other experiments. One major one is the possibility that ethnicity rather than exposure to tone language could be responsible for the development of absolute pitch. There must be enough people of Chinese, Vietnamese, etc. descent living abroad and raised with little exposure to tone languages by now to test the prevalence of absolute pitch in this population? (I see online that there are articles/experiments addressing this – including a couple by Deutsch) (Michael)
Along similar lines, there is a question – not raised in the article – of whether absolute pitch might be a result of a broader (i.e. not entirely linked to speech) early emphasis on pitch in development. Could a child raised without a tonal language but exposed to music a great deal, e.g. with musician parents who practice hours a day or encourage the child to sing music with them in set keys (say church hymns with piano accompaniment), or even in a (hypothetical?) environment where pitch detection is key to survival, develop perfect pitch at a rate similar to the Beijing conservatory students? (Michael)
Reading questions: Development

• Are all children who begin music study at a young age prone to better pitch memory? (Victoria)

• Could other musical attributes be enhanced or learned when certain characteristic languages are introduced during the critical learning period of child development? For example, could the introduction of some highly rhythmic language enhance a child's ability to dictate rhythm or meter changes. (Jacob)
Reading questions: Method

• As the described experiments employed an interval separation greater than the octave between stimuli for perfect pitch testing, and acknowledging that relative pitch ear training also targets open intervals, what other strategy could be taken to minimize relative pitch recognition between stimuli? (Jorge)

• In the methodology section, authors specified that the notes generated from an electronic piano were 500 ms in duration. Based on that, why didn’t they form different subgroups of note durations, since there is a huge difficulty difference between recognizing the pitch of a 1500 ms note and 20ms note? (Mert)
Reading questions: Language factors

• Does inflection in speech play a part in acquiring absolute pitch among those who don’t speak tone languages? (Sarah)

• The paper operates under the idea that tonal languages use pitch to convey different meanings of words, but don't non-tone languages employ a different, but equally important set of pitch differences and inflections to indicate meaning? E. G. When asking a question versus saying a statement, the pitch of many of the words in the question would rise up (like the contours of tones). Is this negligible compared to the pitch processing requirements of tonal languages? (Ned)
Reading questions: Genetic influence

- In the last paragraph of the discussion, the study suggested that absolute pitch may be genetic, does this seem persuasive while they did not provide evidence that absolute pitch can not be obtained through training? (Taihua)
Reading questions: Is AP universal?

• Meanwhile, do most of us actually still possess absolute pitch abilities without us knowing it? How is the skill for pitch labeling different from our "accurate long-term memories of pitch" (as the Levitin article suggests), what is missing from the latter compared to the former? (Chi)
Reading questions: Other musical proficiencies

• How do we measure musical proficiency among those with perfect pitch against those without? Is there truly a correlation? (Daniel)