21M.380 · Music and Technology
Recording Techniques & Audio Production

Sound quality & critical listening

Session 22 · Wednesday, November 23, 2016

# 1 Student presentations (pa1)

- [redacted]
- [redacted]

# 2 Announcement: Schlepping reminder

- Please remember if you are signed up for pre- or post-class schlepping for either recording session on Mon, 11/28, Wed, 11/30.
- Pre-class schlepping: Meet at room [redacted], 10 minutes before class

# 3 Digital sound quality

## 3.1 Sample rate

- Higher sample rate: higher frequencies can be accurately reproduced
- Remember sampling theorem: $f_S \overset{!}{>} 2 \cdot f_{max}$
- But since upper range of hearing is 20 kHz, what justifies $f_S = 192$ kHz?
- Practical engineering reason: Reconstruction filter design (filter slope)!
- Many also argue in favor of a real *perceptual* difference (cf., Schoepe 2006, p. 67, Katz 2014a, p. 25)
- Montgomery (2012) argues that even so, "192 kHz digital music files offer no benefits" since transducers and power amplifiers are not designed to be distortion-free in the ultrasonic range.
- Katz (2014b) also discusses subject in depth
- Also: Sound fidelity as a social & cultural product (Sterne 2003)

## 3.2 Bit depth

- No hard limit comparable to sampling theorem
- Higher bit depth $N$: larger dynamic range $\Delta L \approx 6 \cdot N$ (cf., table 1)
- Compare to dynamic range of human ear ($\approx 130$ dB)

Table 1. Dynamic range $\Delta L$ for different bit depths $N$

| $N$ | $\Delta L$/dB |
|---|---|
| 8 | 48 |
| 16 | 96 |
| 24 | 144 |

- For bit depths > 24, other rationales apply (DSP round-off errors etc.)
- But what if music itself exhibits a much smaller dynamic range?
- Sound examples: Can you hear the difference between 8 bit & 16 bit?

# 4 Ear training

- Represents limiting factor more often than gear (Senior 2011, p. 2)
- Ladies and gentlemen, meet the human ear!
  - Detects pressure changes of a billionth of atmospheric pressure
  - Handles sound pressures 10 000 000 000 000 times larger than that
  - Covers a range of 9–10 octaves
  - Is an excellent learner!
- Integrate ear training into everyday music listening (Katz 2014a, pp. 25 f.)
- Ear training exercises specifically for sound engineers:
  - Katz (2014a, pp. 27 ff.)
  - Corey (2010)

## 4.1 Rhythm, melody, harmony

Figure 1. "Transcribe both parts" (key and first note for both staves given). Example from an entry exam for the *Tonmeister* program at the Vienna University of Music.

- Ear training as part of a traditional music education (e.g., 21M.051)
- Examples of typical exercises:
  - Meter identification (e.g., $\frac{3}{4}$ vs. $\frac{6}{8}$)
  - Rhythm transcription
  - Interval recognition (song mnemonics)
  - Triad identification (M, m, A, or d? Root position or inversion?)
  - Scale recognition (M or m? Natural, harmonic, or melodic minor?)
  - Melody transcription (monophonic or polyphonic)
  - Cadence identification (Authentic, plagal, deceptive, or half?)
- Open source software package (Mac, Win, Linux): GNU Solfege

- Excellent hardware tool: your voice!
  - Freely available, cross-platform, open source ☺
  - Rule of 👍: If you can sing it, you can hear it.

## 4.2 Learning to distinguish different frequency ranges[1]

[1] Cf., Katz 2014a, p. 27.

- Popular exercise:
  - 10 bandpass-filtered noise bands at different center frequencies
  - Bandpass center frequencies given
  - Put center frequencies in order in which examples were played
- Available as online listening test series by Pigeon (2007–2014)
- Also: *Golden Ears* series of training CDs (Moulton 1995)

## 4.3 Recognizing bandwidth limiting[2]

[2] Cf., Katz 2014a, pp. 28 f.

Sound examples in SoX:

```
$ play test.wav rate 44.1k ⏎
$ play test.wav rate 22.05k ⏎
$ play test.wav rate 16k ⏎
$ play test.wav rate 8k ⏎
```

## 4.4 Identifying musical instruments[3]

[3] Cf., Katz 2014a, p. 35.

- Upright vs. electric bass
- Soprano vs. alto vs. tenor vs. baritone saxophone
- Curved vs. straight soprano sax
- Trumpet vs. flugelhorn
- Oboe vs. bassoon vs. English horn
- String quartet: first vs. second violin
- Piano: beating strings on same key

## 4.5 Distinguishing sampled from 'real' pianos[4]

[4] Cf., Katz 2014a, p. 30.

- Sound example: Same tune played by 2 different pianos
- Which is sampled, which is 'real'?

[5] Cf., Katz 2014a, pp. 30 f.

## 4.6 Identifying tiny differences[5]

> Make a test master with 0.5 dB difference in equalization of one band. Can you hear the difference in a blind test? (Katz 2014a, p. 30)

- Implemented as SoX example:

```
$ play test.wav equalizer 4k 0.5o +18 ↵
$ play test.wav equalizer 4k 0.5o +18.5 ↵
```

- Get to know (and improve) your JND for various sound parameters
- Online exercises by Pigeon (2007–2014)

## 4.7 Is it actually stereo?[6]

[6] Cf., Katz 2014a, pp. 30 f.

- Try to judge this solely by ear!
- Confirm your judgement with the help of:
  1. Level meter
  2. Visual waveform inspection (at high zoom levels)
  3. Phase correlation meter
  4. Mix L with phase-inverted R. If result is silence, it was mono!

## 4.8 Identifying lossy encoder artifacts[7]

[7] Cf., Katz 2014a, pp. 31 f.

- Sound example: MP3 file re-encoded 0, 5, 20 & 50 times
- Many more examples can be found on YouTube ☺

## 4.9 Identifying other artifacts[8]

[8] Cf., Katz 2014a, pp. 27 ff., 35 f.

- Comb filtering (interference between reflections and direct sound)
- Phasing & flanging (comb filtering that varies over time)
- Proximity effect (bass boost for directional microphones close to source)
- Different flavors of overload (e.g., tube saturation vs. digital clipping)
- Clicks due to rapid amplitude changes (e.g., bad splices)
- Pops due to DC offset
- Dropouts (digital vs. analog; best checked on headphones)
- Bad edits (inconsistent reverberation; obvious cuts, splices, or cross-fades; etc.)
- Polarity problems (e.g., out-of-phase stereo speaker pair)
- ‘Pumping’ or ‘breathing’ compressors

- Stereo center shift
- Unstable phantom source localization
- Hum frequencies (60 Hz in US, 50 Hz in EU)
- Wow and flutter (tape speed irregularities)

# 5 Listening beyond the ears

- Video: Demonstration of the *McGurk effect* (BBC 2017)
- Factors beyond the auditory system which affect auditory perception:
  - Visual perception (Katz 2014a, p. 34)
  - Habituation (Katz 2014a, p. 31)
  - Focus (Katz 2014a, p. 32)
  - Peer pressure (Katz 2014a, p. 34)
  - Psychology (expectations) (Katz 2014a, pp. 30 f.)
- Anecdote: The Vienna high-end audio store
- Importance of systematic, unbiased listening test methodologies

# 6 Subjective listening tests

- Listening test terminology
  - Objective tests (models) vs. subjective tests (human subjects)
  - Blind tests & double-blind tests (subject and tester blinded)
  - Preference vs. discrimination (or equality) tests
- Software tool `squishyball`
  - Open-source command-line tool by 'Monty' Montgomery (`xiph.org`)
  - Implements basic subjective listening test methodologies
  - On Debian-based Linux systems (e.g., Ubuntu):
    `sudo apt-get install squishyball`

## 6.1 Casual comparison

- Mixing requires frequent and rapid decision making
- Good idea to establish a method to efficiently *compare* different versions
- Squishyball demo:

```
$ squishyball --casual A.wav B.wav C.wav D.wav [...] ↵
```

  - Use 1, 2, 3, or ↑, ↓ keys to switch between samples
  - Samples are presented in specified order (no randomization)
  - Single trial without selection

## 6.2 (AB) or XY: Paired comparison

Table 2. Listening test notation

| | |
|---|---|
| A, B | knowns |
| X, Y | unknowns |
| (AB) | order unknown (AB or BA) |
| Hence, (AB) = XY | |

- More informative than casual comparison: Ask a specific question
- (AB) or XY test: Which of 2 samples is preferred in terms of _?
  - Samples are *known* to be different (not an equality test)
  - Need to know in advance the attribute likely to change ☹
- Squishyball demo:

```
$ squishyball -n 5 --ab A.wav B.wav ↵
```

  - `-n` ... number of trials (defaults to 20)
  - a, b: switch between samples
  - A, B: select preferred sample and move on to next trial
  - Presentation order re-randomized for each trial

## 6.3 ABX test

- Rule of 👍 in mixing: If you can't *hear* an edit, don't do it.
- So question becomes: Perceptible difference between 2 samples?
- Problem: How to reliably determine whether there is?
  - Answer: Through an *equality test*
  - Different methodologies exist: ABX, AXY, (AB)X, (XXY)
- Simplest is ABX test (Munson and Gardner 1950)
  - Widely used in testing audio data compression algorithms
  - Flaw: Sample order bias (test always starts with AB) ☹
  - Method: Is X identical to A or identical to B?
- Squishyball demo:

```
$ squishyball -n 5 --abx A.wav B.wav ↵
```

  - `-n` ... number of trials (defaults to 20)
  - a, b, x: switch between ABX
  - A, B: select sample that *X* matches and move on to next trial
  - Presentation order re-randomized for each trial

## 6.4 (AB)X: Duo-trio test with constant reference

- Objective: Perceptible difference between 2 samples?
- Method: Is X identical to 1 or identical to 2?
- Partly eliminates sample order bias (can be ABX or BAX) ☺
- But not entirely (since X is always last) ☹
- Not implemented in `squishyball`

### 6.5 (XXY): Triangle test

- Objective: Perceptible difference between 2 samples?
- Method: Which of 3 samples is the odd one out?
- Eliminates sample order bias ☺
- Squishyball demo:

```
$ squishyball -n 5 --xxy A.wav B.wav ↵
```

  - `-n` … number of trials (defaults to 20)
  - [1], [2], [3]: switch between (XXY)
  - Mark odd one out and move on to next trial:
    [⇧]+[1] = [!] for $Y = 1$
    [⇧]+[2] = [@] for $Y = 2$
    [⇧]+[3] = [#] for $Y = 3$
  - Identities ($A = Y$ vs. $B = Y$) and order re-randomized per trial

# 7 Caring for your ears

- Arguably the sound engineer's most important tool
- A 'piece of equipment' that no money in the world can replace!
- Ear training also means learning when and how to protect your ears.

### 7.1 Hearing disorders

- Stapedius reflex: ear's (very limited!) built-in protection mechanism
- Hearing loss due to age (review: ≈ 1 kHz per life decade)
- Noise-induced hearing loss: *irreversible* damage to inner ear hair cells
- Tinnitus: Hearing sound when no external sound is present
  - Often described as ringing, whistling, buzzing, roaring, etc.
  - Various causes: Noise-induced hearing loss, ear infections, brain tumors, emotional stress, certain drugs, etc.
  - Objective vs. subjective tinnitus
  - Intermittent tinnitus (for a few seconds) is a common occurence
  - Continuous tinnitus requires *early* treatment before it becomes chronic!

### 7.2 Hearing protection

- Consider getting custom-moulded earplugs (ca. $100)
  - Option №1: Non-neutral frequency response, but high attenuation
  - Option №2: Neutral frequency response, but lower net attenuation
- Avoid long-term exposure to high sound pressure levels.
- Avoid loud impulses close to your ears (e.g., firecrackers).
- Don't mix at too high sound pressure levels.
  - Studio monitor calibration procedure recommended by Katz (2014c, pp. 263 f.)
  - Pink noise at 0 dB monitor control should yield 83 $dB_{SPL}$ (C-weighted, slow meter response) at sweet spot
- Be particularly careful when programming audio (e.g., Pd).
- Be particularly careful with headphones.
- Take breaks.

## References & further reading

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