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# Music Perception and Cognition

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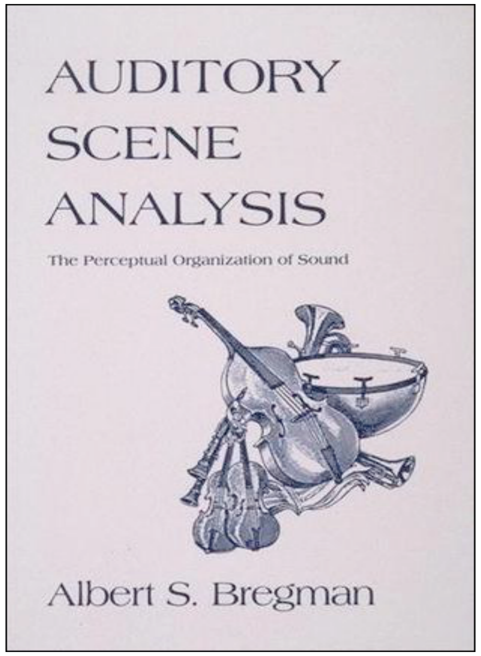
Imagine that you are on the edge of a lake and a friend challenges you to play a game. Your friend digs two narrow channels up from the side of the lake [...] Halfway up each one, your friend stretches a handkerchief and fastens it to the side of the channel. As waves reach the side of the lake, they travel up the channels and cause the two handkerchiefs to go into motion. You are allowed to look only at the handkerchiefs and from their motion to answer a series of questions: How many boats are there on the lake and where are they? Which is the most powerful one? Which is closer? Is the wind blowing? Has any large object been dropped suddenly into the lake? Solving this problem seems impossible, but it is a strict analogy to the problem faced by our auditory systems.



# Music Perception & Cognition

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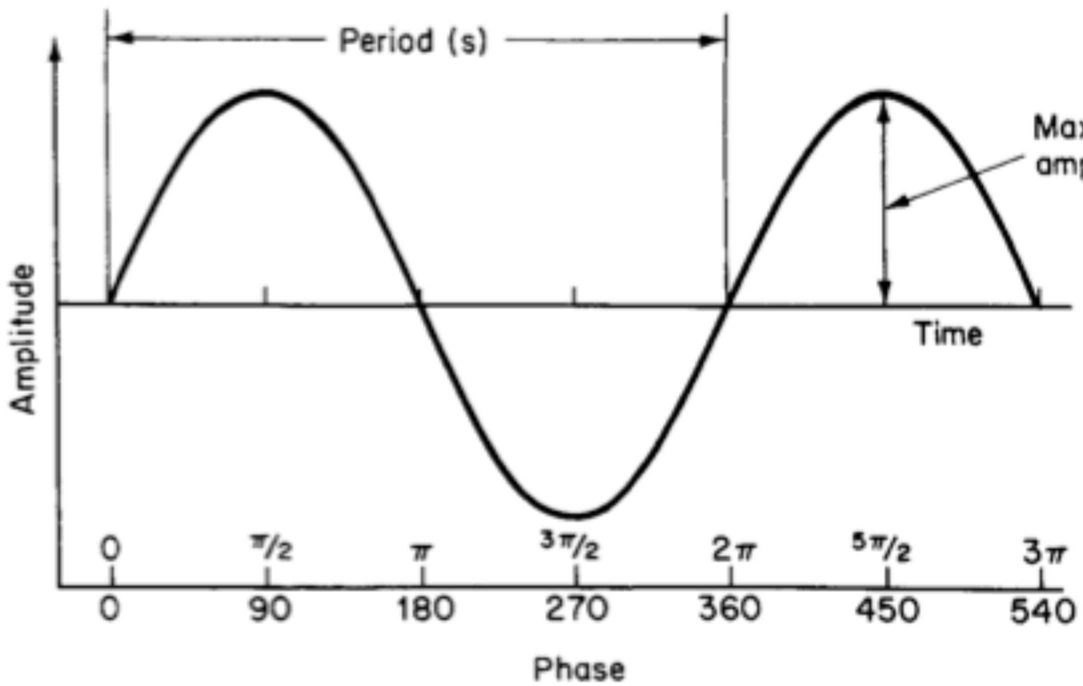
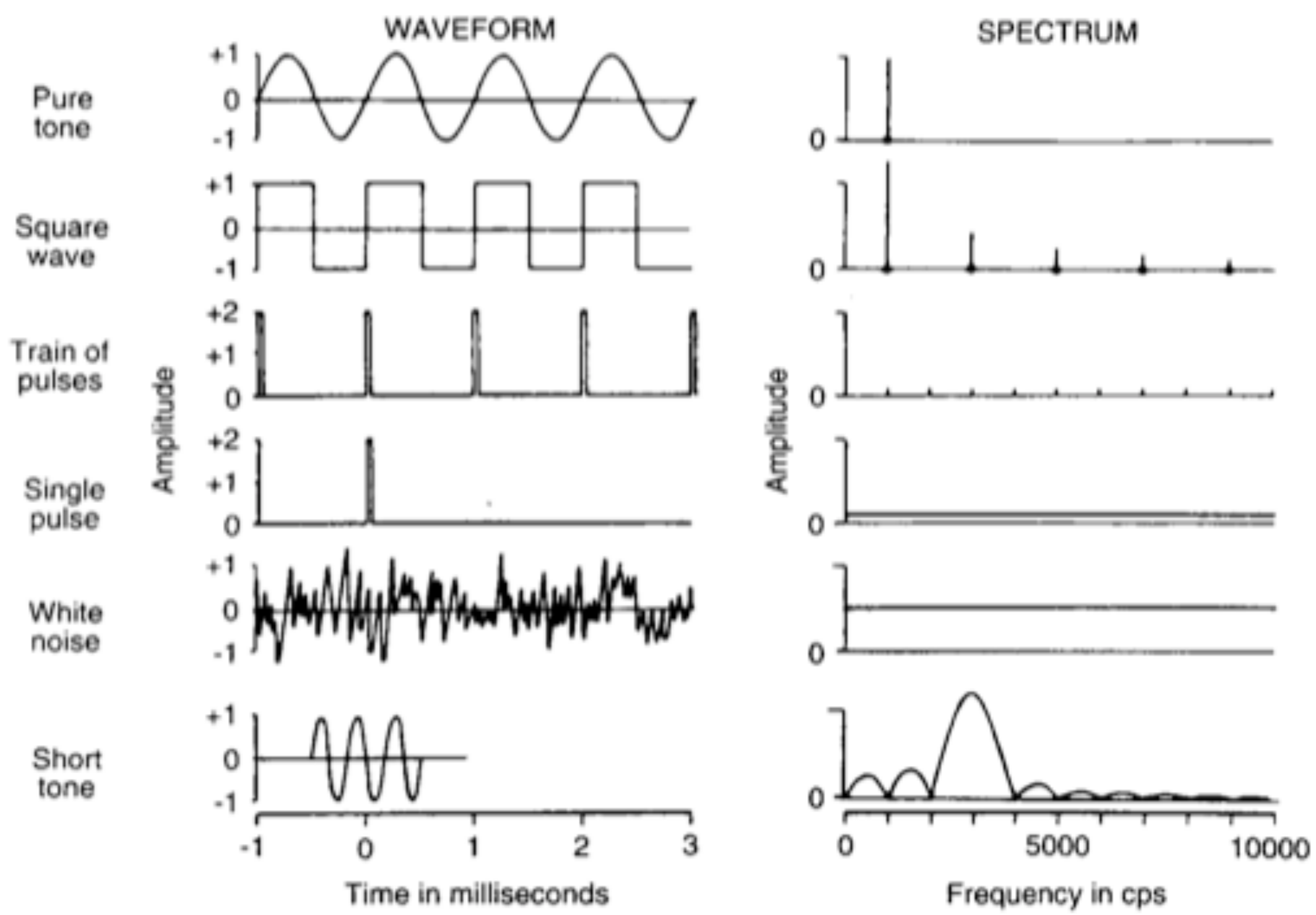
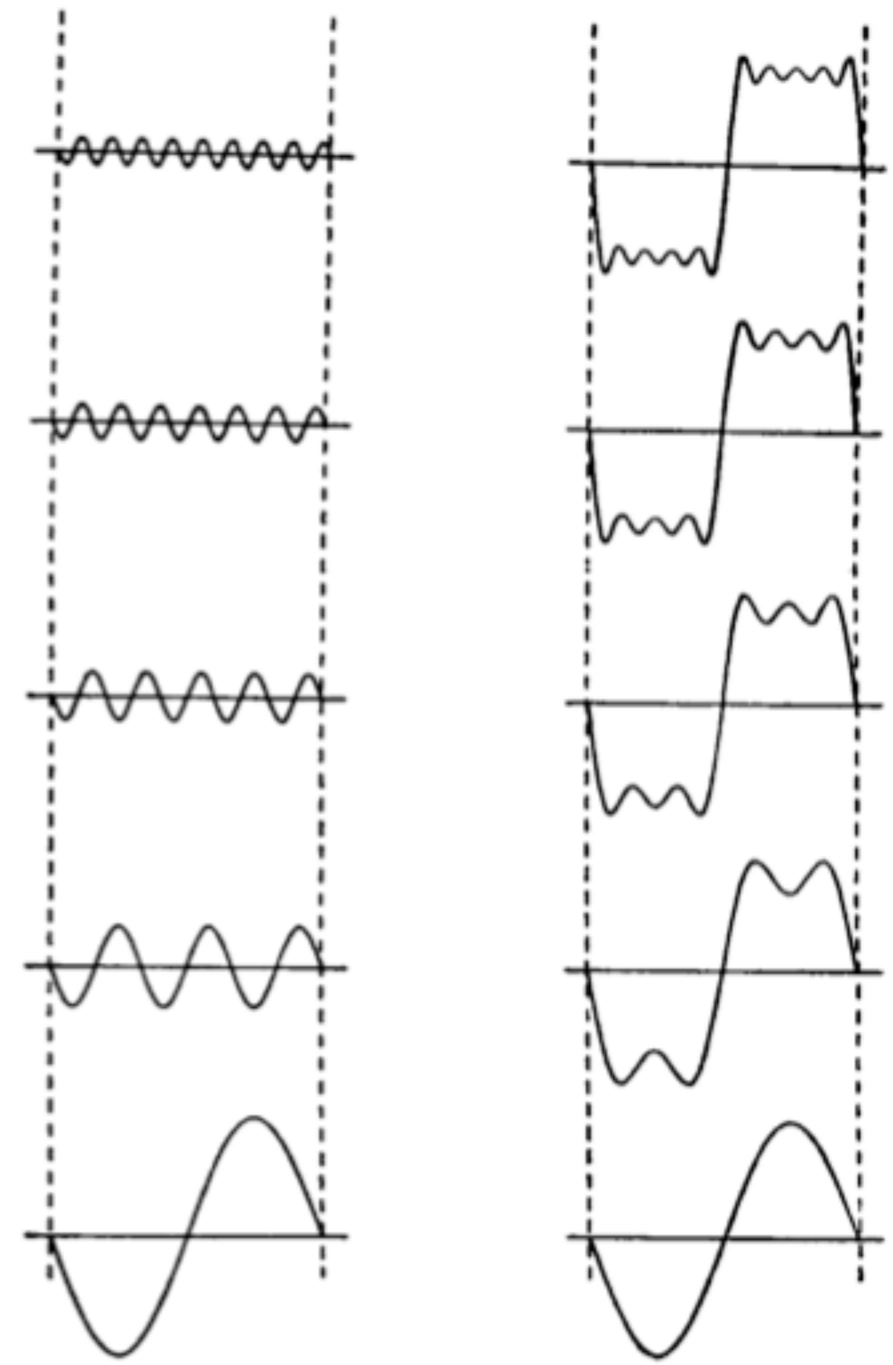
- The structure of sound
- Neurophysiology of the auditory system
- Perception of basic musical features:
  - Pitch: absolute, scale degree, interval, contour
  - Timing: event onset and duration
  - Dynamics: amplitude
  - Timbre
  - Spatial location
- Higher-level cognitive representation of music:
  - Grouping
    - Fusion (harmony)
    - Streaming (compound melody)
    - Grouping (motifs & phrases)
  - Rhythm, metre, tempo
- Music and general cognitive & neural processes
  - Memory and attention
  - Performance & communication
  - Emotion and aesthetics

# Structure of Sound



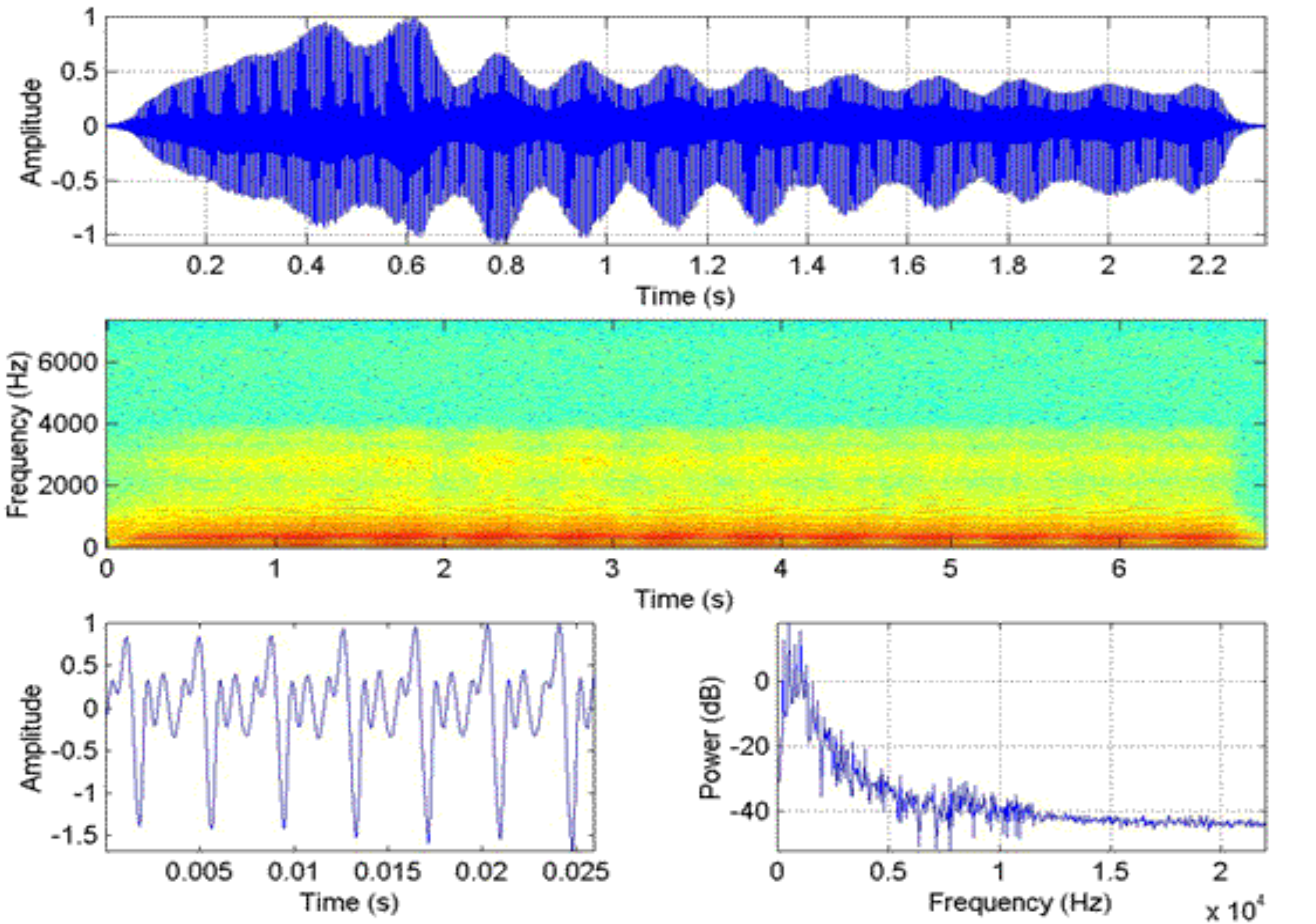


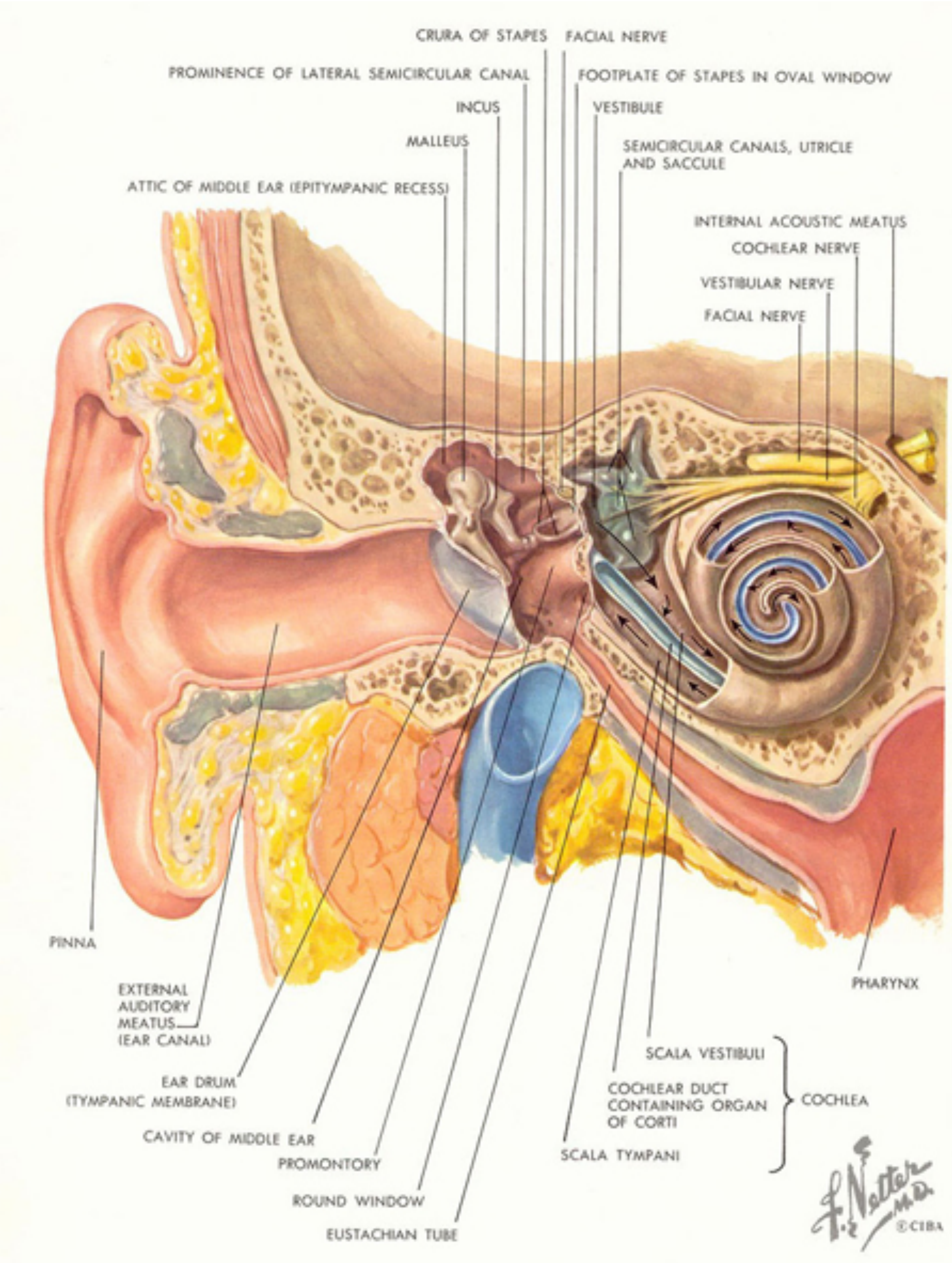
# Structure of Sound

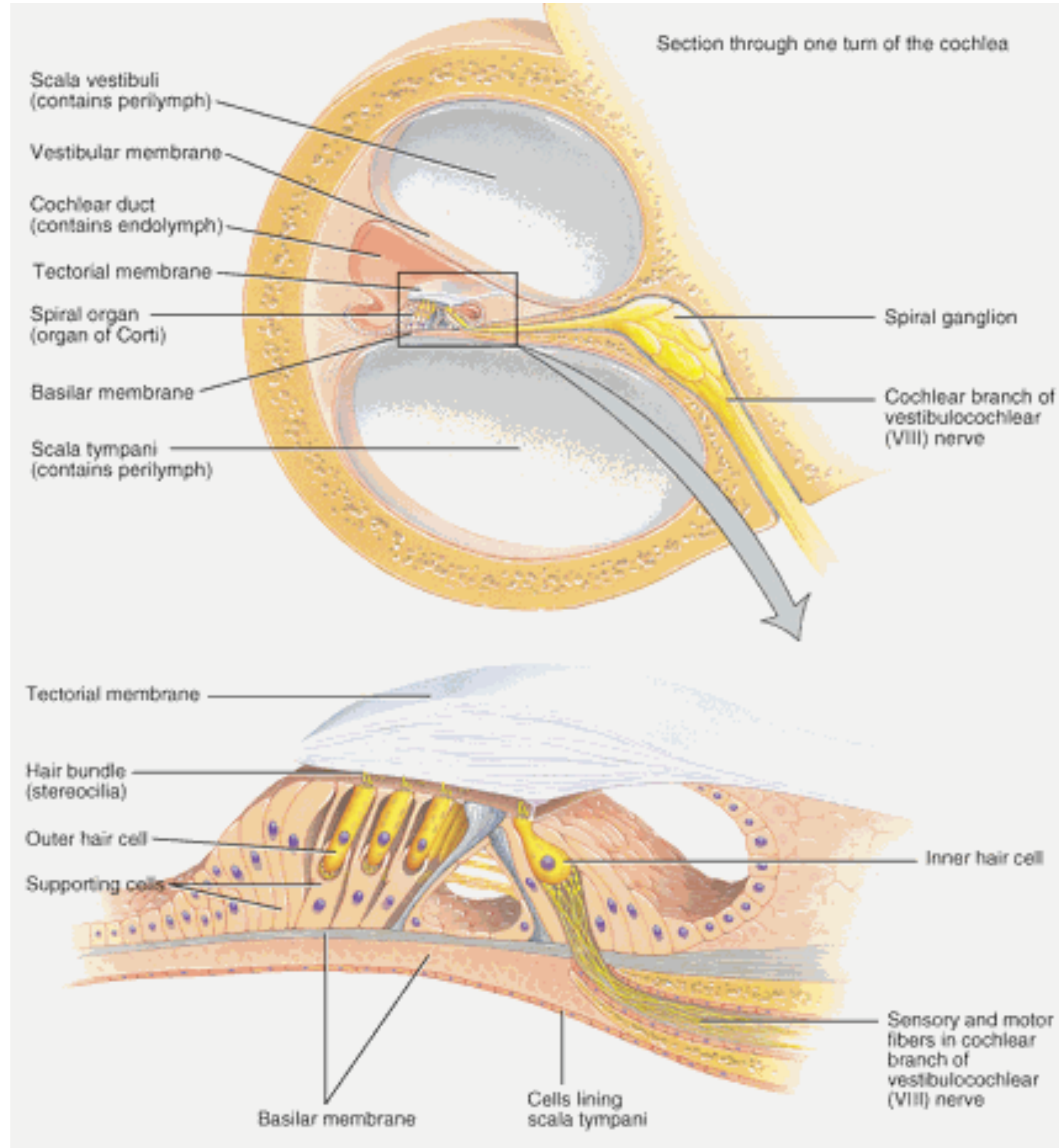




# The Auditory System





# The Auditory System

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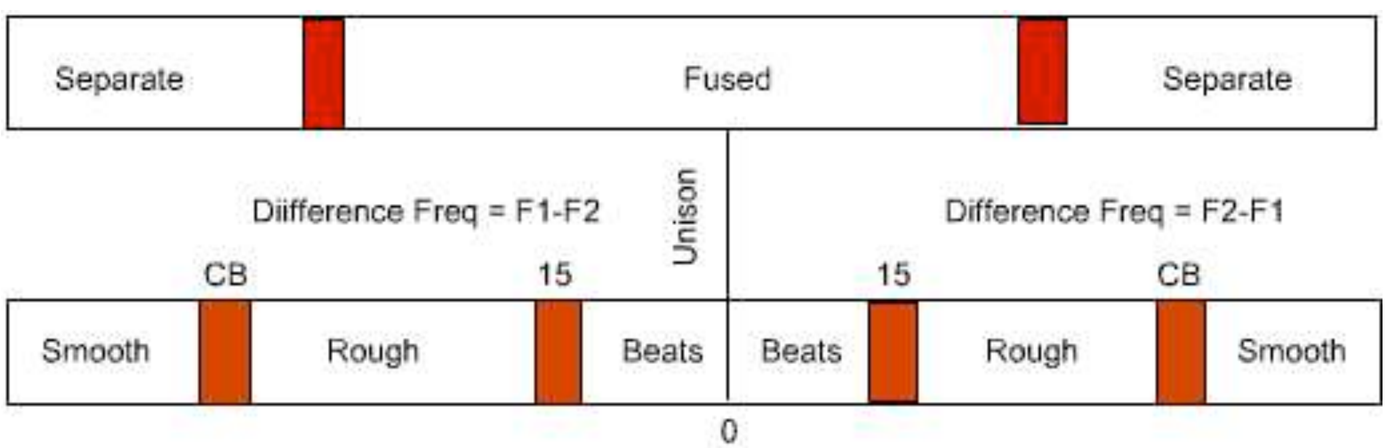
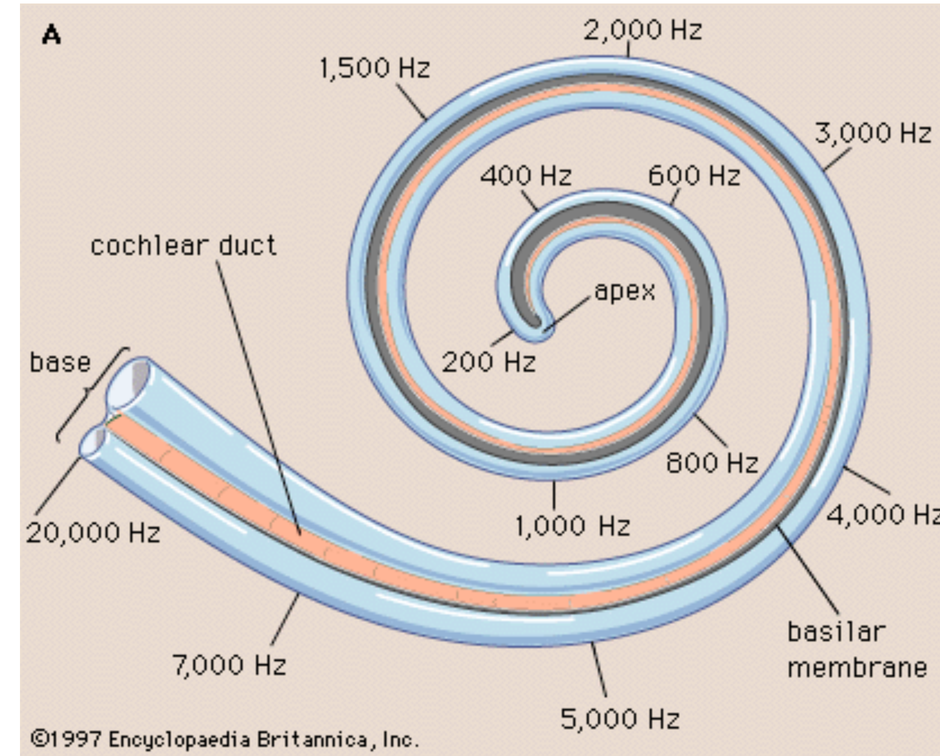
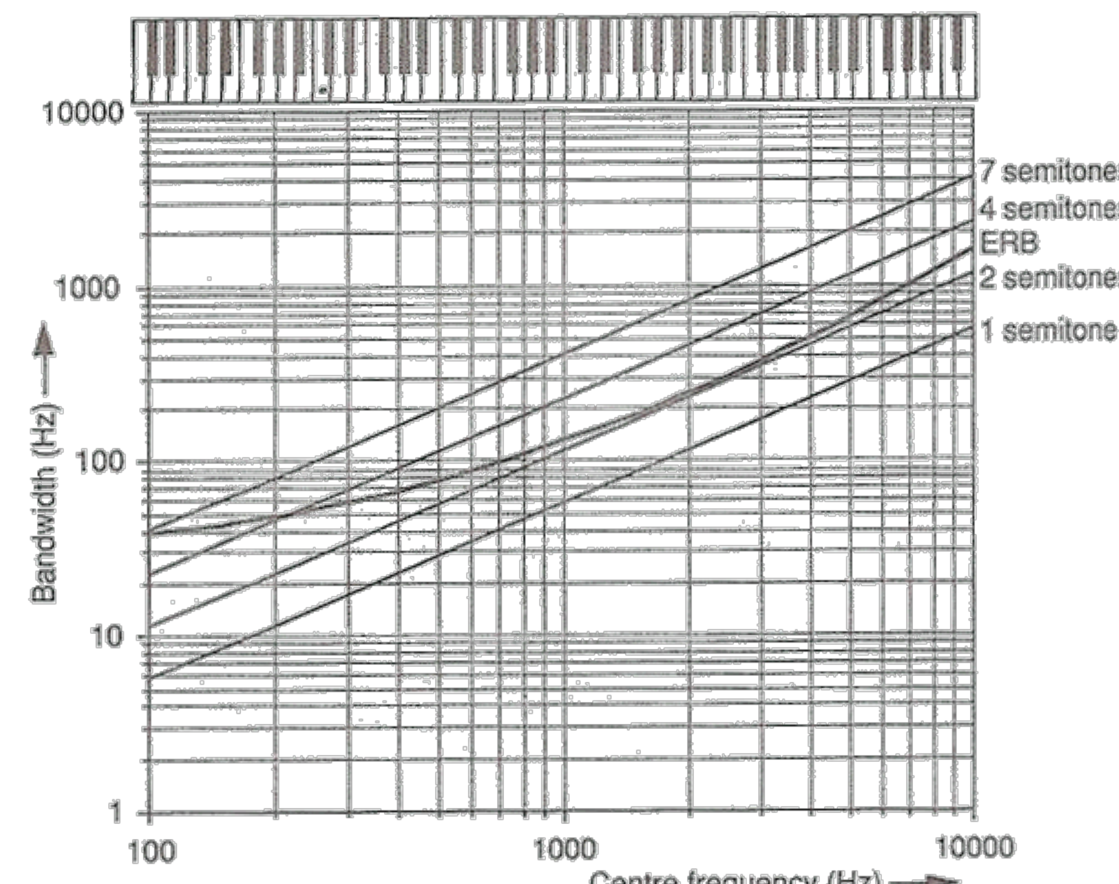
- Basilar membrane
  - narrow/thin at base and wide/thick at apex
  - distance of optimal response proportional to log frequency
- Critical bandwidth
  - the frequency difference at which the displacement of the basilar membrane by two sounds no longer overlaps perceptibly
  - creates beats and sensory dissonance (roughness)




  - dependent on frequency:

$$\text{bandwidth/Hz} \approx 6.23 \times 10^{-6} f^2 + 9.339 \times 10^{-2} f + 28.52$$



# The Auditory System

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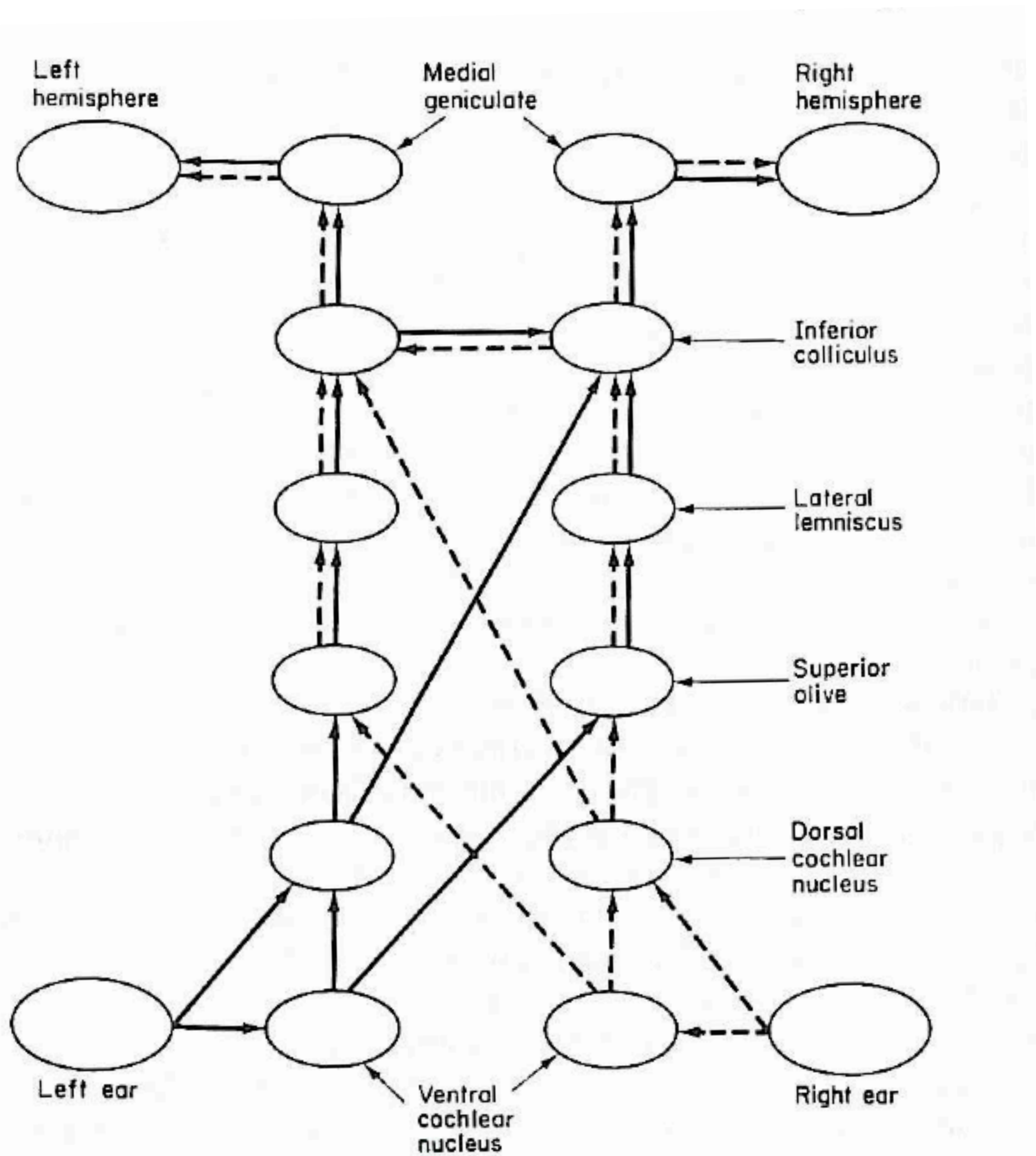


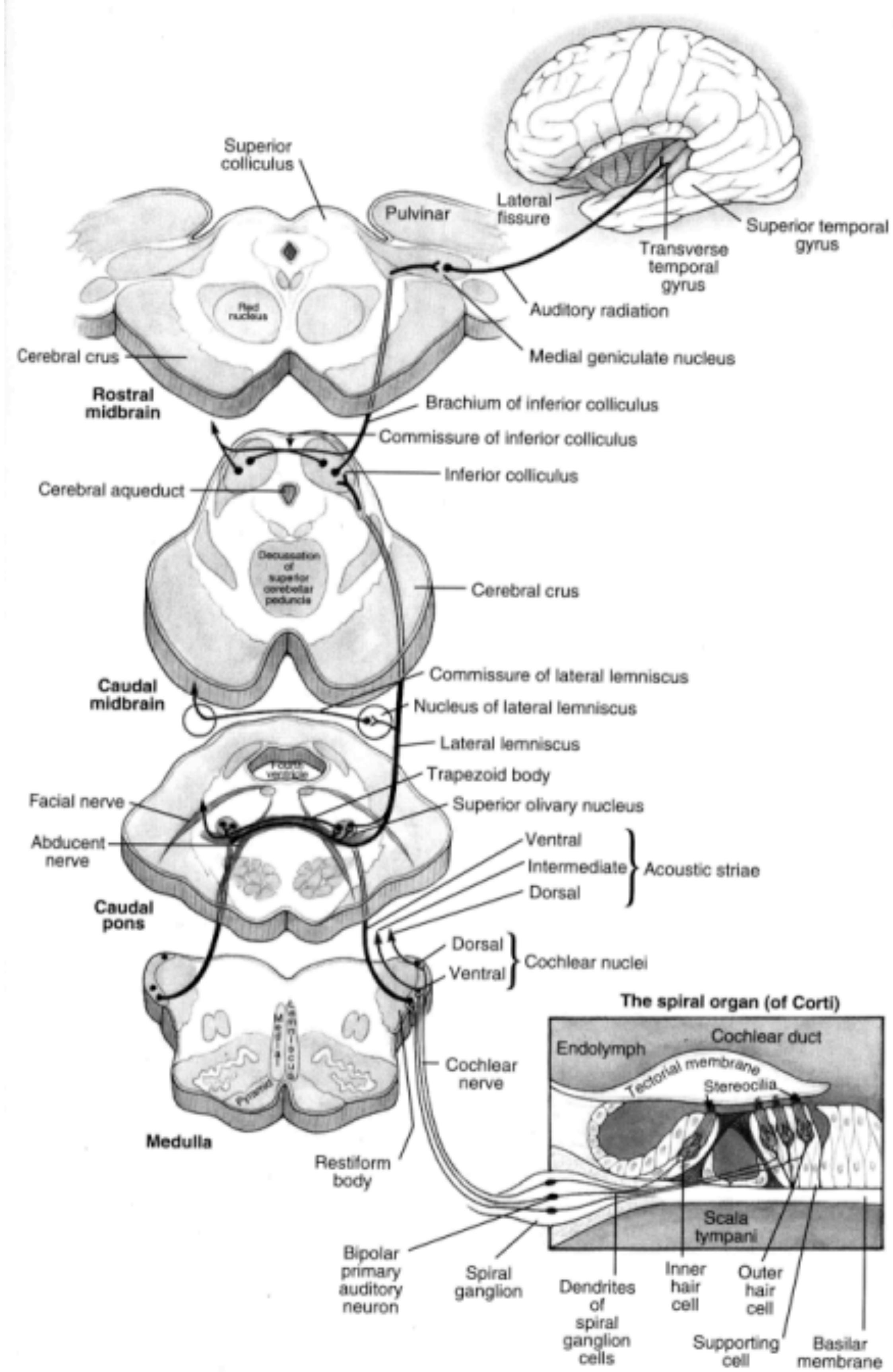

# The Auditory System

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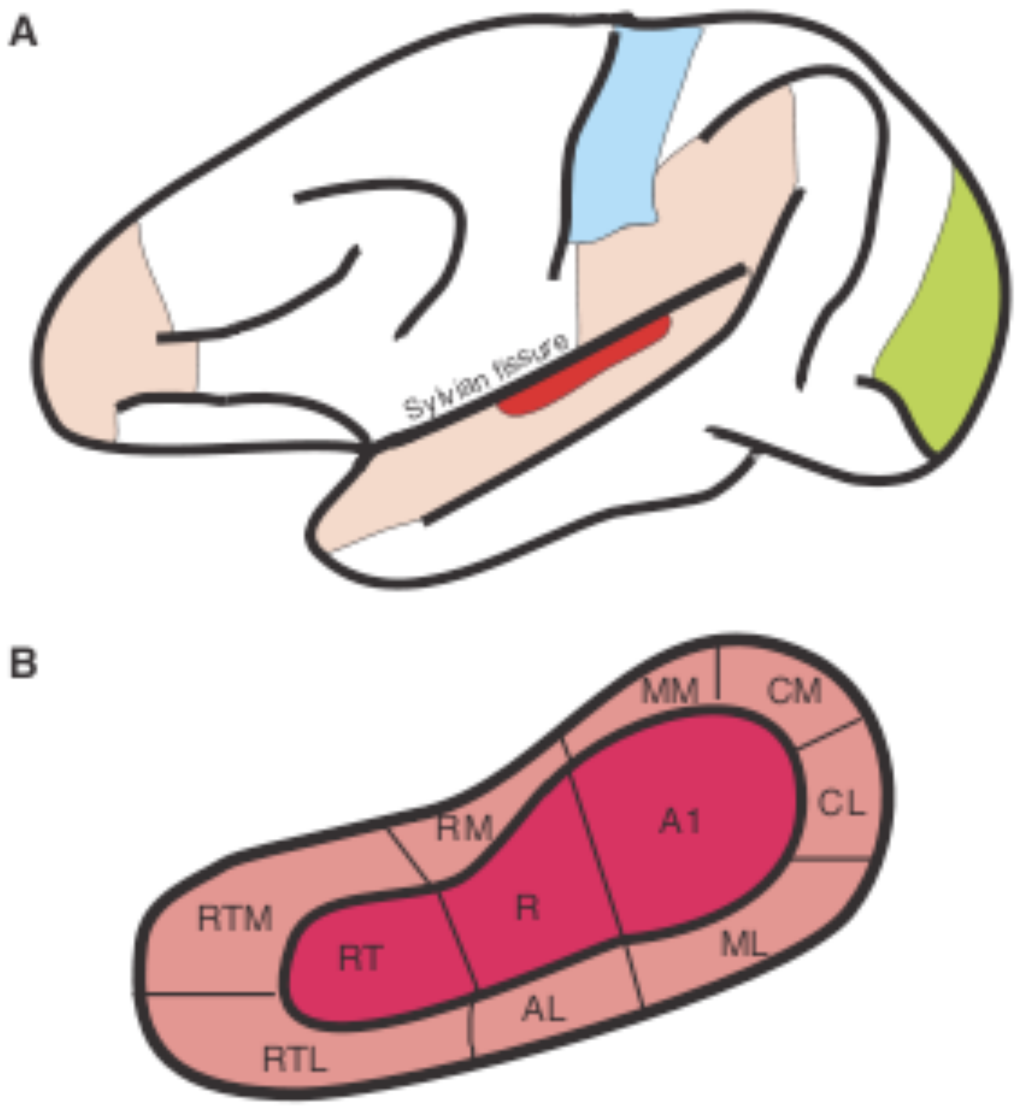


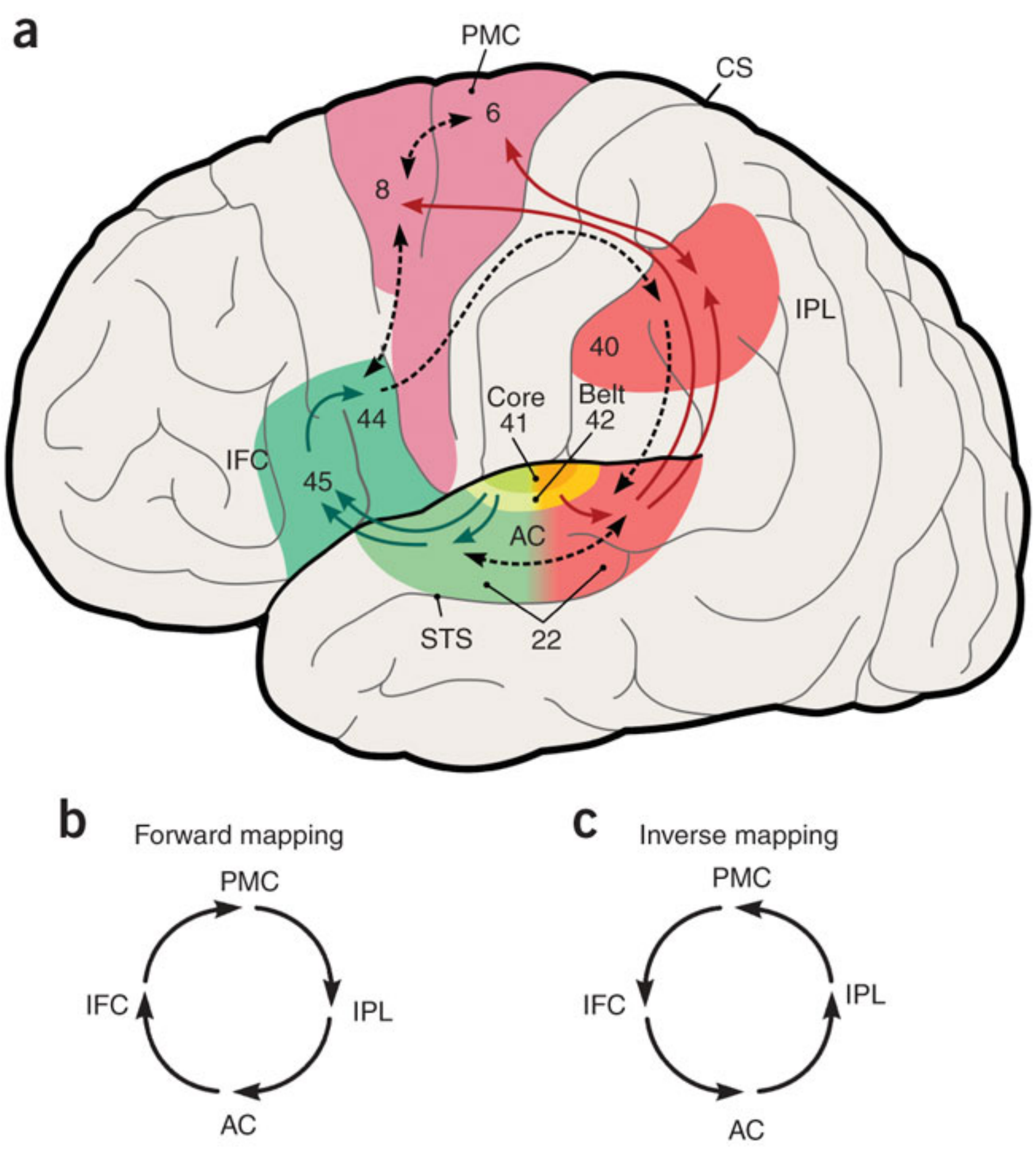


King & Schnupp (2008, *Current Biology)*

Rauschecker & Scott (2009, *Nature Neuroscience)*

# Pitch Perception

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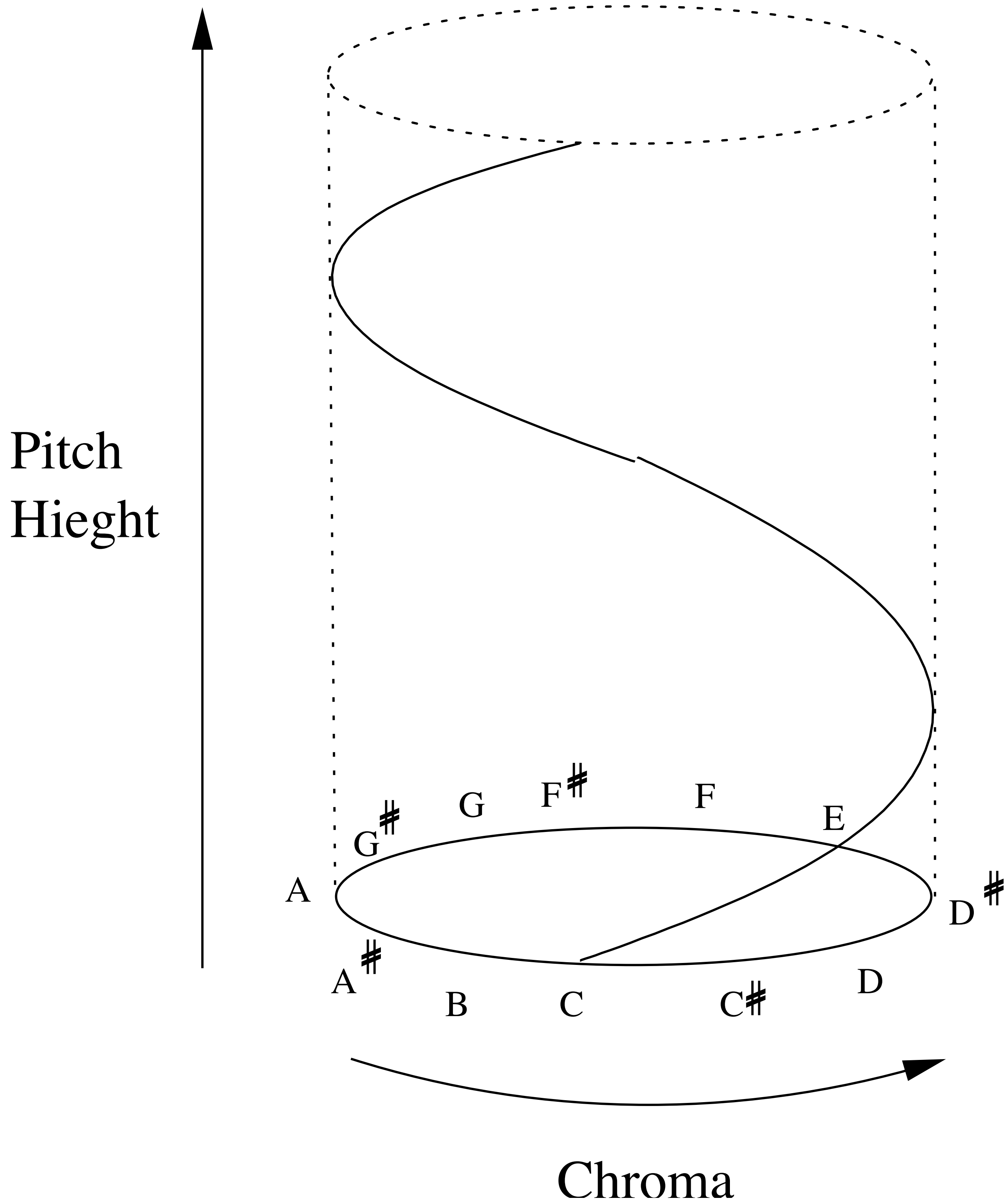
- Types of pitch
  - Absolute pitch (pitch height)
    - log frequency (octave = doubling of frequency)
    - familiar melodies recognised at their absolute pitch (Schellenberg, 2003)
    - tonotopic maps (+ maybe pitch maps in A1)
    - activate posterior regions of auditory cortex (Warren et al. 2003)
  - Pitch chroma
    - octave equivalence (also in other animals)
    - we can recognise melodies preserving tone chroma + contour but not height (Massaro et al., 1980)
    - activate anterior regions of auditory cortex (Warren et al. 2003)




Shepard (1982, *Psychology of Music*)

# Pitch Perception

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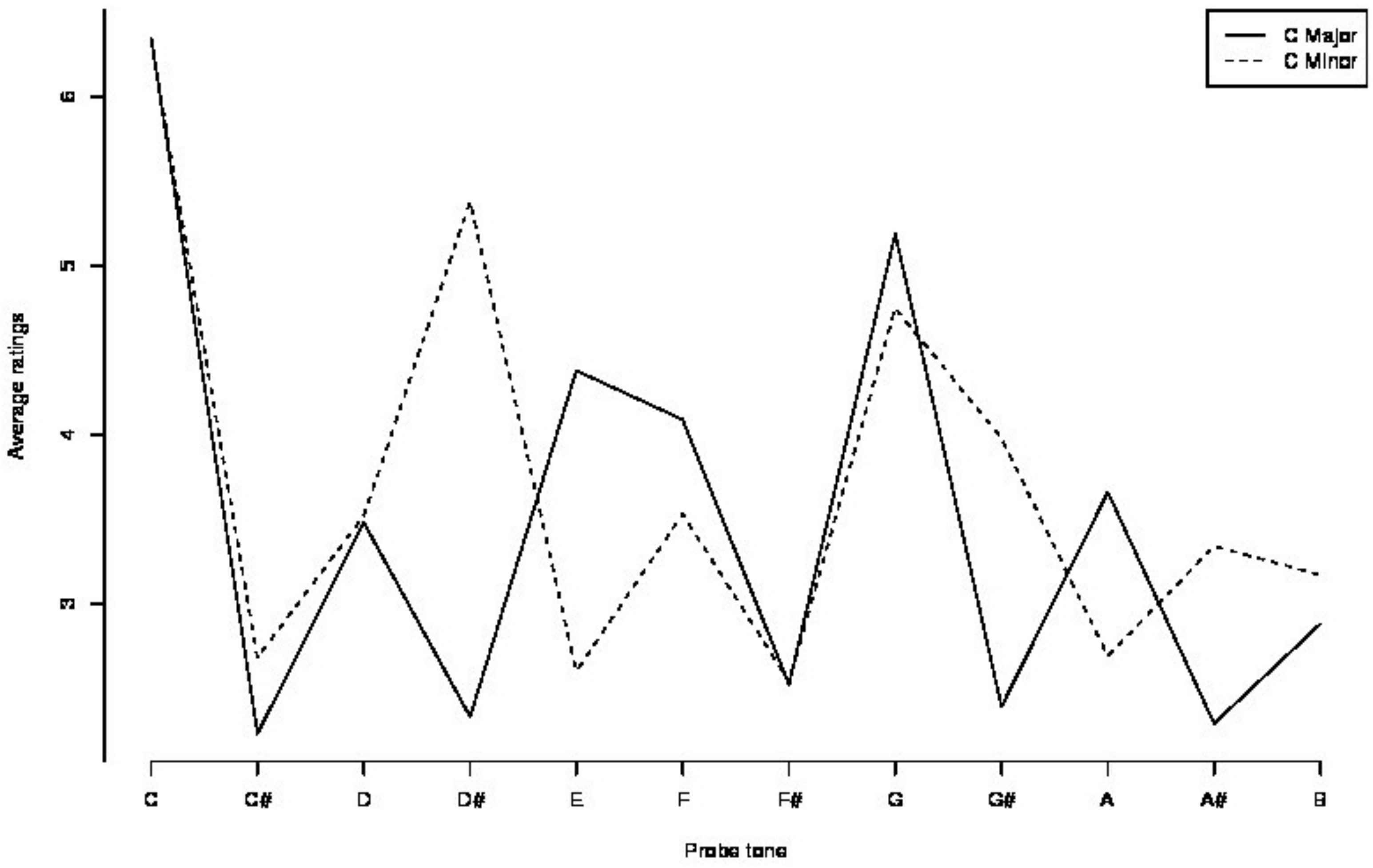
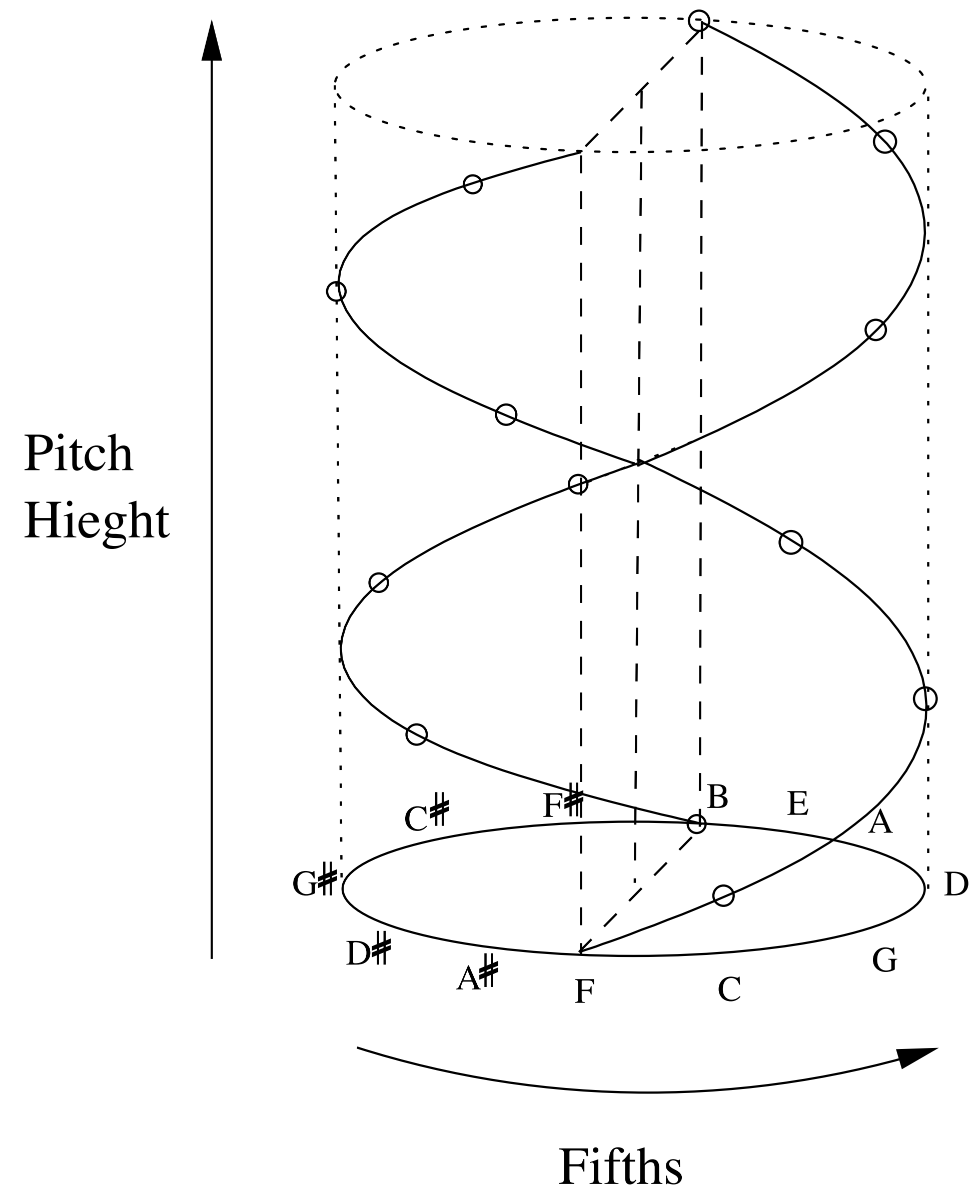
- Types of pitch
  - scale degree
  - cycle of fifths



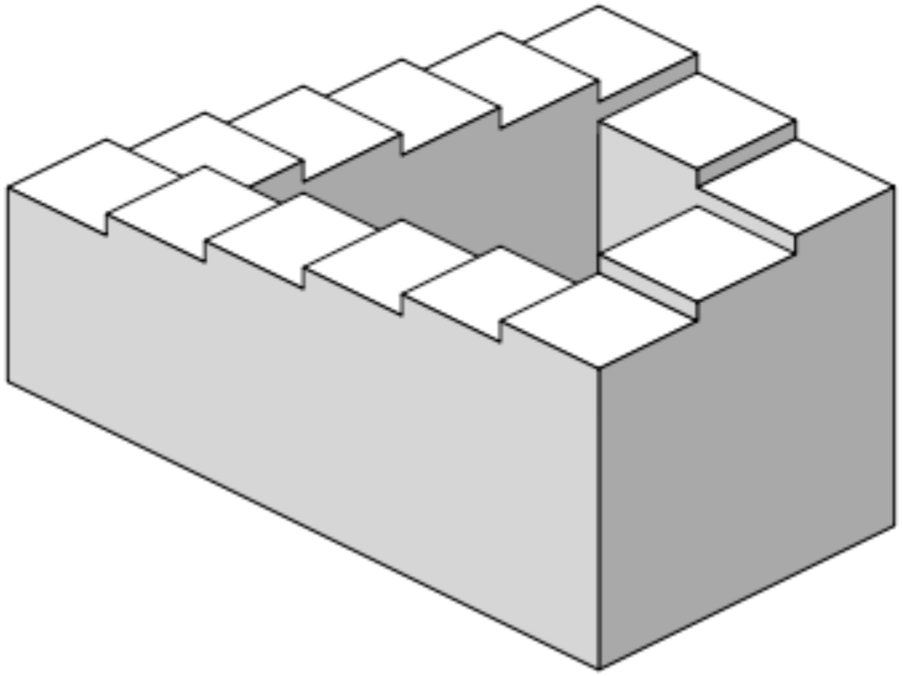

Krumhansl & Kessler (1982, *Psychological Review*)

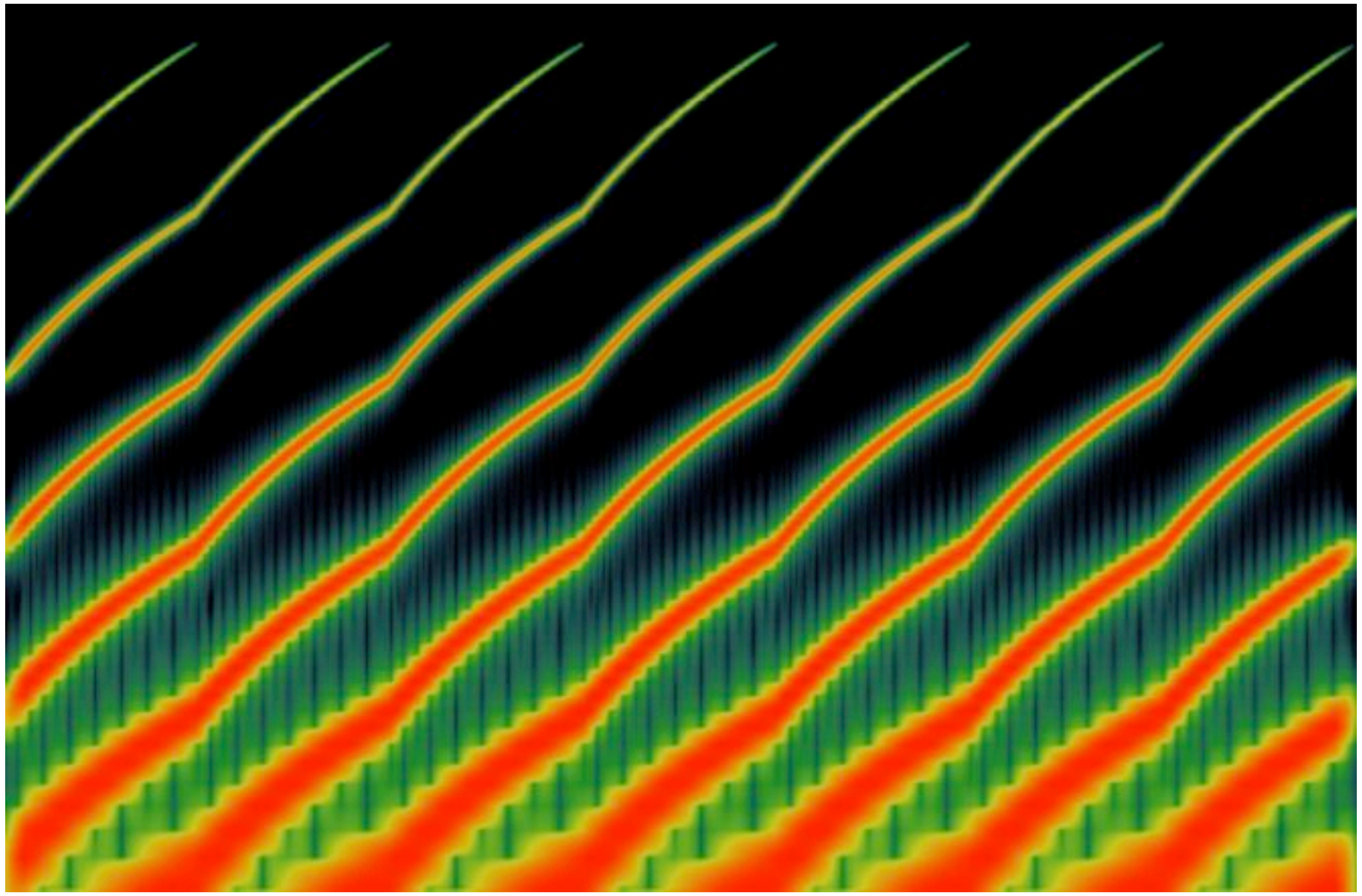
Shepard (1982, *Psychology of Music*)

# Pitch Perception



- Shepherd Tones
  - series of overlapping ascending or descending scales varying in intensity





# Pitch Perception

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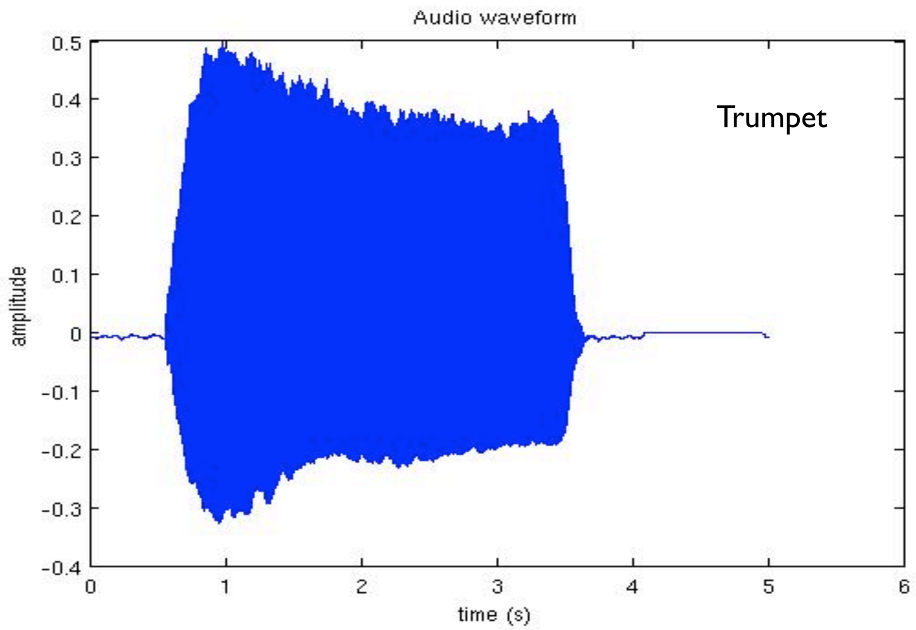
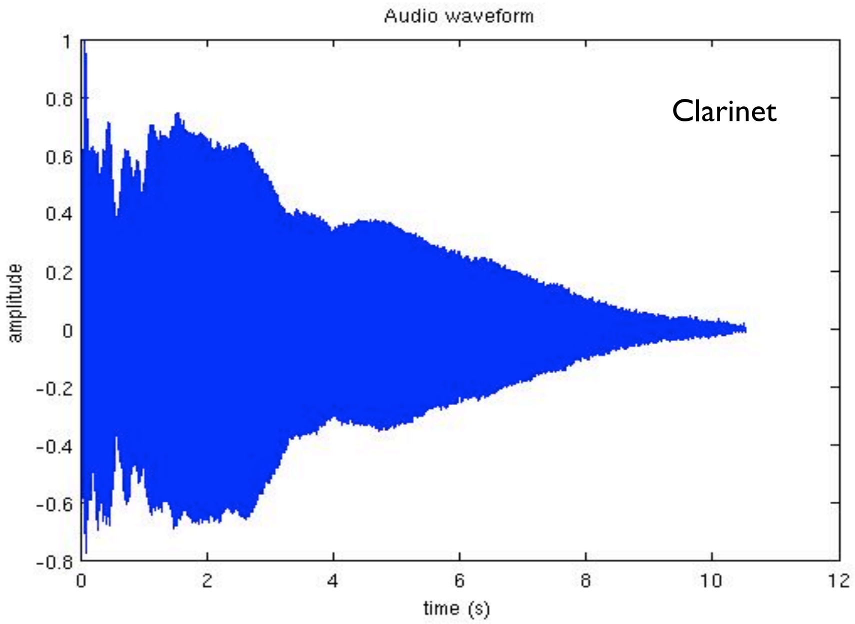
- Sequential pitch relations
  - Pitch interval
    - we can recognise a melody when it is transposed by a fixed pitch interval
    - note that non-human animals (e.g., birds, monkeys) are not able to do this (e.g., Hauser & McDermott, 2003)
  - Pitch contour (up, down or same)
    - but listeners are typically unable to tell if intervals change in transposed melodies as long as the contour remains the same (Dowling & Fujitani, 1970; Edworthy, 1985)
    - may be perceived in dimensions other than pitch (e.g., loudness & brightness, McDermott et al., 2008)
- intervals and contour appear to be processed in secondary auditory cortex in the Superior Temporal Gyrus and Planum Polare (Patterson et al., 2003)
- lesions of antero-lateral HG produce particular deficits in pitch interval processing (Zatorre, 1988)

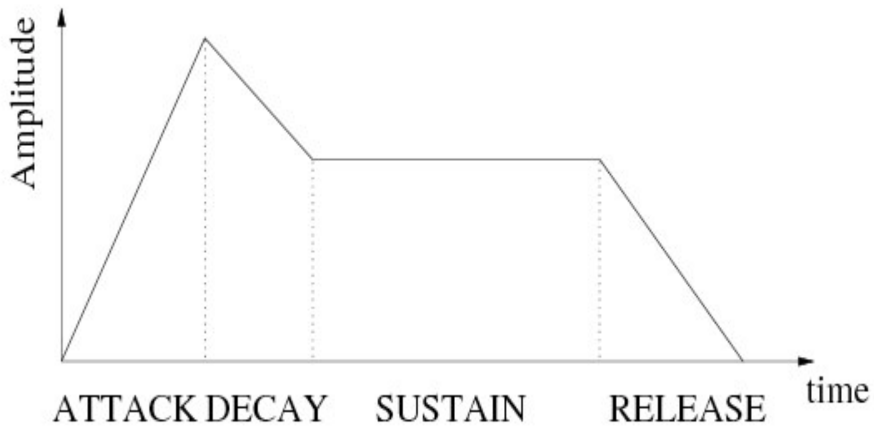
# Timbre



- timbre corresponds to any attributes of auditory sensation whereby a listener is able to judge two sounds to be dissimilar using any criterion other than pitch, loudness and duration (Pratt & Doak, 1976)

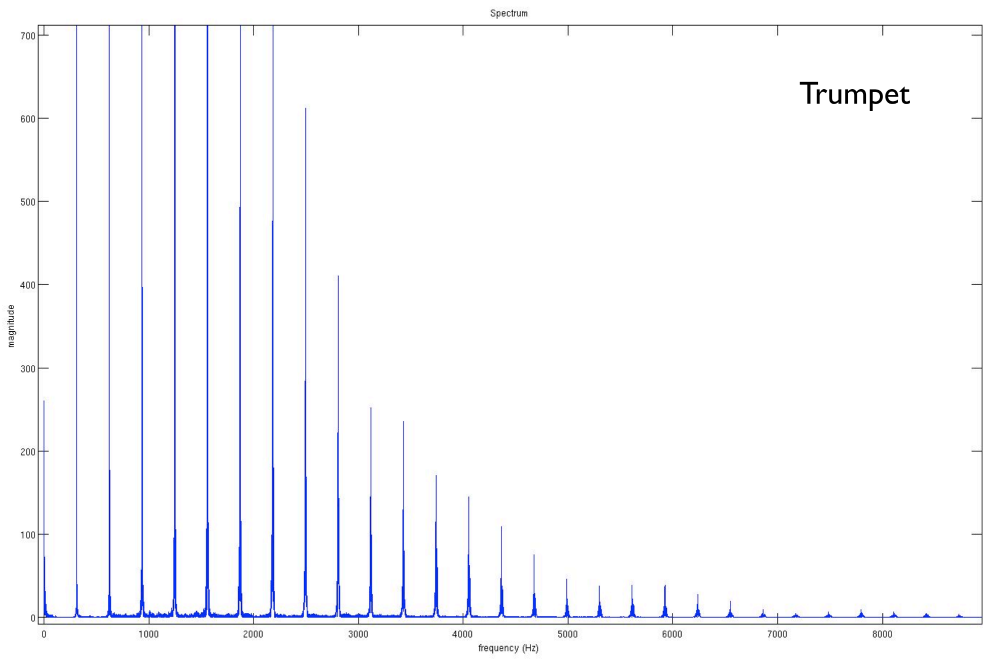


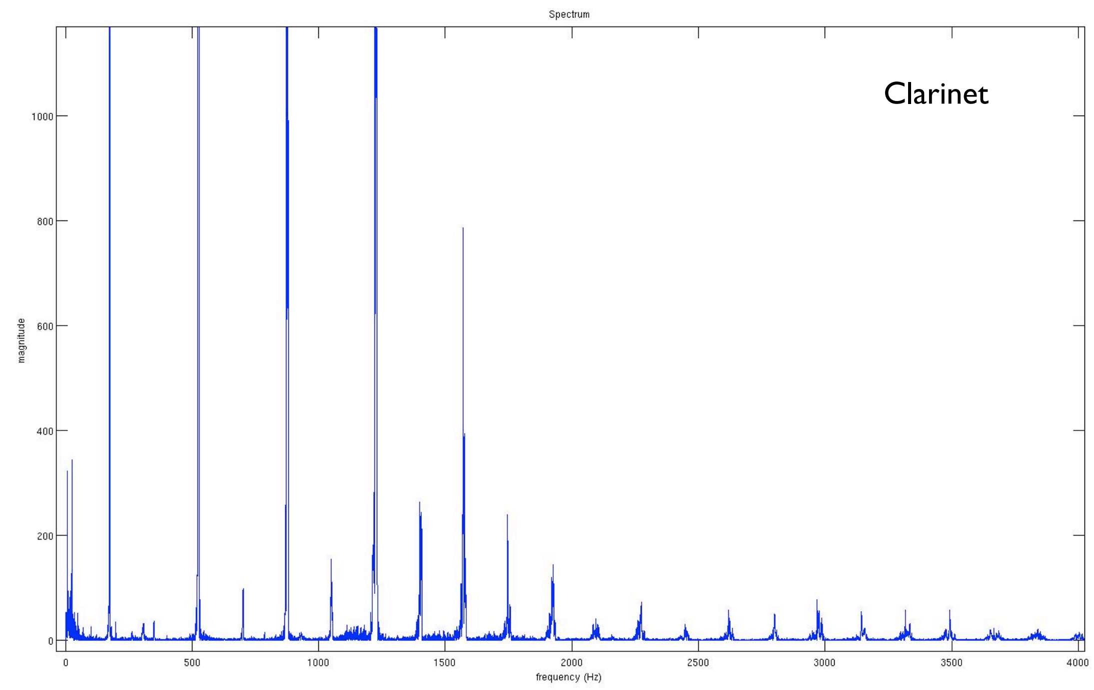



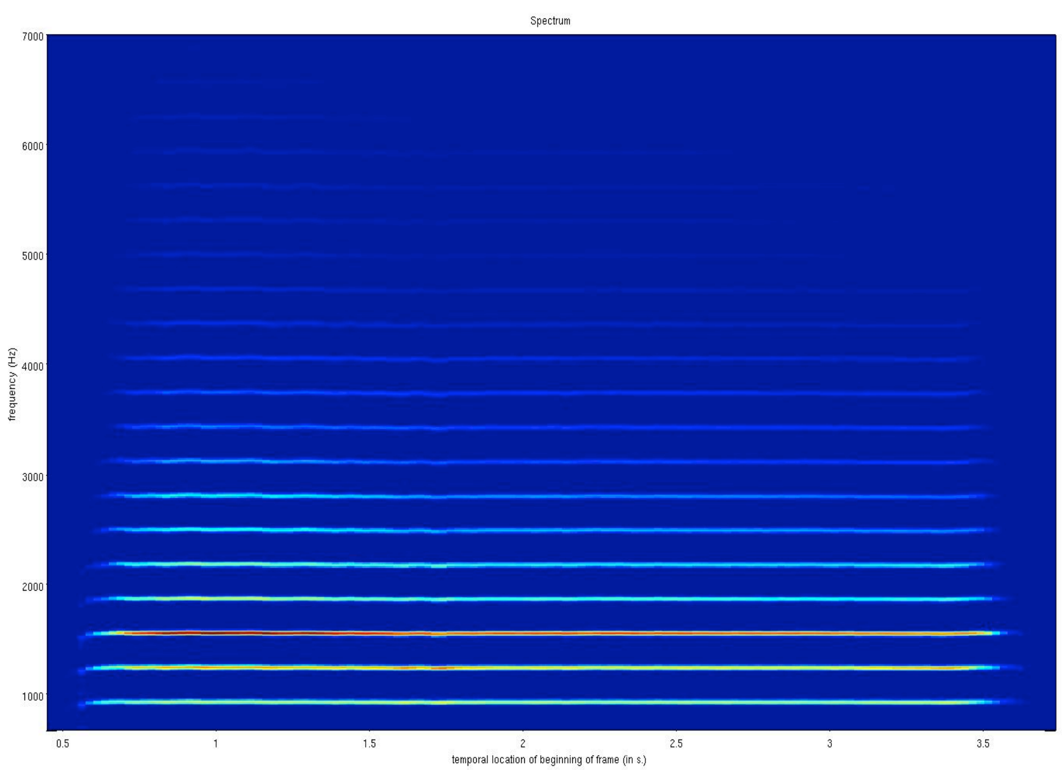



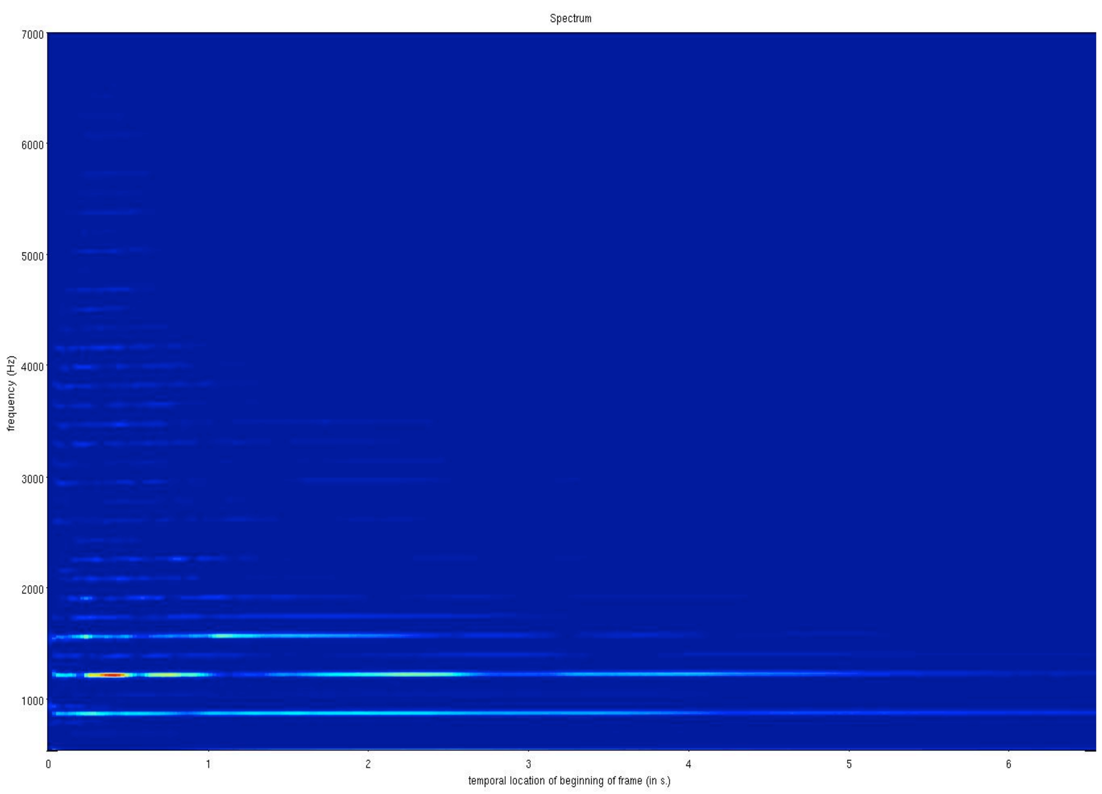
# Timbre




Spectrum
Trumpet
magnitude
0
100
200
300
400
500
600
700
0
1000
2000
3000
4000
5000
6000
7000
8000
frequency (Hz)


Spectrum
Clarinet
magnitude
0
200
400
600
800
1000
0
500
1000
1500
2000
2500
3000
3500
4000
frequency (Hz)


Spectrum
frequency (Hz)
1000
2000
3000
4000
5000
6000
7000
0.5
1
1.5
2
2.5
3
3.5
temporal location of beginning of frame (in s.)


Spectrum
frequency (Hz)
1000
2000
3000
4000
5000
6000
7000
0
1
2
3
4
5
6
temporal location of beginning of frame (in s.)

# Timbre

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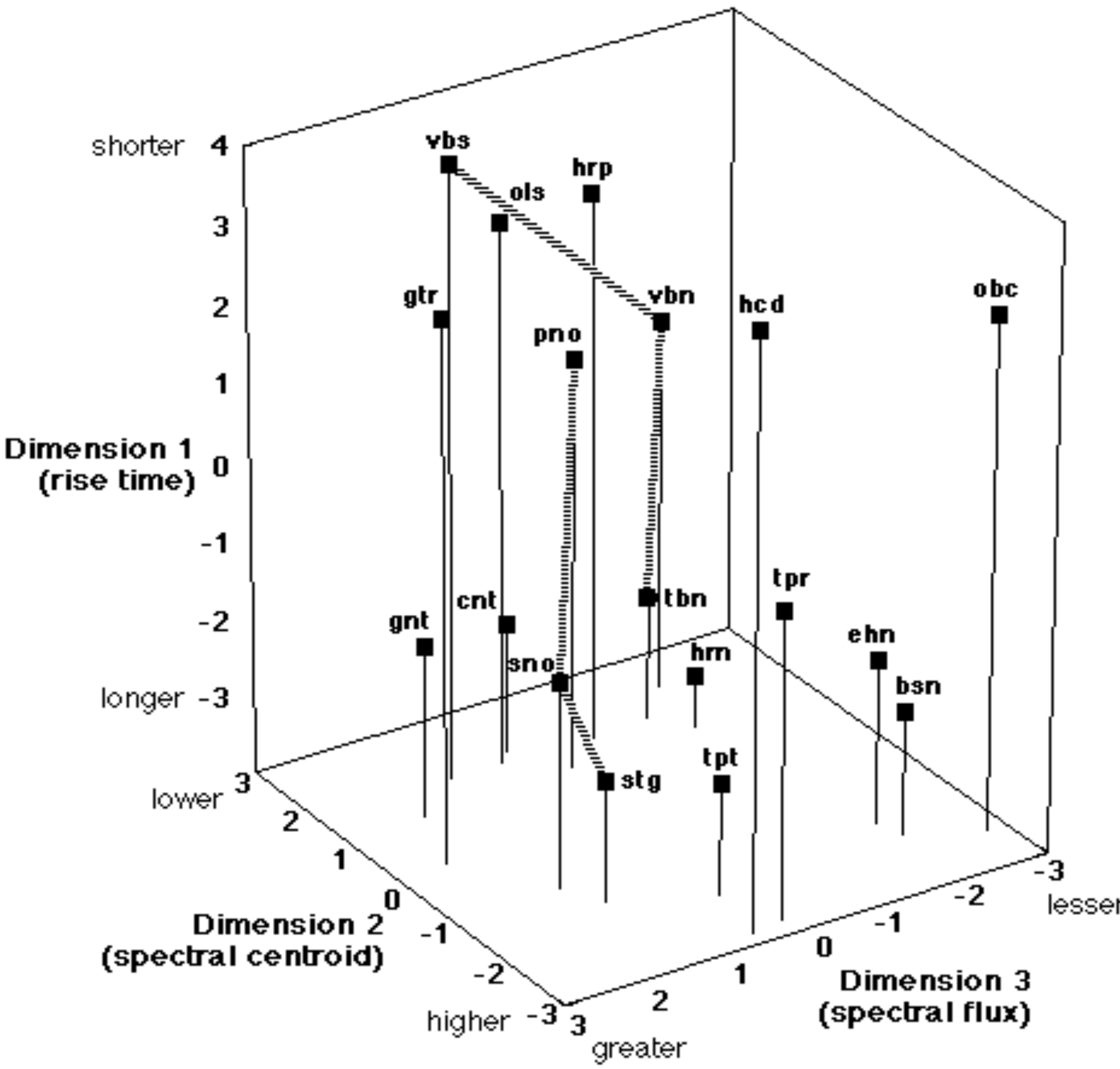
- 88 subjects (24 professional musicians, 45 amateur musician, 18 nonmusicians)
- 18 synthesised sounds, 153 pairwise comparisons
- Multidimensional Scaling
  - 5 classes of subject
  - 3-d timbre space
  - Specificities
    - General properties (raspiness, graininess, hollowness)
    - Specific properties (e.g., Harpsichord's clunk on offset)
  - Musical training/activity: ambiguous effects

McAdams et al. (1995, *Psychological Research*)

# Timbre






| Timbres | Dimension 1 | Dimension 2 | Dimension 3 | Specificities$^{1/2}$ |
|---|---|---|---|---|
| French horn | – 3.3 | 1.3 | – 1.5 | 1.4 |
| Trumpet | – 2.6 | – 1.9 | 0.4 | 1.6 |
| Trombone | – 2.4 | 1.7 | – 1.2 | 1.4 |
| Harp | 3.0 | 1.7 | – 0.4 | 0.8 |
| *Trumpar* | – 0.1 | – 2.7 | 0.1 | 1.9 |
| *Oboleste* | 3.0 | 1.7 | 0.7 | 1.4 |
| Vibraphone | 3.8 | 1.8 | 1.3 | 1.9 |
| *Striano* | – 1.4 | – 0.9 | 1.6 | 1.8 |
| Harpsichord | 3.6 | – 2.8 | 0.5 | 2.2 |
| English horn | – 1.9 | – 1.5 | – 1.9 | 1.9 |
| Bassoon | – 2.4 | – 1.8 | – 2.0 | 1.4 |
| Clarinet | – 2.4 | 1.9 | 0.5 | 2.5 |
| *Vibrone* | 0.7 | 2.3 | – 1.6 | 2.5 |
| *Obochord* | 2.5 | – 2.3 | – 2.7 | 0.0 |
| Guitar | 2.9 | 0.2 | 2.4 | 0.0 |
| String | – 2.4 | – 1.4 | 1.4 | 1.1 |
| Piano | 1.3 | 1.3 | 0.2 | 2.0 |
| *Guitarnet* | – 1.8 | 1.2 | 2.0 | 1.4 |
| Range | 7.1 | 5.0 | 5.1 | 2.5 |

**Table 4** Estimated weights in the selected 3-dimensional model with specificities for 5 latent classes of subjects obtained from dissimilarity ratings by 88 subjects for 18 timbres

| Dim | 1 | 2 | 3 | Specif |
|---|---|---|---|---|
| Class | | | | |
| 1 | 1.14 | 0.94 | 1.18 | 1.72 |
| 2 | 0.81 | 0.69 | 0.73 | 0.74 |
| 3 | 1.05 | 1.77 | 1.22 | 0.58 |
| 4 | 1.24 | 0.44 | 0.51 | 1.09 |
| 5 | 0.76 | 1.15 | 1.36 | 0.88 |

McAdams et al. (1995, *Psychological Research*)

# Timbre



- Psychoacoustic interpretation of dimensions:

**Table 7** Correlations ($df = 16$) between acoustic parameters (Krimphoff, 1993; Krimphoff et al., 1994) and the coordinates of 18 timbres along the three common dimensions of our spatial model (5 latent classes and specificities derived from dissimilarity ratings by 88 subjects)

| Acoustic Correlate | Dim 1 | Dim 2 | Dim 3 |
|---|---|---|---|
| Log-Attack Time | – .94† | – .12 | – .16 |
| Spectral Centroid | – .04 | – .94† | – .21 |
| Spectral Irregularity | .41 | .31 | .13 |
| Spectral Flux | – .07 | .13 | .54* |

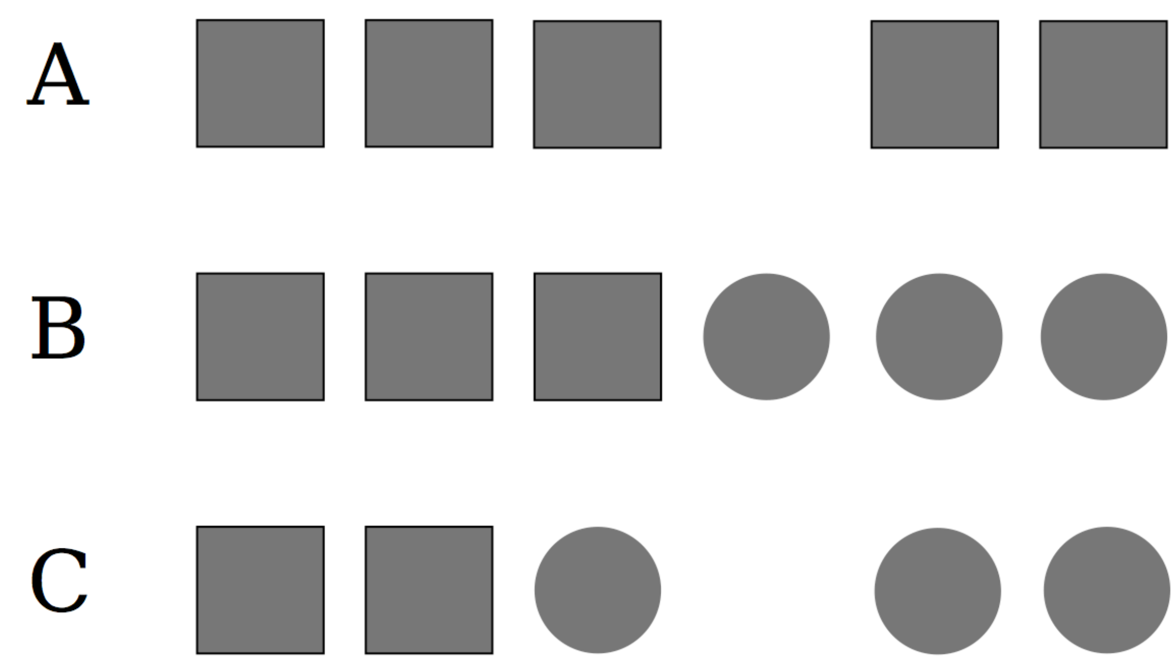
*$p < .05$, †$p < .0001$ (Fisher's $r$-to-$z$).

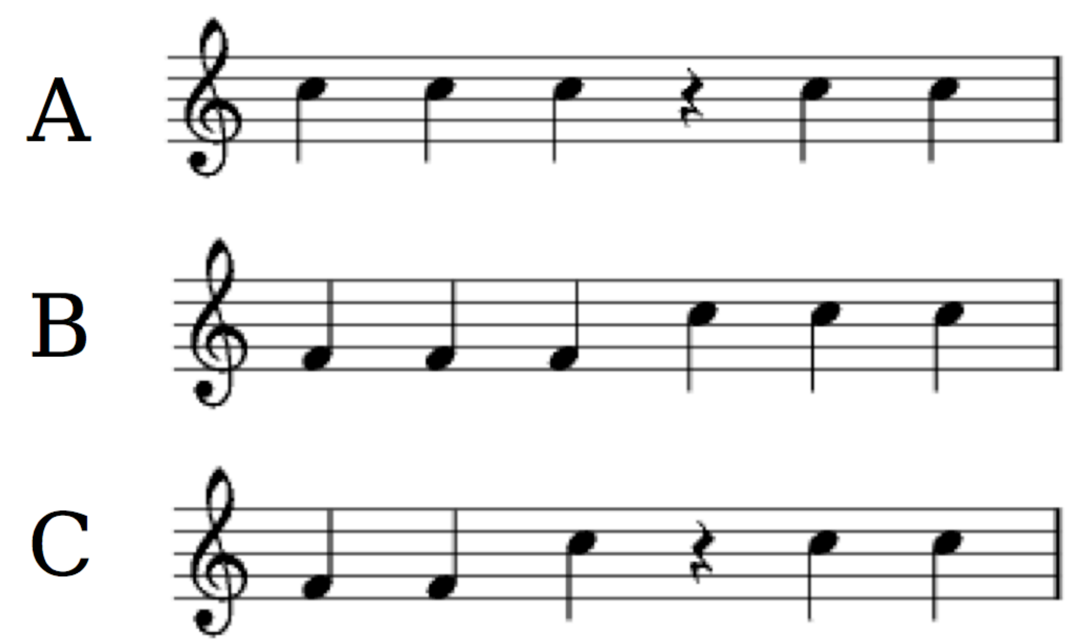
McAdams et al. (1995, *Psychological Research*)

# Auditory Grouping



- Gestalt principles
  - apply also to auditory objects
  - e.g., segmentation of musical phrases



# Auditory Grouping

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Mozart, G minor symphony

# Auditory Grouping

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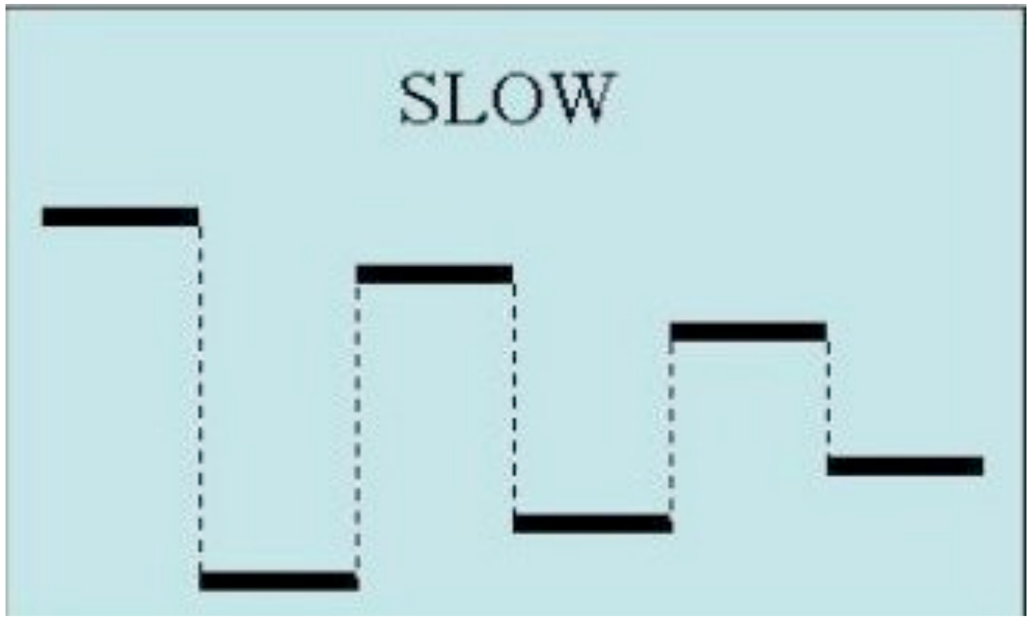
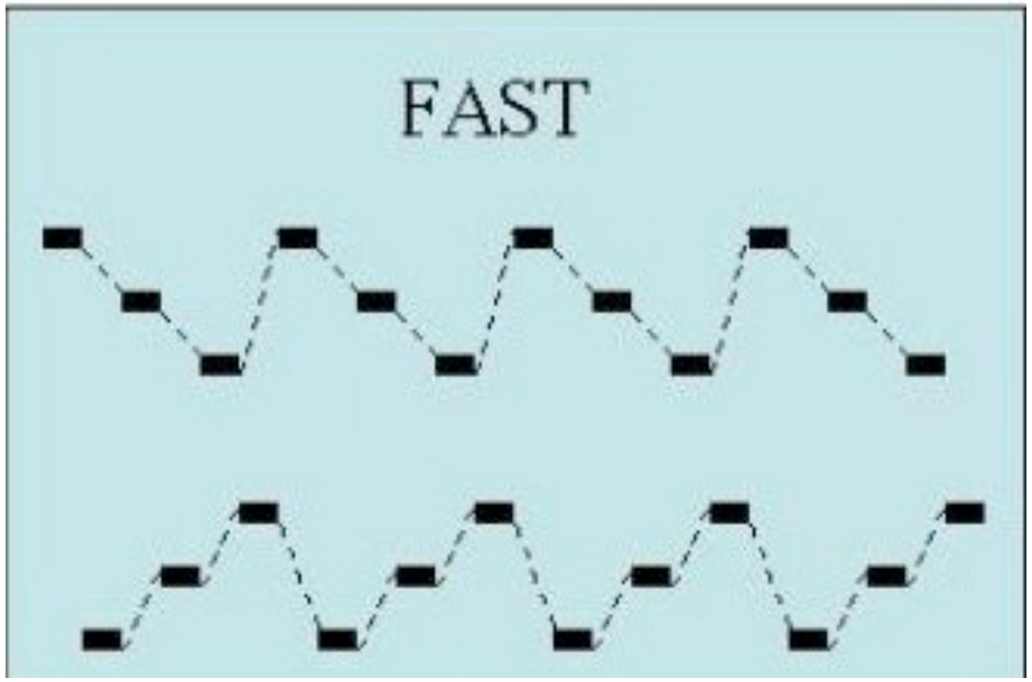
- Pitch proximity (Bregman & Campbell, 1971)
- Slow:
  - All six tones form a single stream
  - Temporal order is apparent
- Fast:
  - Forms two streams
  - Difficult to perceive temporal order between streams
- Listeners reported order of tones (ABCDEF)



# Auditory Grouping

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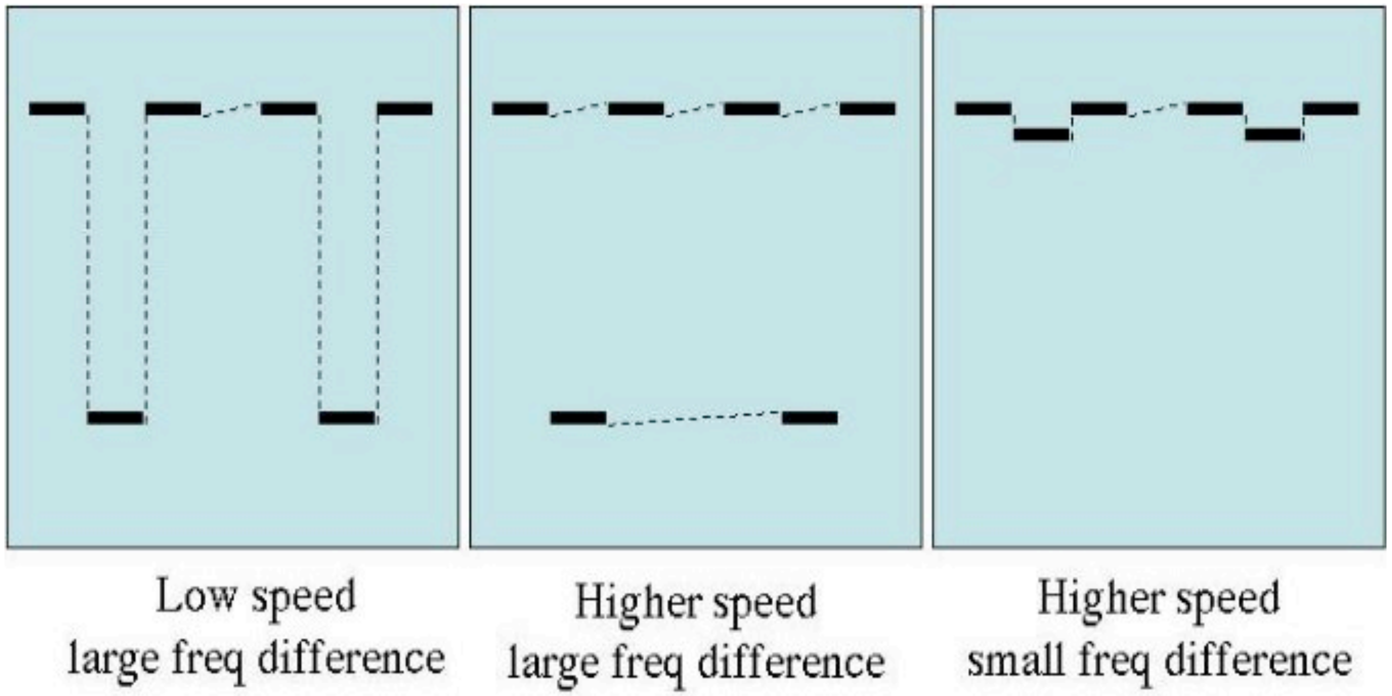
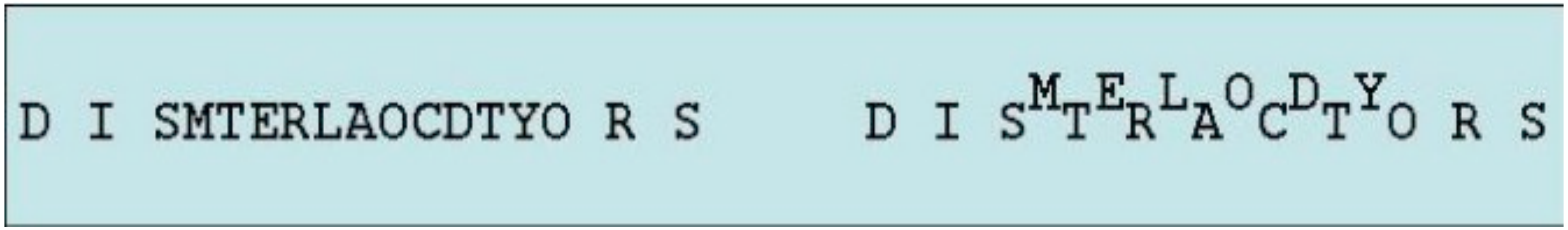



- Galloping pattern (van Noorden, 1975, 1977)
  - Each stream is isochronous (has own rhythm/melody)
- Stream segregation encouraged by
  - Higher frequency difference
  - Higher tempo

# Auditory Grouping

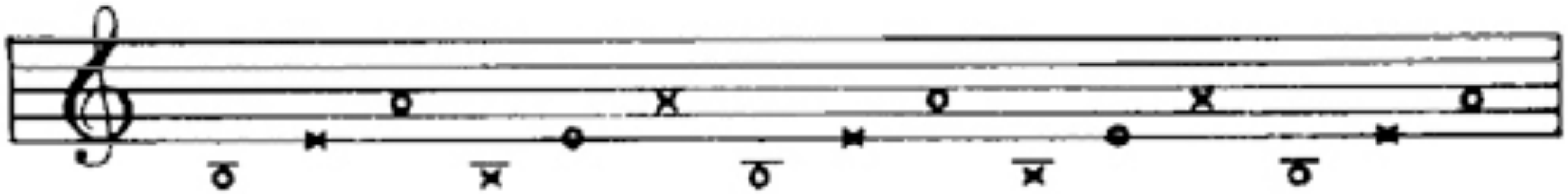





- Effect of expectation
  - In each repetition the pitch of the distractor tones becomes more distant from the melody tones
  - By the fifth sequence, two streams have formed
    - Segregation without repetition in a musical context
- Dowling (1973)
  - interleaved tones from one familiar melody with those from another
  - when melodies occupied same frequency range, they could not be recognised
  - but if one is transposed upwards, they can be recognised
  - Interleaved, overlapping melodies can be recognised if the target is prespecified
    - top-down expectation

# Auditory Grouping

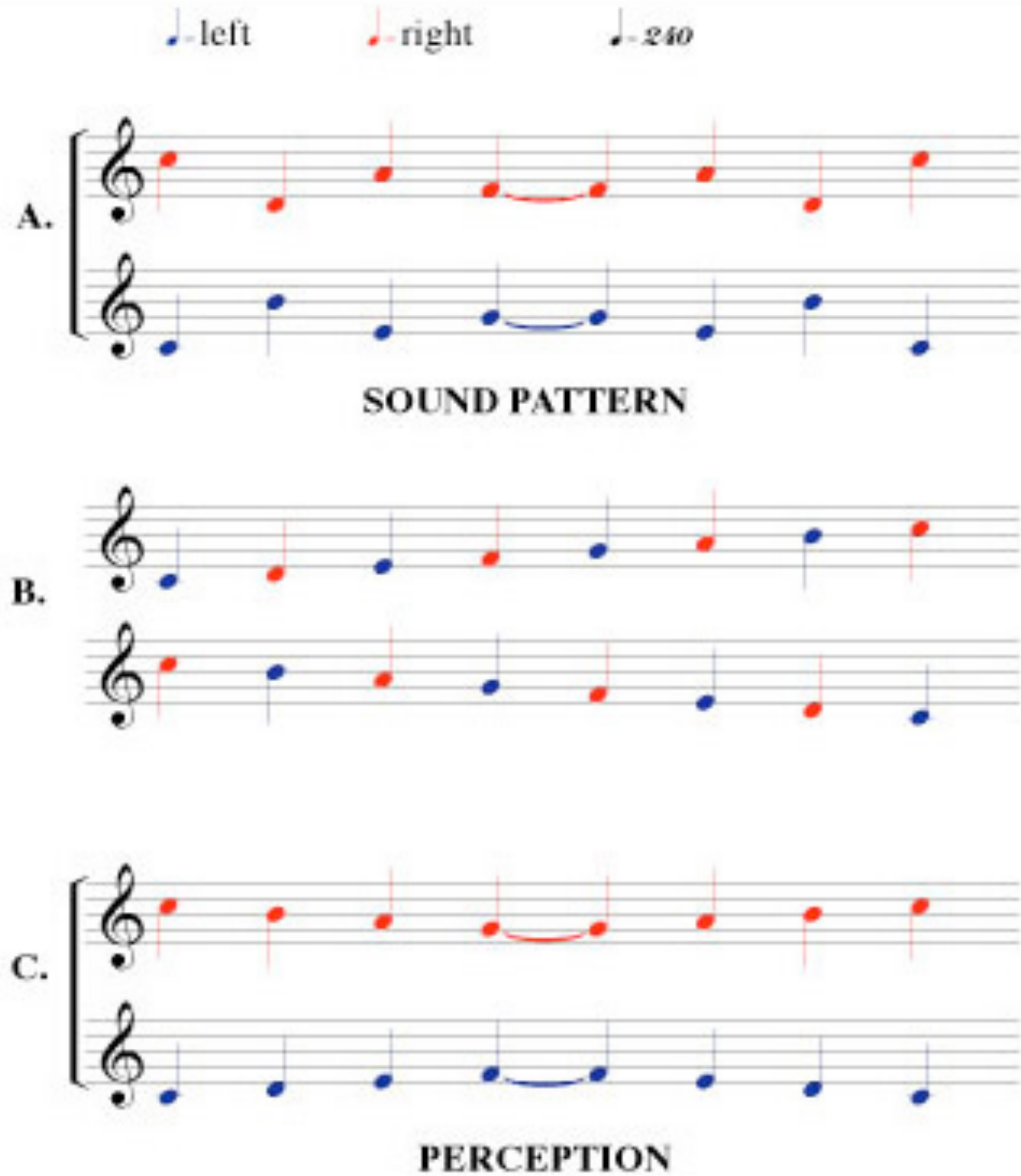




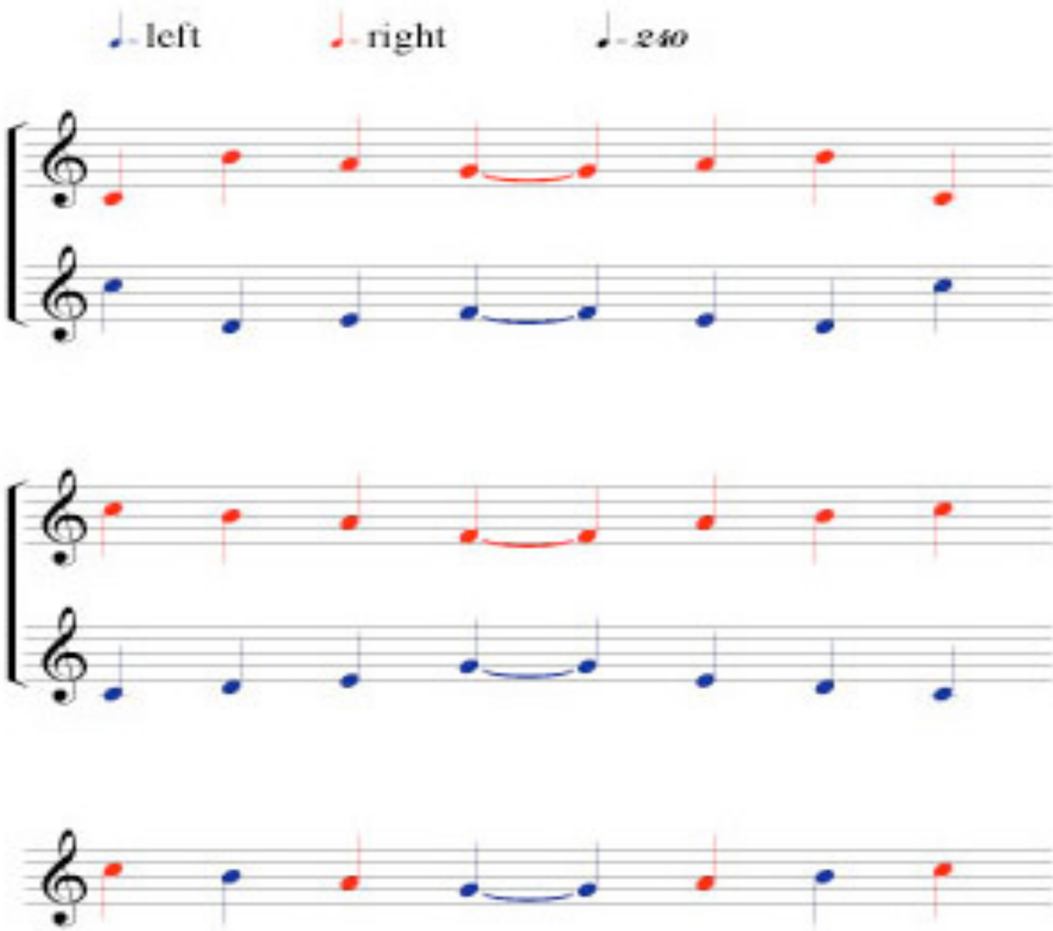
- Timbral Similarity (Wessel, 1979)
  - 16 synthetic orchestral instrument tones
  - MDS on similarity judgements
    - Spectral
    - Onset transients
  - Streaming based on spectral but not temporal similarity

# The Scale Illusion






*The pattern that produces Deutsch's scale illusion (A), and a way that it is often perceived (C). The notation in (B) shows how the pattern is composed of ascending and descending scales.*




*Some other ways that Deutsch's scale illusion is perceived.*

# Rhythm and Metre



- Rhythm:
- Metre:


- Metrical accents (Povel & Essens, 1985)
  - relatively isolated tones
  - second of a cluster of two tones
  - first or last tone in a cluster of of 3 or more tones

- Non-isochronous metre

# Rhythm and Metre

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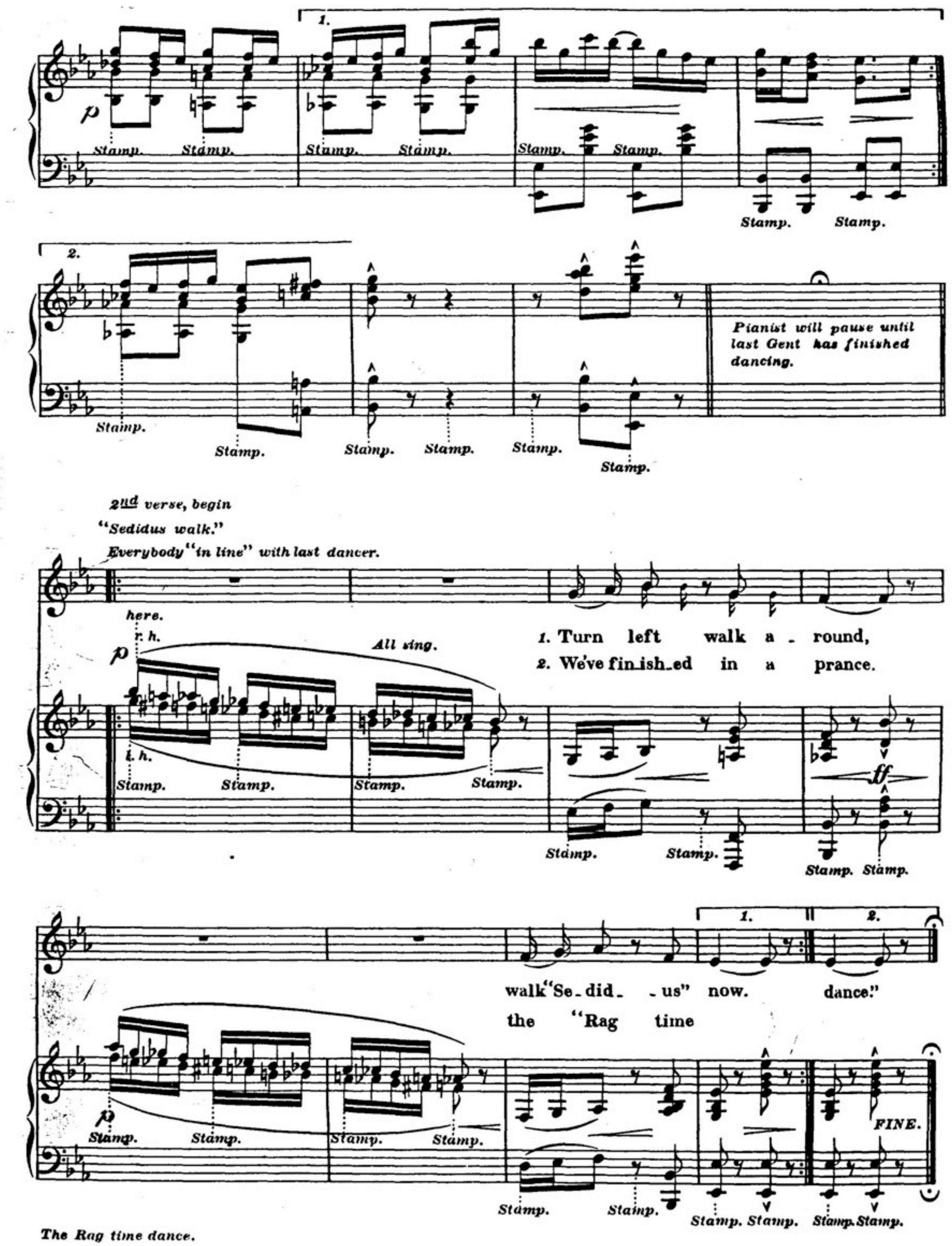
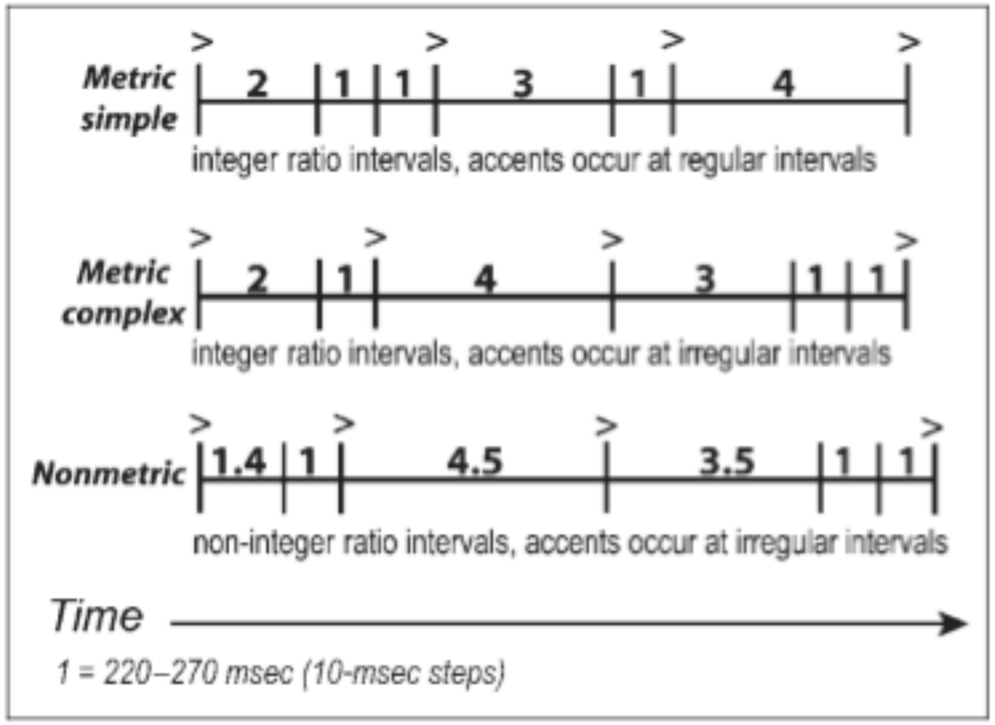
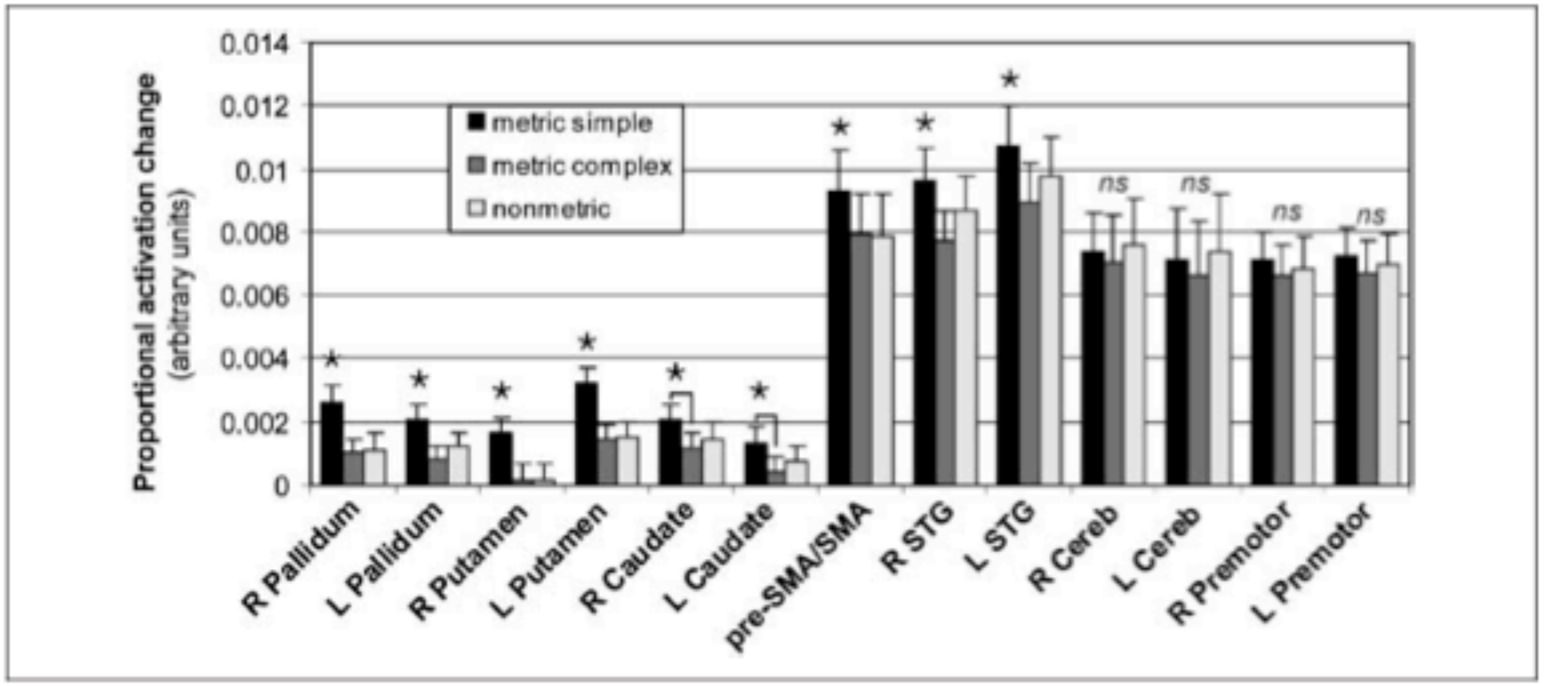


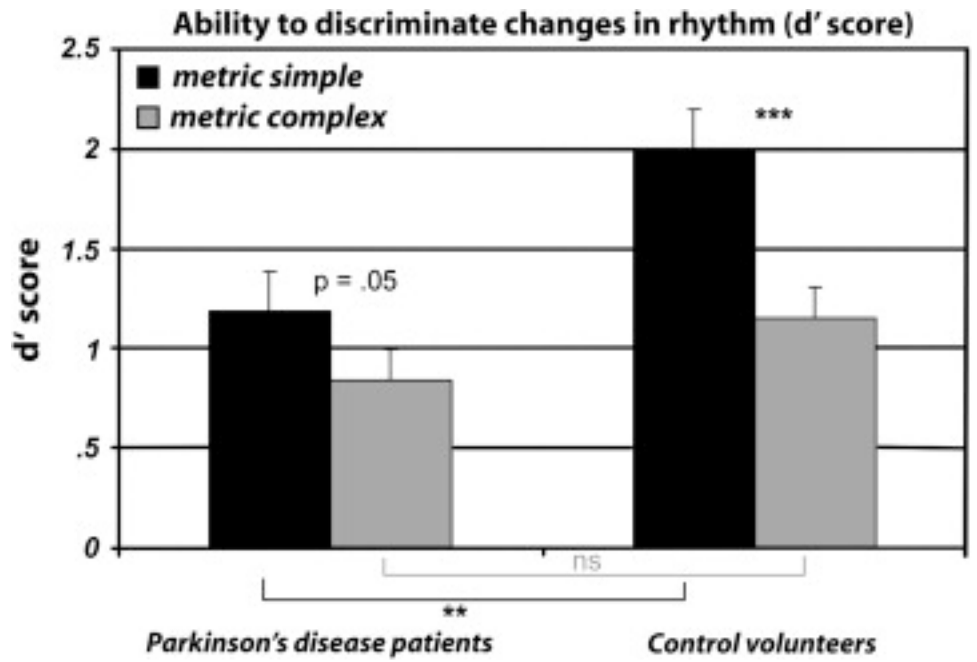
# Rhythm and Metre



- Beat-based rhythms:
  - activation in basal ganglia and SMA (Grahn & Brett, 2007; Grahn & Rowe, 2009)
  - impaired in Parkinson's disease (Grahn & Brett, 2009)

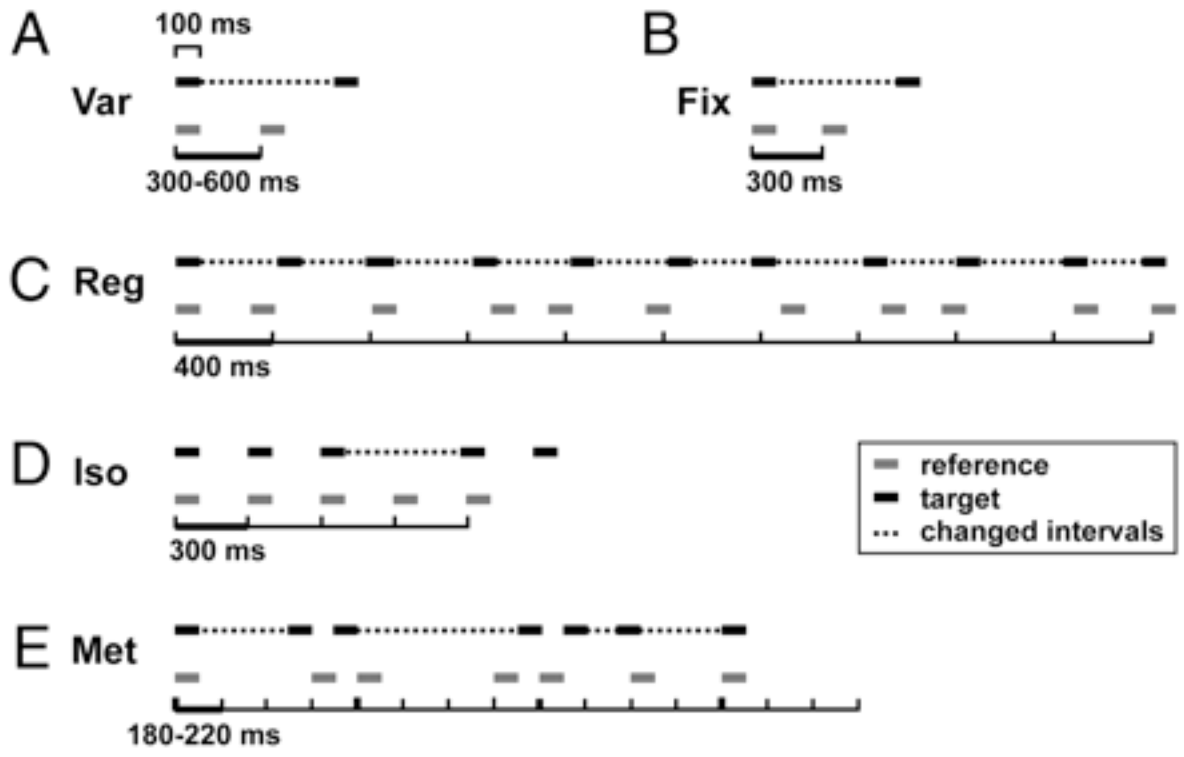


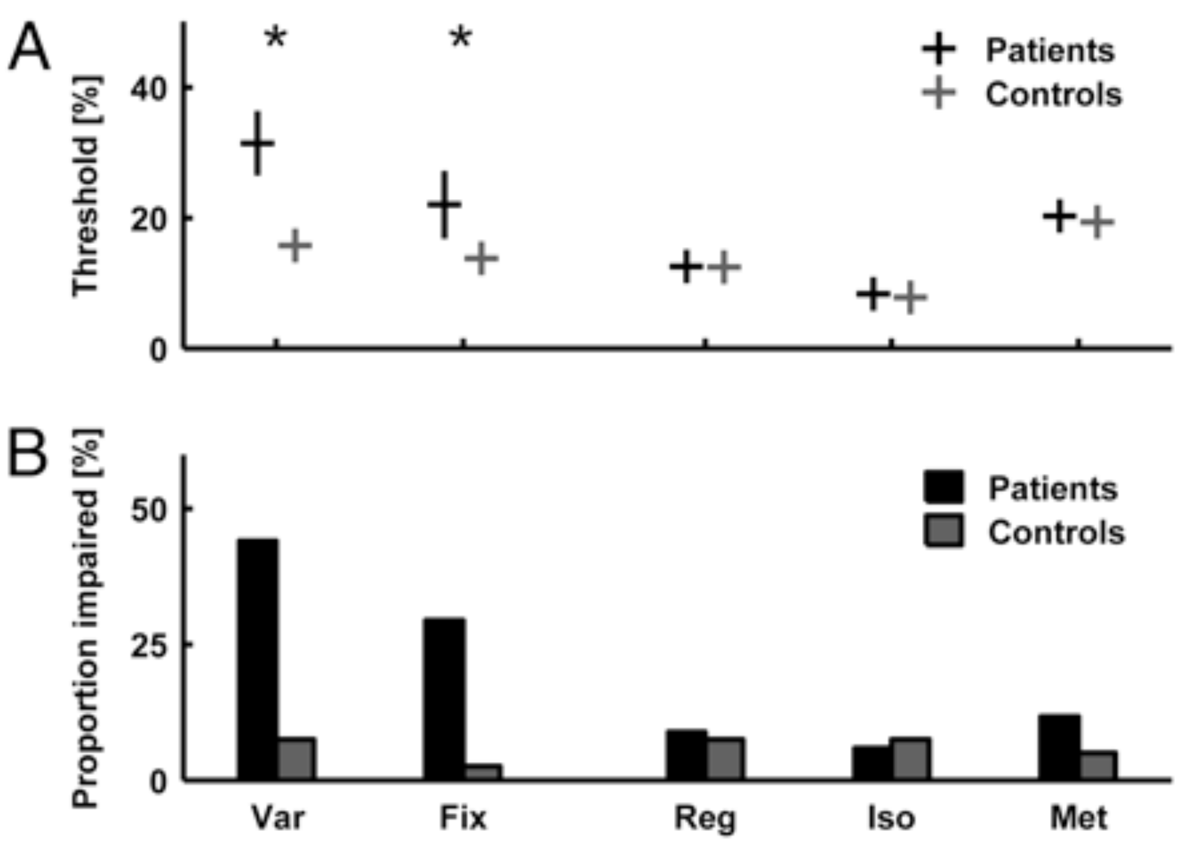



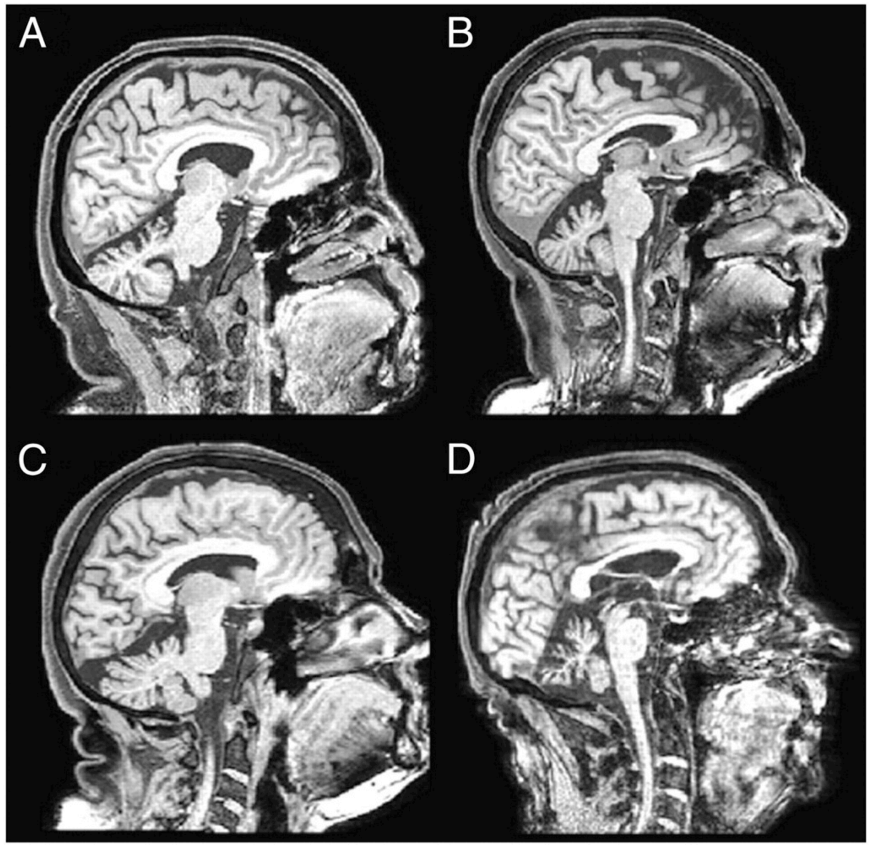



# Rhythm and Metre

- Interval-based timing:
  - cerebellar activation during perception of absolute duration of single time intervals (Lewis & Miall, 2003, 2006)
  - impaired in cerebellar degeneration (Grube et al., 2010)



# Evolution of Music

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- Darwin: “As neither the enjoyment nor the capacity of producing musical notes are faculties of the least use to man in reference to his daily habits of life, they must be ranked amongst the most mysterious with which he is endowed”
- Exaptation:
  - music is ‘auditory cheesecake’ (Pinker, 1997)
  - a useful null hypothesis
- Various adaptive theories:
  - Sexual selection (Miller, 2001; Darwin, 1871)
  - Group functions: vocal grooming (Dunbar, 1993, 1996)
  - Mother/infant bonding (Dissanayake, 2000; Trehub, 2000)
  - Music as play: way to practice cognitive, behavioural and social abilities during the altricial period (Cross, 1993)

# Evolution of Music

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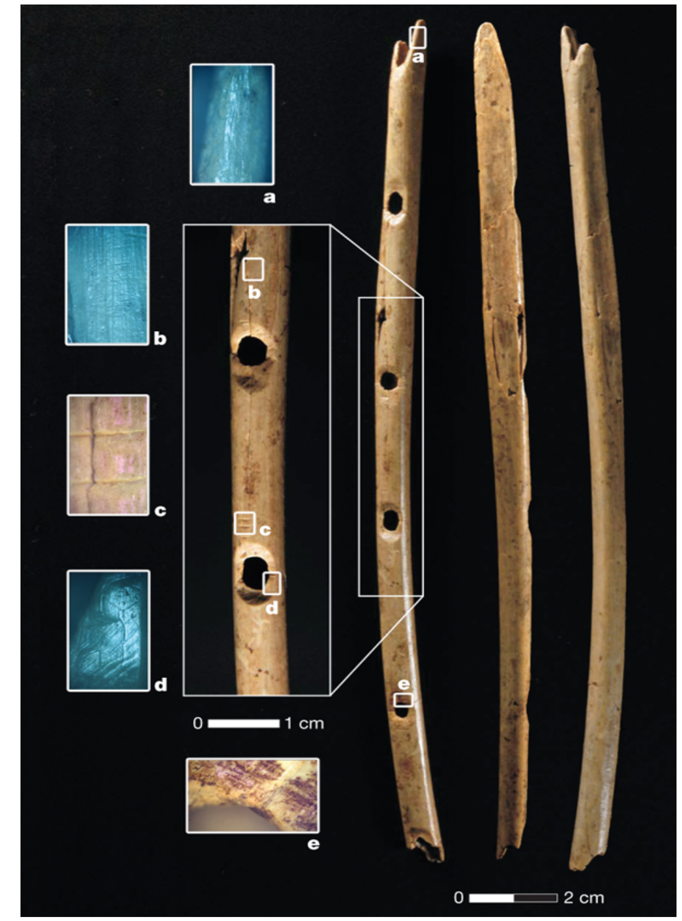
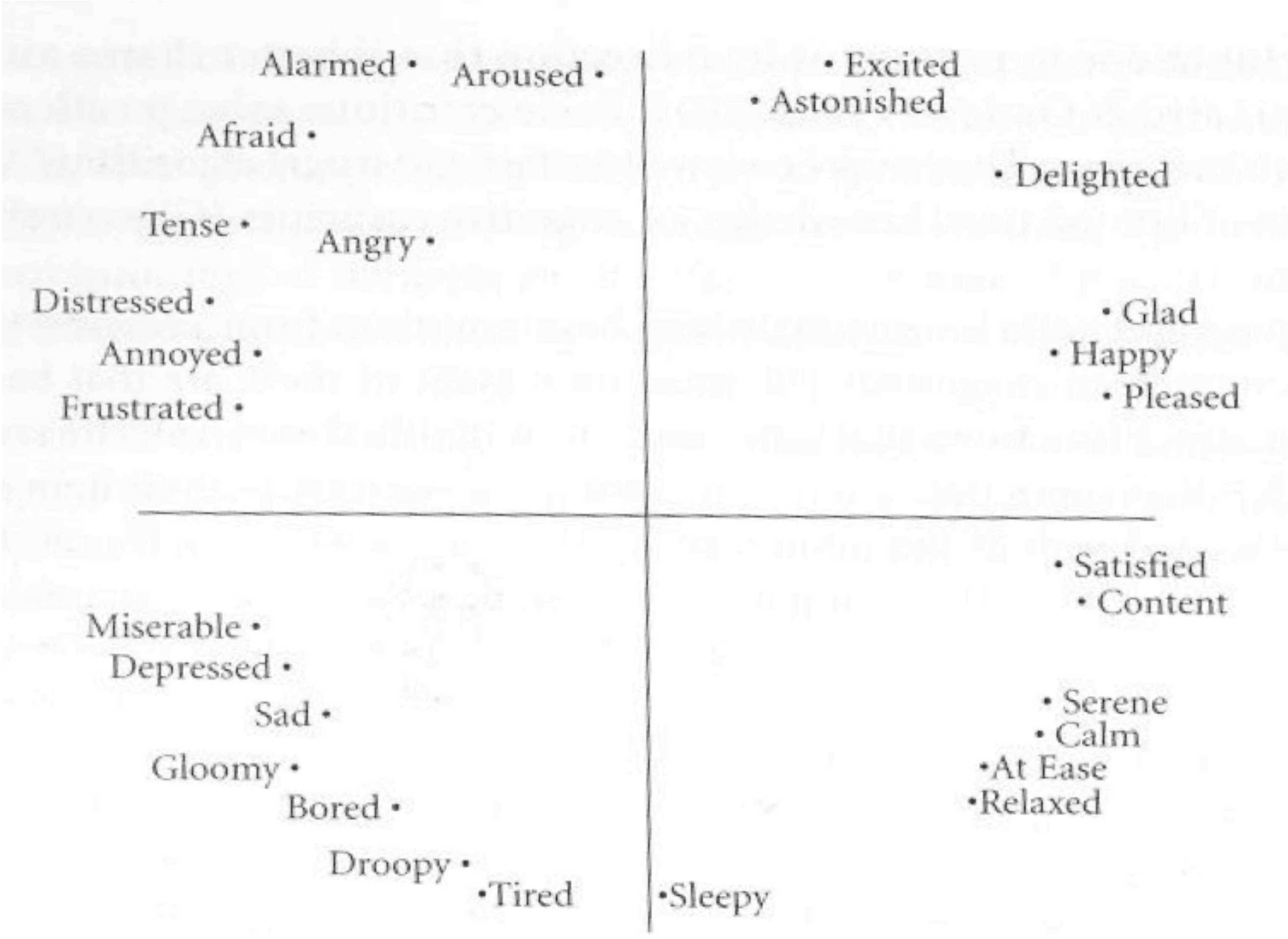
- Approaches
  - Paleo-archeology
    - bone flutes dating to 40k BP found in Germany (Conard et al., 2009)
  - Comparative research
    - homologous traits cannot be adaptations for music
  - Cross-cultural anthropology
    - what is universal across cultures?
  - Computational psychology
    - what behaviours can be learned in principle?
  - Developmental psychology
    - identify musical capacities of infants




# Music & Emotion



- some issues in studying musical emotions:
  - emotion vs mood
  - emotion expressed vs emotion felt
  - are musical emotions the same as everyday emotions
    - music does not have goal implications
    - there are a range of subtly different music-specific emotions (Scherer & Zentner, 2009)
  - Circumplex model of emotion (Russell, 1980)



# Music & Emotion



| Emotion component | Finding | Selected references |
| --- | --- | --- |
| Subjective feeling | Listeners report that they experience emotions while listening to music in experiments, questionnaires, diary studies, and qualitative interviews. Positive emotions are more commonly reported than negative emotions. | Behne 1997; DeNora 2000; Juslin & Laukka 2004; Pike 1972; Sloboda & O'Neill 2001 |
| Psychophysiology | Music listening may give rise to physiological reactions similar to those shown to other "emotional" stimuli, including changes in heart rate, skin temperature, electrodermal response, respiration, and hormone secretion. | Bartlett 1996; Krumhansl 1997; Lundqvist et al., in press; Nyklíček et al. 1997; Vaitl et al. 1993 |
| Brain activation | Listeners' responses to music involve regions of the brain that are known from previous research to be implicated in emotional responses, including thalamus, hippocampus, amygdala, prefrontal cortex, orbitofrontal cortex, midbrain/periaqueductal gray (PAG), insula, and nucleus accumbens. | Blood & Zatorre 2001; Blood et al. 1999; Brown et al. 2004; Koelsch et al. 2006; Menon & Levitin 2005 |
| Emotional expression | Music listening makes people cry, smile, laugh, and furrow their eyebrows, as indicated by self-reports, observations, and electromyographic measures of facial muscles. | Becker 2004; Frey 1985; Gabrielsson 2001; Sloboda 1991; Witvliet & Vrana 2007 |
| Action tendency | Music influences people's action tendencies, such as their tendency to help other people, to consume products, or to move – either overtly or covertly. | Fried & Berkowitz 1979; North et al. 2004; Rieber 1965; Harrer & Harrer 1977 |
| Emotion regulation | Listeners attempt to regulate their own emotional reactions to music, e.g., with regard to what are deemed appropriate responses in a social context. | Becker 2001; Gabrielsson 2001 |

Juslin & Västfjäll (2008, *Behavioural & Brain Sciences*)

# Music & Emotion

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- Brain-stem reflex
  - sudden, loud, dissonant or rapidly pulsing sounds stimulate arousal
  - brainstem mechanisms (e.g., IC)
- Evaluative conditioning
  - music as a conditioned stimulus
- Emotional contagion
  - music mimics other means of expressing emotion (e.g., language, Juslin & Laukka, 2003)
  - e.g., slow tempi associated with sadness
  - e.g., fast, loud, harsh timbre associated with distress
- Visual imagery
  - e.g., the storm in Beethoven's sixth symphony
- Episodic memory
  - music evokes a memory of a particular event
  - 'Darling, they're playing our tune'
- Expectation
  - the generation and violation of expectations can induce experience of tension, release, surprise, uncertainty...
  - based on learning and most related to musical structure

Juslin & Västfjäll (2008, *Behavioural & Brain Sciences*)

# Music & Aesthetics

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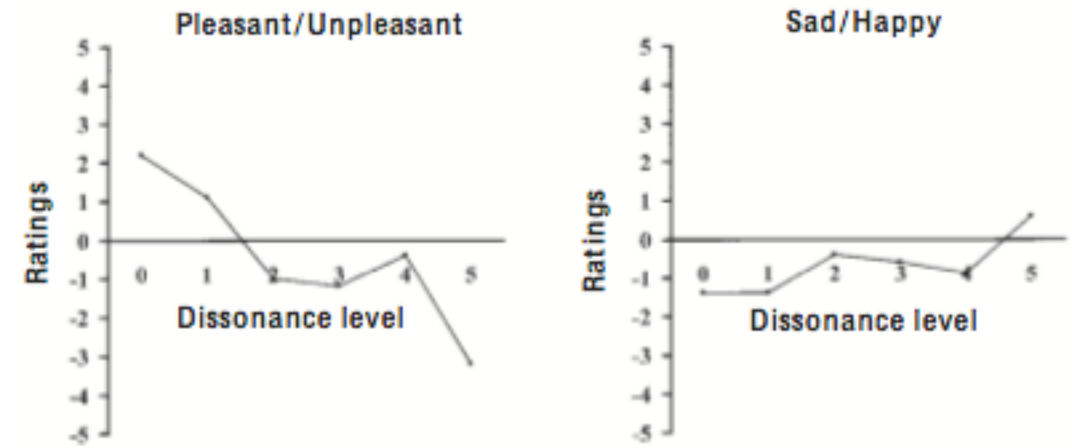
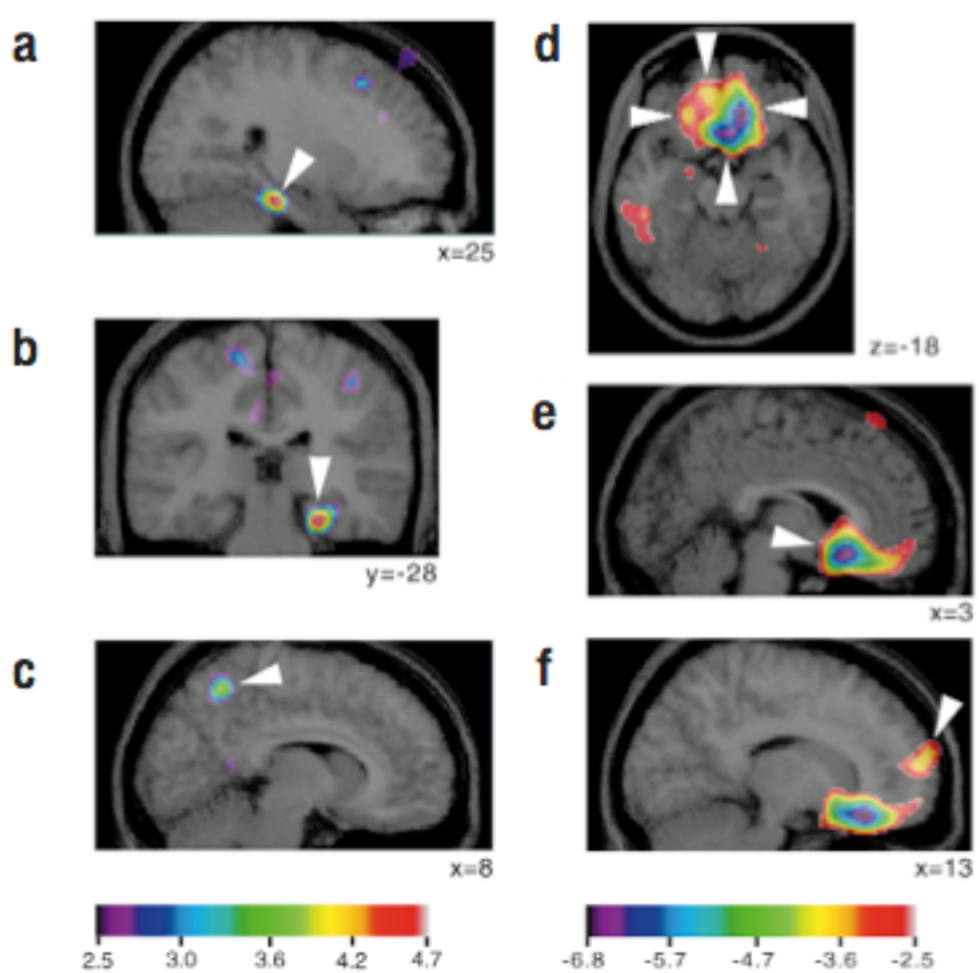
- 10 listeners
- 6 variants of a musical passage varying systematically in dissonance
- PET while listening to dissonant and consonant musical excerpts


- Positive correlation with dissonance
  - right parahippocampal gyrus
  - right precuneus
- Negative correlation
  - bilateral OFC
  - medial subcallosal cingulate
  - right frontal pole

Blood et al. (1999, *Nature Neuroscience*)

# Music & Aesthetics

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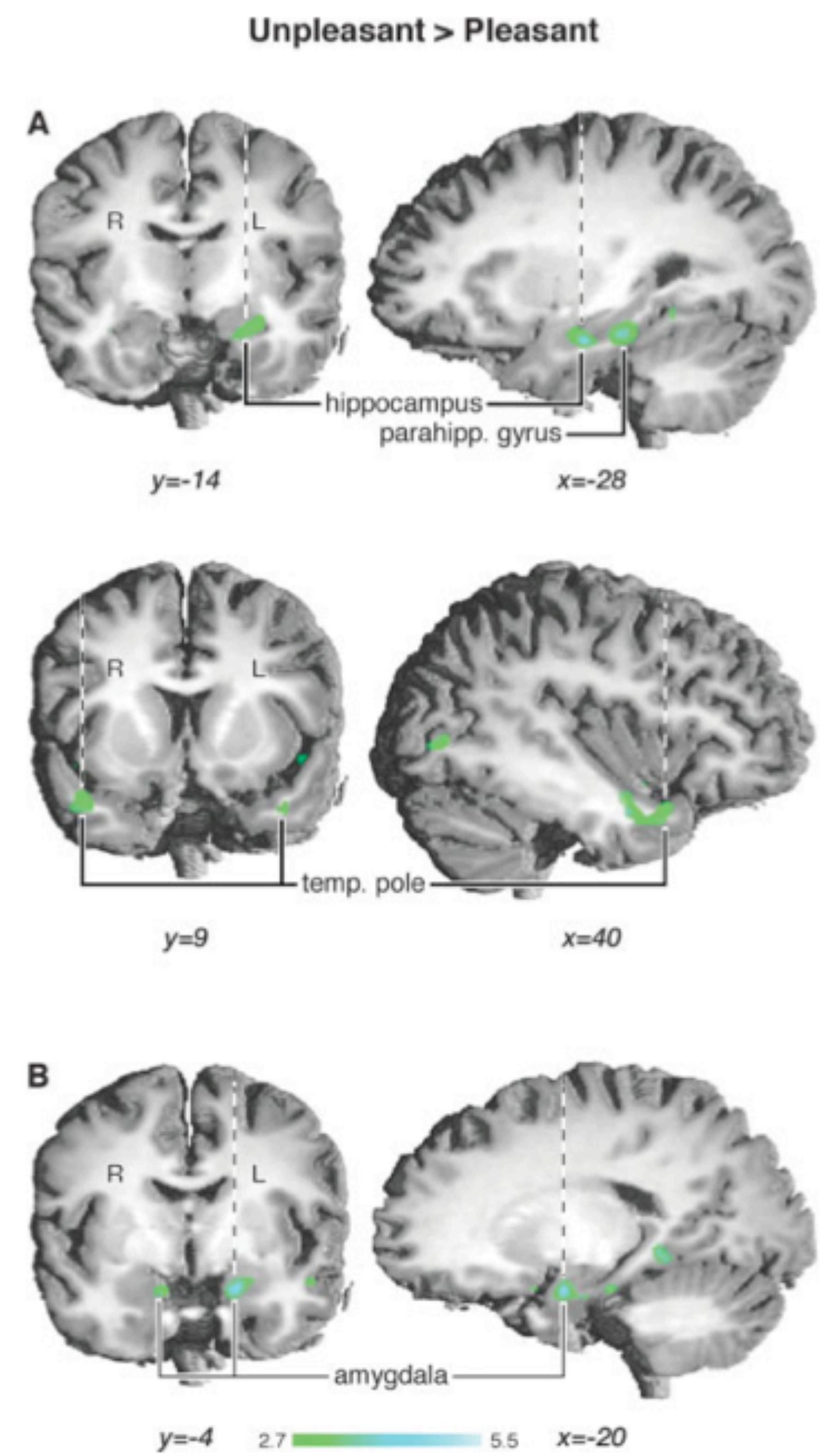
- 11 listeners
- 8 excerpts of joyful dance tunes
  - original & dissonant versions
- fMRI + tapping, followed by pleasantness rating

**TABLE II. Results of ROI analyses**

| Anatomical structure | Condition | Cond. × Block |
|---|---|---|
| Unpleasant > Pleasant | | |
| Amygdala | 0.002 | 0.0005 |
| Hippocampus | 0.0005 | — |
| Parahippocampal g. | 0.005 | 0.0001 |
| Temporal pole | 0.0001 | 0.002 |
| Unpleasant > Pleasant | | |
| Heschl's g. | 0.002 | 0.0001 |
| IFG (BA45/46) | 0.001[a] | 0.0001 |
| IFG (BA44i) | 0.01 | 0.0001 |
| Ant. sup. insula | 0.001 | 0.0002 |
| Rolandic op. (BA43) | 0.001 | 0.0001 |
| Ventral striatum | 0.005 | 0.001 |

Values are expressed as $P$.
[a] Interaction Condition × Hemisphere: $P > 0.05$.
For each anatomical structure, ROI values were compared at the group level using ANOVAs with factors condition (pleasant, unpleasant), block (first, second), and hemisphere.
IFG, inferior frontal gyrus.




Koelsch et al. (2006, *JOCN*)

# Music & Aesthetics



- ITPRA theory: we have evolved the ability to acquire accurate expectations to facilitate survival
- Two responses to surprising events:
  - Reactive: fast, automatic, subcortical, attention/arousal
    - an uncertain future → pessimism
  - Appraisal: slow, conscious, cortical

| *Response* | *Epoch* | *Questions addressed* | *Biological function* |
|---|---|---|---|
| **I**maginative | pre | What might happen? How does it feel? | motivate behaviour to increase likelihood of future reward |
| **T**ension | pre | Are you ready for it? | tailor arousal / attention to uncertainty / importance / imminence of anticipated outcome |
| **P**rediction | post | Did you guess right? | encourage formation of accurate expectations |
| **R**eactive | post | What to do in worst-case? | fast / autonomic / pessimistic responses prevent immediate disaster (reflex or learnt schema) |
| **A**ppraisal | post | How to respond in future? | slow / conscious assessment provide positive/negative reinforcement related to outcome |

Huron (2006)

# Music & Aesthetics

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- Prediction Effect:
  - Familiar, predictable stimuli are rewarding
  - Why?
    - Reduce orienting response and arousal (Zajonc, 1968, mere exposure)
    - Misinterpret ease of processing as a positive property of the stimulus (Bornstein and d'Agostino)
  - Huron argues that it is predictability that is important not familiarity
- Contrastive Valence:
  - How can surprise have a positive aesthetic effect?
  - Limbic contrast between:
    - Negative reactive response
    - Neutral or positive appraisal responses

Huron (2006)

# Music & Aesthetics

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| *Type* | *Response* | *Physiology* | *Control/Danger* |
|---|---|---|---|
| Awe | Freeze | Gasp/hold breath | Low / High |
| Laughter | Flight | Pant | Medium / Medium |
| Frisson | Fight | Chill/Piloerection | High / Low |

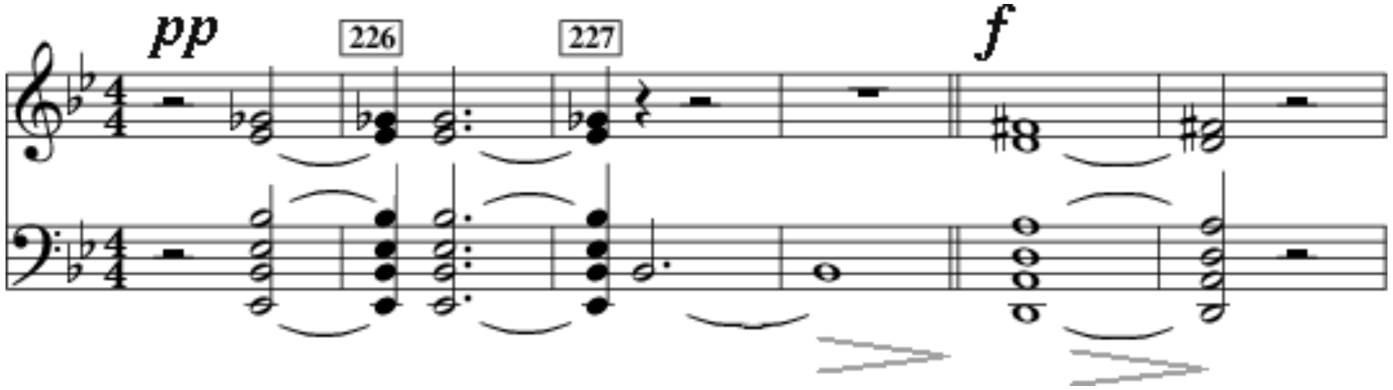
- Awe: ?
- Laughter:


Huron (2006)

# Music & Aesthetics



- Frisson:
  - A preparation to fight:
  - Rearing up, pilo-erection
- Examples:
  - Metrical syncopation
  - Schoenberg, Verklarte Nacht




Huron (2006)

# Music & Aesthetics

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- Chills, shivers or frisson
  - a common physiological response to music (Panksepp, 1995; Sloboda, 1991)
  - usually experienced as pleasurable (Goldstein, 1980)
  - involve increased subjective emotion and physiological arousal (Grewe et al., 2009)
  - are influenced by familiarity with the music (Grewe et al., 2009)
  - Are more often experienced by women
  - tend to be associated with:
    - unexpected harmonies
    - sudden dynamic or textural changes
    - introduction of new elements

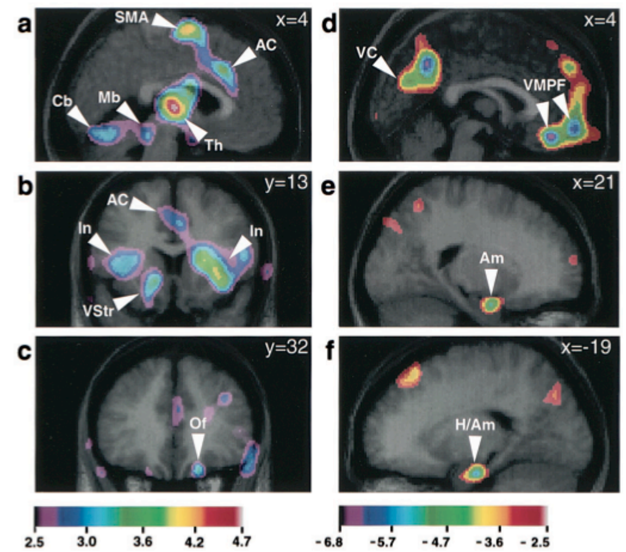
| | *Mean score (max = 5)* | *% experiencing in previous five years* |
|---|---|---|
| Shivers down the spine | 3·08 | 90 |
| Laughter | 2·80 | 88 |
| Lump in the throat | 2·68 | 80 |
| Tears | 2·65 | 85 |
| Goose pimples | 2·40 | 62 |
| Racing heart | 2·31 | 67 |
| Yawning | 2·15 | 58 |
| Pit of stomach sensations | 2·11 | 58 |
| Sexual arousal | 1·56 | 38 |
| Trembling | 1·51 | 31 |
| Flushing/blushing | 1·46 | 28 |
| Sweating | 1·44 | 28 |

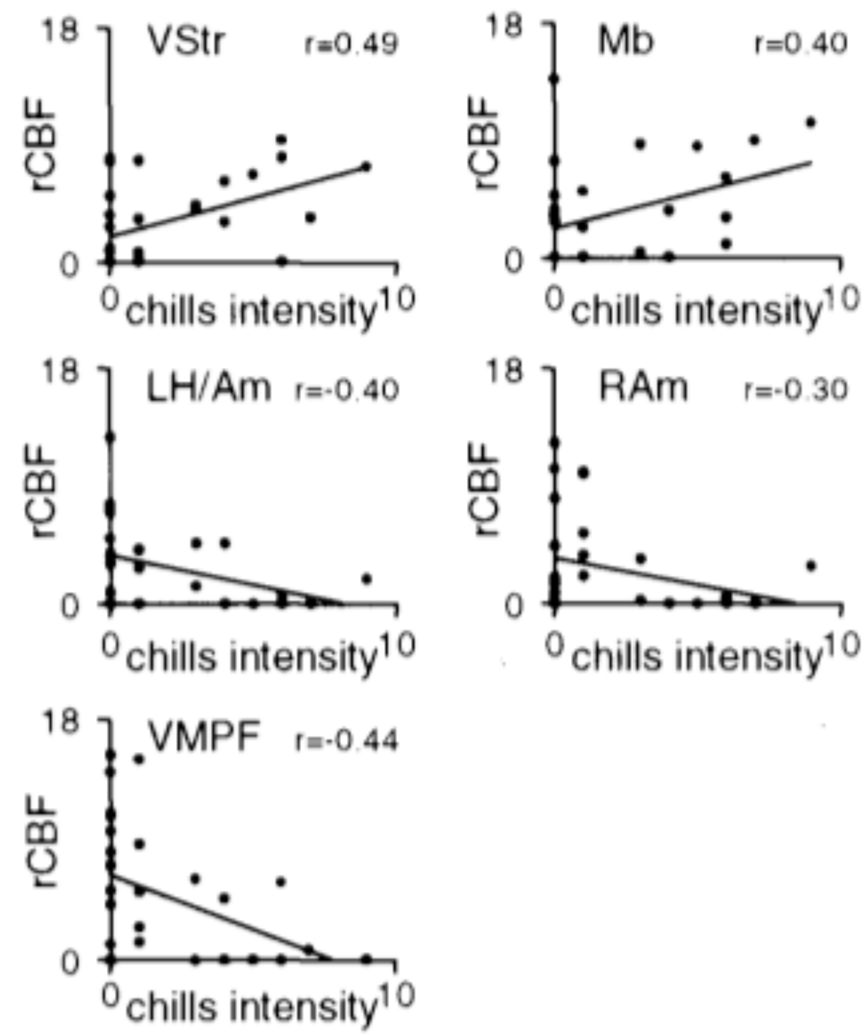
| Response: | *Tears* | *Shivers* | *Heart* | | |
|---|---|---|---|---|---|
| Total No. of passages provoking each response: | 20 | 13 | 5 | | |
| *Feature* | *Number of passages containing each feature* | | | *χ-square* | *P* |
| 1. Harmony descending cycle of fifths to tonic | 6 | 0 | 0 | 8·96 | <0·02 |
| 2. Melodic appogiaturas | 18 | 9 | 0 | 17·36 | <0·001 |
| 3. Melodic or harmonic sequence | 12 | 4 | 1 | 8·06 | <0·02 |
| 4. Enharmonic change | 4 | 6 | 0 | 2·00 | NS |
| 5. Harmonic or melodic acceleration to cadence | 4 | 1 | 2 | 3·19 | NS |
| 6. Delay of final cadence | 3 | 1 | 0 | 1·88 | NS |
| 7. New or unprepared harmony | 3 | 12 | 1 | 8·56 | <0·02 |
| 8. Sudden dynamic or textural change | 5 | 12 | 3 | 4·92 | NS |
| 9. Repeated syncopation | 1 | 1 | 3 | 13·97 | <0·001 |
| 10. Prominent event earlier than prepared for | 1 | 4 | 3 | 8·83 | <0·02 |

Sloboda (1991)

# Music & Aesthetics

- Method
  - 10 participants, at least 8 years of musical training
  - Self-selected musical excerpts that produced emotional responses including chills
  - Control: others' selections that didn't produce emotional responses (< 3 / 10)
- Results:
  - Reported chills during 77% of scans with selected music
  - increased heart rate, muscle contraction and respiration during chills compared to controls
  - Emotional intensity ratings correlated with:
    - Changes in brain areas involved in reward, emotion ar arousal (ventral striatum, dorsomedial midbrain, amygdala, OFC, VMPF)
  - Areas also involved in responses to biologically relevant stimuli such as food, drugs and sex
  - Increases in ventral striatum and decreases in amygdala




Blood & Zatorre (2001, *PNAS*)

# Summary

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- The structure of sound
- Neurophysiology of the auditory system
- Perception of basic musical features:
  - Pitch: absolute, scale degree, interval, contour
  - Timing: event onset and duration
  - Dynamics: amplitude
  - Timbre
  - Spatial location
- Higher-level cognitive representation of music:
  - Grouping
    - Fusion (harmony)
    - Streaming (compound melody)
    - Grouping (motifs & phrases)
  - Rhythm, metre, tempo
- Music and general cognitive & neural processes
  - Memory and attention
  - Performance & communication
  - Emotion and aesthetics

# References

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- Music Perception & Cognition
  - Key texts:
    - Helmholtz (1863). *On the Sensations of Tone as a Physiological Basis for the Theory of Music*
    - Seashore (1938). *The Psychology of Music*
    - Meyer (1956). *Emotion and Meaning in Music*
    - Roger Shepard (1964). Circularity in Judgements of Absolute Pitch. *JASA*, 36(12)
    - Diana Deutsch (1982). *The Psychology of Music*
    - Lerdahl & Jackendoff (1983). *A Generative Theory of Tonal Music*
    - Krumhansl (1990).*The Cognitive Foundations of Music Pitch*
    - Bregman (1990). *Auditory Scene Analysis*
    - Peretz & Zatorre (2003). *The Cognitive Neuroscience of Music*
  - Journals
    - Music Perception (1.7)
    - Psychology of Music ()
    - Journal of New Music Research ()
    - Musicae Scientiae (-)
    - Empirical Musicology (-)
    - Psychomusicology (-)
  - Conferences
    - International Conference on Music Perception and Cognition (ICMPC, http://www.icmpc.org, biennial)
    - Society for Music Perception and Cognition (SMPC)
    - European Society for the Cognitive Sciences of Music (ESCOM, triennial)
    - The Neurosciences and Music (9-12 June 2011, Edinburgh)

# Music Cognition @

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- *Intelligent Sound & Music Systems (ISMS)* group
  - Music Information Retrieval (MIR)
  - Understanding and replicating human creativity
  - Generative Music
  - Music Cognition
- *Music, Mind & Brain (MMB)* group
  - Disorders of music perception
  - Music performance
  - Music & emotion
  - Musical memory and similarity (earworms and copyright infringement)
  - Brain responses to music (EEG)

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