

## HST 725 Music Perception & Cognition (spring, 2004)

Assignment #1, Due April 27, 2004.

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### 1. Harmonic series.

- What are the first 10 harmonics of a 200 Hz fundamental ( $F_0$ )?
- Which partials can be "heard out" or "resolved" as individual pitches?
- What would be the first 10 sub harmonics of 200 Hz?
- What would be the fundamental of 400, 500, 600 and 700 Hz?
- What are sub harmonics 1-10 of 400, 500, 600, and 700 Hz.
- Which sub harmonic(s) do the partials have in common?
- How is this related to the fundamental frequency?

### 2. Common harmonics

We will assume that each note consists of a harmonic complex of harmonics 1-12.

Let the lower note  $F_0 = 200$  Hz.

A musical interval of an octave in just tuning is a frequency ratio of  $2/1$ .

A musical interval of a fifth in just tuning is a frequency ratio of  $3/2$ .

A musical interval of a fourth in just tuning is a frequency ratio of  $4/3$ .

A musical interval of a major third in just tuning is a frequency ratio of  $5/4$ .

- What is the fundamental frequency of a note an octave above 200 Hz?  
How many harmonics do the two notes share?  
How many sub harmonics do the two notes share above 30 Hz? What are they?
- What is the fundamental frequency of a note a fifth above 200 Hz?  
How many harmonics do the two notes share?  
How many sub harmonics do the two notes share above 30 Hz? What are they?
- What is the fundamental frequency of a note a fourth above 200 Hz?  
How many harmonics do the two notes share?  
How many sub harmonics do the two notes share above 30 Hz? What are they?
- What is the fundamental frequency of a note a major third above 200 Hz?  
How many harmonics do the two notes share?  
How many sub harmonics do the two notes share above 30 Hz? What are they?
- Do you see any patterns emerging here?

### 3. Tuning systems

We have decided to devise a tuning system in which we divide the octave into 12 logarithmically spaced semitones (equally temperament tuning, chromatic scale). There are several ways of doing this. One is to take the twelfth root of 2. The first note in the scale is 1, the second note is  $2^{1/12}$ , the third  $2^{2/12}$ , the fourth  $2^{3/12}$  and so on up to the octave  $2^{12/12} = 2$ . These frequency ratios are multiplied by the frequency of the first note in the scale (the tonic). Frequency ratios can be expressed in cents. There are 1200 cents to the octave. A semitone is 100 cents, a perfect fifth is 800 cents, and a tritone is 600 cents.

A. If ( $F_0$ ) note A = 440 Hz, what are the frequencies of the other notes in the octave that spans 440 to 880 Hz? What are the frequencies in the octave below it?

B. How big is a semitone (one step in the scale) in terms of percent change in frequency? What percent change in frequency is 50 cents? 25 cents?

C. In percentage terms, how much does the equally tempered scale differ from just intonation for the fifth ( $3/2$ ), fourth ( $4/3$ )? You can calculate this out or consult the table in

Handel, p. 331. If the jnd for fundamental frequency is in the neighborhood of 0.2% under the best of conditions, do you expect this difference to be audible? Where is the greatest discrepancy between intervals based on just intonation and those based on equal temperament?

D. If one were to devise a tuning system that divided the octave into 10 logarithmically equal steps, what would the frequencies be for the octave that spans 440-880 Hz? How far would these notes diverge from those of just-intonation? William Sethares in his book *Tuning, Timbre, and Spectrum* discusses such a scale and has written musical compositions based on it.

#### 4. Major aspects of music

A. Which aspects of music depend (most directly) on perception of pitch? (Two or more examples)

B. Which aspects of music depend on perception of distinct events?

C. Which aspects of music depend on memory processes (musical contexts, kinds of expectations)?

#### 5. Pitch and the limits of musical tonality

A. Roughly, what is the range of pure tone frequencies that we can hear?

B. What is the range of pitch ( $f$ ,  $F_0$ ) frequencies for musical tonality (i.e. over which octaves, musical intervals, and melodies can be readily recognized).

C. What would constitute an explanation (neural or psychological) for why these ranges are different?

D. Provide a possible (neural or psychological) explanation for why we hear the missing fundamental. (Paragraph)

E. What does it mean to say that musical pitch is highly invariant with respect to tone intensity, location, and duration? What is metamery? What would be an example of pitch metamery?

#### 6. Timbres of musical instruments

A. What is the main functional role that timbre plays in most western tonal music?

B. What is the acoustic dimension that distinguishes timbres of stationary sounds?

C. What are two factors that distinguish timbres of non-stationary (time-varying) sounds?

Classes of instruments: 1. pipe organ (vibrating air column), 2. Violin (bowed string), 3. Piano (struck string), 4. Bells (struck, metal), 5. Snare drum (struck, membrane)

D. Which classes produce harmonic tones? Inharmonic tones?

E. Which classes can produce a melody? Rhythm?

#### 7. Scales and musical intervals

A. What is a scale?

B. What role do scales play in music perception?

C. What is the tonic? What functional role does the tonic play in perception of melody and harmony?

D. Why do melodies played in different modes have distinctive qualities, despite their use of the same set of notes?

#### 8. Consonance

- A. What defines a musical interval? Does an interval depend on the absolute (F0) frequency of its root?
- B. "Consonance" is associated with 1) euphony and tonal preference on one hand and 2) stability/instability and tension/resolution on the other. Dependence of consonance on musical context notwithstanding, which isolated intervals (octaves, seconds, fourths, fifths, sevenths) are perceived as more consonant? Octaves, fourths, fifths. more dissonant? Seconds, sevenths.
- C. Two rival theories of consonance were proposed by Helmholtz and Stumpf in the 19th century. What perceptual aspect of tone combinations does each rely on?
- D. Which aspect is thought to be the result of the beating of nearby harmonics? of waveform regularity and its consequences for pitch?

## 9. Harmony and harmonics

- A. What notes and musical intervals constitute a major triad chord (I) in the key of C (major)? What notes and musical intervals constitute a minor triad chord (I) in the key of C (minor)?
- B. Tonal hierarchy of notes. In the context of Krumhansl's probe-tone studies, we discussed tonal hierarchies based on 1) the tonic, 2) notes in I - triad, 3) other notes in the diatonic scale, and 4) other notes in the chromatic scale. Which notes would fall into these respective classes for the key of C major?

For simplicity assume that the tonic (F0) of a just-tuned diatonic scale is 200 Hz and the notes of the scale consist of harmonics 1-6 (consult Handel, p. 331 for just temperament F0 ratios, p. 364 for chord notes).

- C. What would be the fundamental frequencies (F0s) of the notes in the major triad (I) if the root is 200 Hz?
- D. What harmonics would be present? How many pairs of common harmonics (overlaps) are there?
- E. What would be the fundamentals of the notes in the minor triad (I)? How many harmonic overlaps would there be?

In major keys, chords of scale degrees I, IV, and V have major interval patterns (Major 3rd + Minor 3rd), while other scale degrees II, III, VI, VII have minor interval patterns (Minor 3rd + Major 3rd). If chord stability, consonance, and pitch unity were determined solely by the proportion of coincident harmonics, would you expect the major or minor triad pattern to be more stable? Why?

If chord stability were determined by the strength of the fundamental bass, which in turn were determined by the number of coincident sub harmonics, which pattern would be more stable?

## 10. Chord progressions

- A. What is a chord progression?
- B. In musical contexts, chord stability is also influenced by its relation to the tonic. If degree of relatedness between a chord (II-VII) and the tonic chord (I) of the key (Krumhansl et al, 1982, Handel, p. 365) determines the perceptual "stability" of that chord, then what pattern of movement would be expected for a I-IV-VII-I progression? Assume that movement from a less stable chord to a more stable one is "resolution" (R), while the opposite movement builds "tension" (T), e.g., a I-IV-II-V-I produces a pattern of movement of T-T-R-R, see Handel, p. 341).
- C. What is key modulation?
- D. Why might perceived relatedness of chords depend on key context? (Handel, p. 373)

## 12. Melody

- A. What is a melody?
- B. What does it mean to say that melody is invariant under transposition?
- C. What distinguishes a tonal from an atonal melody (see Handel, pp. 355-361)?
- D. Which is more important for melody recognition in tonal contexts: absolute pitch, pitch contour sequences of musical intervals, relations of notes to the tonic?
- E. What are the shortest notes that can support a good melody (ballpark)? the longest notes?

## 13. Rhythm

- A. Define tempo, accent, beat, meter, and rhythm.
- B. How does rhythm differ from melody? How are these two aspects of music similar? How are they different?
- C. Why is accent important for perception of rhythmic pattern?
- D. If tempo is set at 1 quarter note = 1 beat at 120 bpm, how long in absolute terms is a quarter note? a 16th note?
- E. How do the note durations needed to support a good melody relate to those needed for a good rhythm?

## 14. Organization of voices (auditory scene analysis)

- A. What acoustical factors influence whether two instruments will be perceptually fused (heard as one voice)?
- B. What distinguishes a homophonic from a polyphonic piece of music? What musical factors (melody, harmony, rhythm) influence whether a musical piece is (perceived as) one or the other?

15. In your opinion, which aspects of music perception and cognition are likely to depend on bottom-up mechanisms of auditory perception? Which aspects are likely to depend on prior auditory experience that is not culture specific? Which are likely to depend on culture-specific auditory experiences, i.e. cultural conditioning? (Paragraph)