Nonperiodic aspects of rhythm as a key link

Patel Ch. 3.4-3.5

Interlude: Rhythm in poetry

- The study of poetic rhythm has been the focus of a good deal of research by literary scholars.
  - Poetic 'meter' refers to the abstract patterning scheme that governs the temporal structure of a poem.
    - E.g. Iambic pentameter, where each line has five iambs (weak + strong feet).
  - 'Rhythm' refers to the actual patterning of durations and accents.
    - E.g. the substitution of a trochaic (strong + weak) foot at the onset of a line.
  - Listeners are said to internalize the regularities of meter and perceive departures as variation from a stable background.

Interlude: Rhythm in poetry cont.

- But musical meter refers to temporal periodicity, whereas poetic meter involves configurational periodicity.
  - E.g. in iambic pentameter it is the weak + strong configuration of the iambic food that is the design focus, not the isochrony of stressed syllables.
- Different languages tend to favor different kinds of poetic meter
  - English verse: number of stresses per line is the focus, independent of the number of syllables.
  - French verse: number of syllables per line is the focus.

Interlude: Rhythm in poetry cont.

- Fant et al. 1991 studied Swedish poetry
  - The weak syllable in iambic feet is about 50% the length of the strong syllable
  - In trochaic feet, the weak syllable is 80% of the length of the preceding strong syllable due to preboundary lengthening.
- Adams 1997
  - Trochaic meters are often associated with awe and the suspension of reality in English.
  - Perhaps due to the contrast with the rhythm of ordinary speech, giving the resulting speech an incantatory feel.
    - Tyger! Tyger! burning bright
      In the forest of the night

Interlude: Rhythm in song

- When words in languages like English with clearly defined stress are set to metrical music, a relationship is established between the syllabic accent patterns and musical metrical accent patterns.
- Composers exploit this relationship for artistic ends.
- Palmer & Kelly 1992 found that stressed syllables tended to align with metrically strong beats in Gilbert and Sullivan songs, contributing to a sense of precision and balance.

Interlude: Rhythm in song cont.

- Temperley 1999 looked at rock songs and found that verbal stress frequently anticipated metrical accent by a fraction of a beat, contributing a sense of syncopation and rhythmic energy.

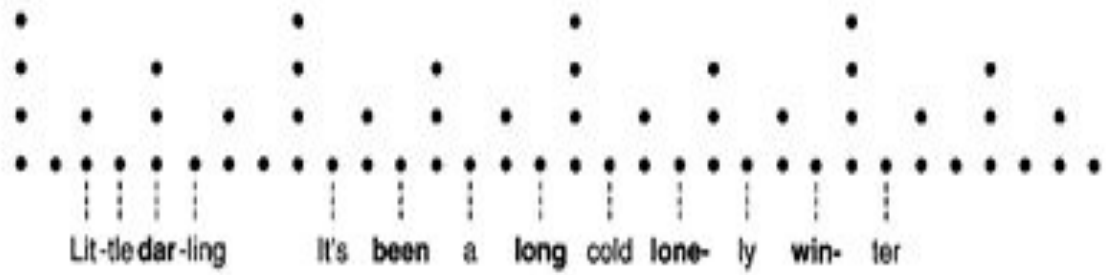

Figure 3.13 A musical metrical grid for a portion of the Beatles' "Here Comes the Sun." The lyrics are aligned below the grid, and linguistically stressed syllables are indicated in boldface: Note how most such syllables slightly precede strong metrical positions in the music. From Temperley, 1999.

Interlude: Rhythm in song cont.

- Areas for research:
  - Arvaniti 1994 showed that Greek tolerates a more irregular alternation between strong and weak syllables than English.
    - And Balkan music features irregularly spaced beats.
    - Would Greek-speaking children find it easier to learn the irregular meters of Balkan songs than English-speaking children?
  - Contemporary rap music could be studied to determine the relations between verbal and musical accent points.
  - Is there anything to the composers' R. Strauss and R. Rolland suggestion that French opera seems to tolerate more mismatch between stress in speech and metrical accent in music than German opera?
    - Debussy: 'Chevéux, chéveux, dé cheveux.'

Relations between musical structure and linguistic rhythm

- The notion that a nation's instrumental music reflects its prosody has long attracted music scholars.
- But this idea has not previously been pursued rigorously.
- Patel & Daniele 2003a compared French and British English music using the nPVI.
  - Normalized Pairwise Variability Index
  - Low, Grabe & Nolan 2000.

Relations between musical structure and linguistic rhythm cont.

- The nPVI is a purely relative measure of contrast.
  - The durational difference between two intervals is measured relative to the average duration of the pair.
  - This normalization, which was originally introduced to control for differences in speech rate, makes the nPVI a dimensionless quantity that can be applied to both speech and music.
    - E.g. speech durations measured in seconds and music durations measured in fractions of a beat.
- The nPVI has been applied to vowels, which form the core of syllables, which can in turn be compared to musical tones.

Relations between musical structure and linguistic rhythm cont.

- The nPVI was applied to short, newslike sentences from British English and continental French (corpus of Nazzi et al. 1998).
- The nPVI is significantly higher for the English speech.
- In the sample English sentence, some vowels are very short (due to vowel reduction) and some are very long (due to stress).
- In the sample French sentence, the vowels are more even.
- Example sentences.

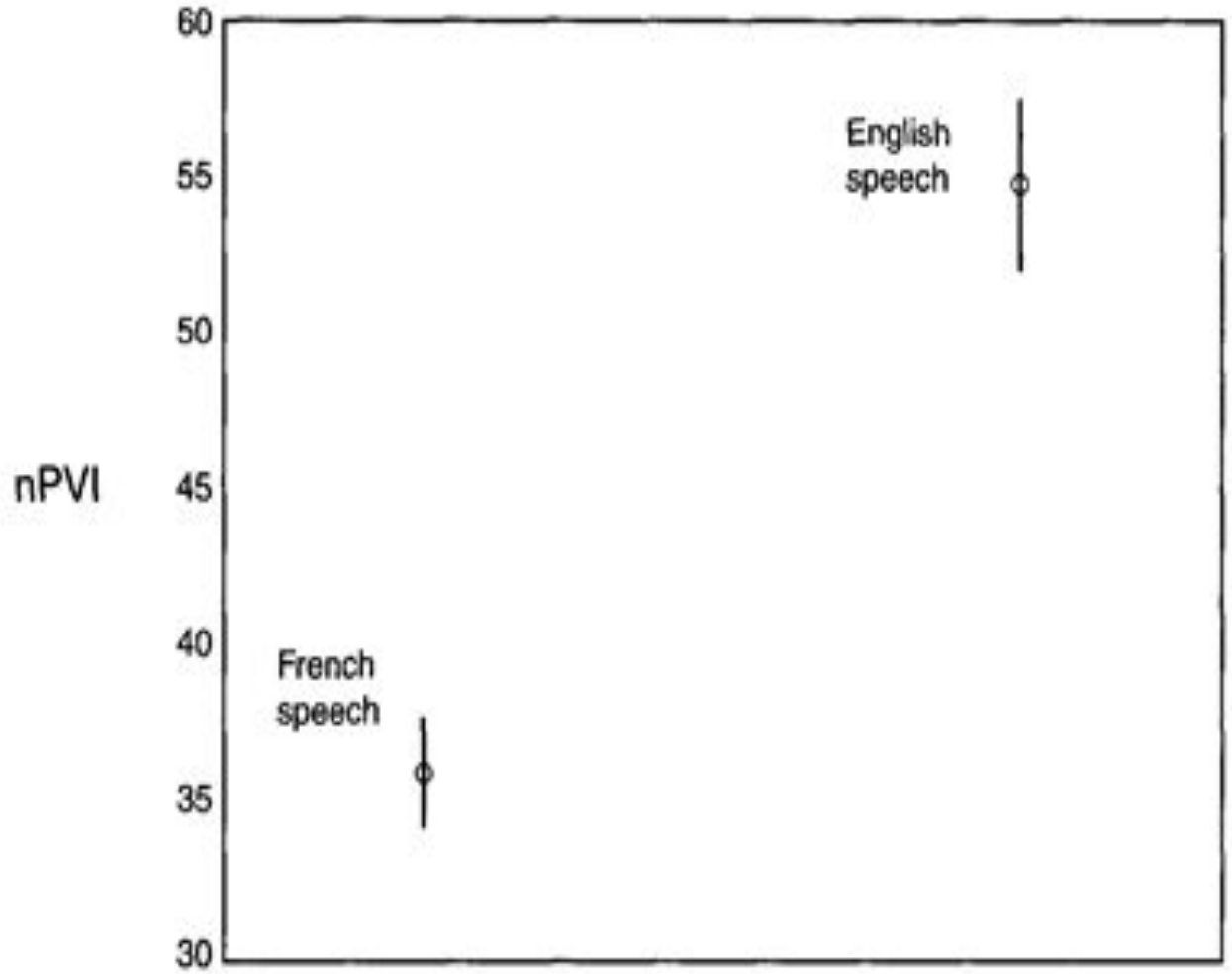

Figure 3.14 The nPVI of British English and French sentences. Error bars show +/- 1 standard error. Data from Patel, Iversen, & Rosenberg, 2006.

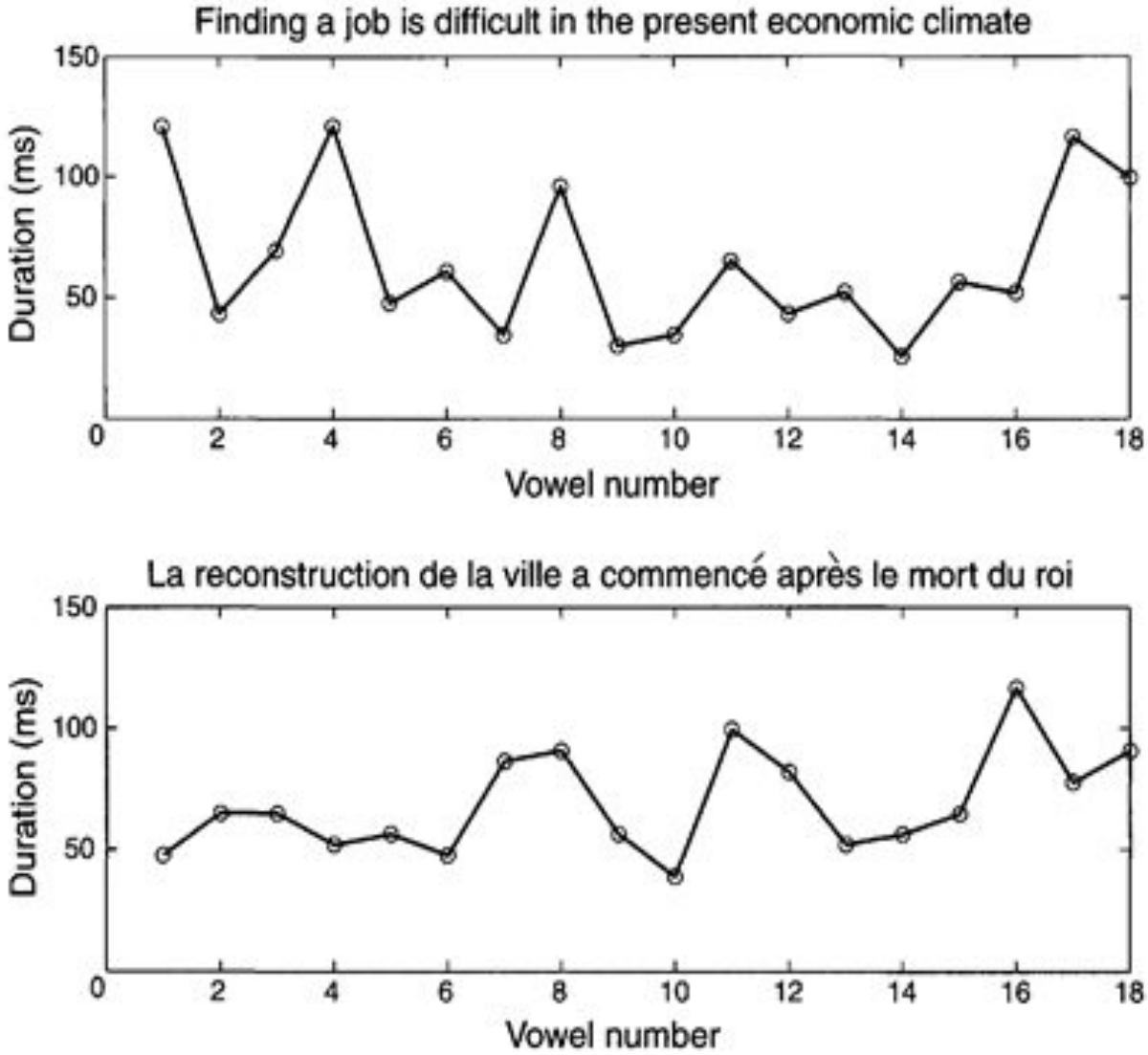

Figure 3.15 Vowel durations in an English and a French sentence. Note the greater degree of short-long contrast in the English sentence between adjacent vowel durations. The nPVI for the English sentence is 54.9, and for the French sentence is 30.0.

Relations between musical structure and linguistic rhythm cont.

- For music, Western musical notation indicates the relative duration of notes in an unambiguous fashion.
- Assign an index of 1 to the first note of each theme, and express the durations of the remaining notes as multiples or fractions of 1.
- The nPVI of the Debussy theme is much lower than the Elger theme despite the fact that the raw variability of the Debussy theme is greater as measured by the coefficient of variation.
  - The nPVI measures the degree of contrast between successive elements, not the overall variability of those elements.

D122: Debussy - Quartet in G minor for Strings, 1st movement, 2nd theme

E72: Elgar - Symphony No. 1 in A flat, Opus 55, 4th movement, 2nd theme

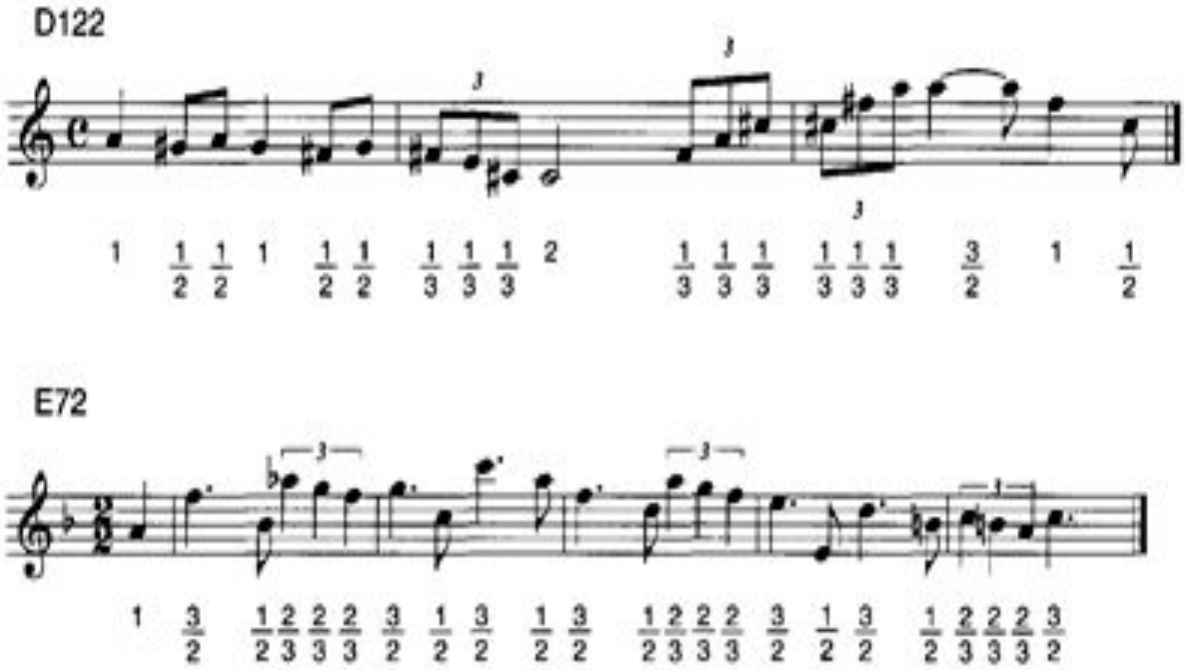

Figure 3.16 Two musical themes with the relative durations of each note marked. nPVI of D122 = 42.2, of E72 = 57.1. Themes are from Barlow & Morgenstern, 1983. From Patel & Daniele, 2003a.

Relations between musical structure and linguistic rhythm cont.

- Musical themes were chosen from *A Dictionary of Musical Themes*, by Barlow & Morgenstern, 1983.
- The composers had to be from a fairly recent musical era because the speech is contemporary.
  - Those who were born in the 1800s and died in the 1900s.
  - The turn of the century was a period of "musical nationalism" in Europe.
- The composers had to be native speakers of British Engish or French who lived and worked in England or France.
- The composers had to have at least five entries.

Relations between musical structure and linguistic rhythm cont.

- 16 composers were included.
  - E.g. Elgar, Delius, Vaughan Williams from England.
  - E.g. Debussy, Poulenc, Saint-Saëns from France.
- One nPVI for each of 300 themes was calculated.
- The two cultures have significantly different nPVI values, with the differences being in the same direction as the linguistic nPVI differences.

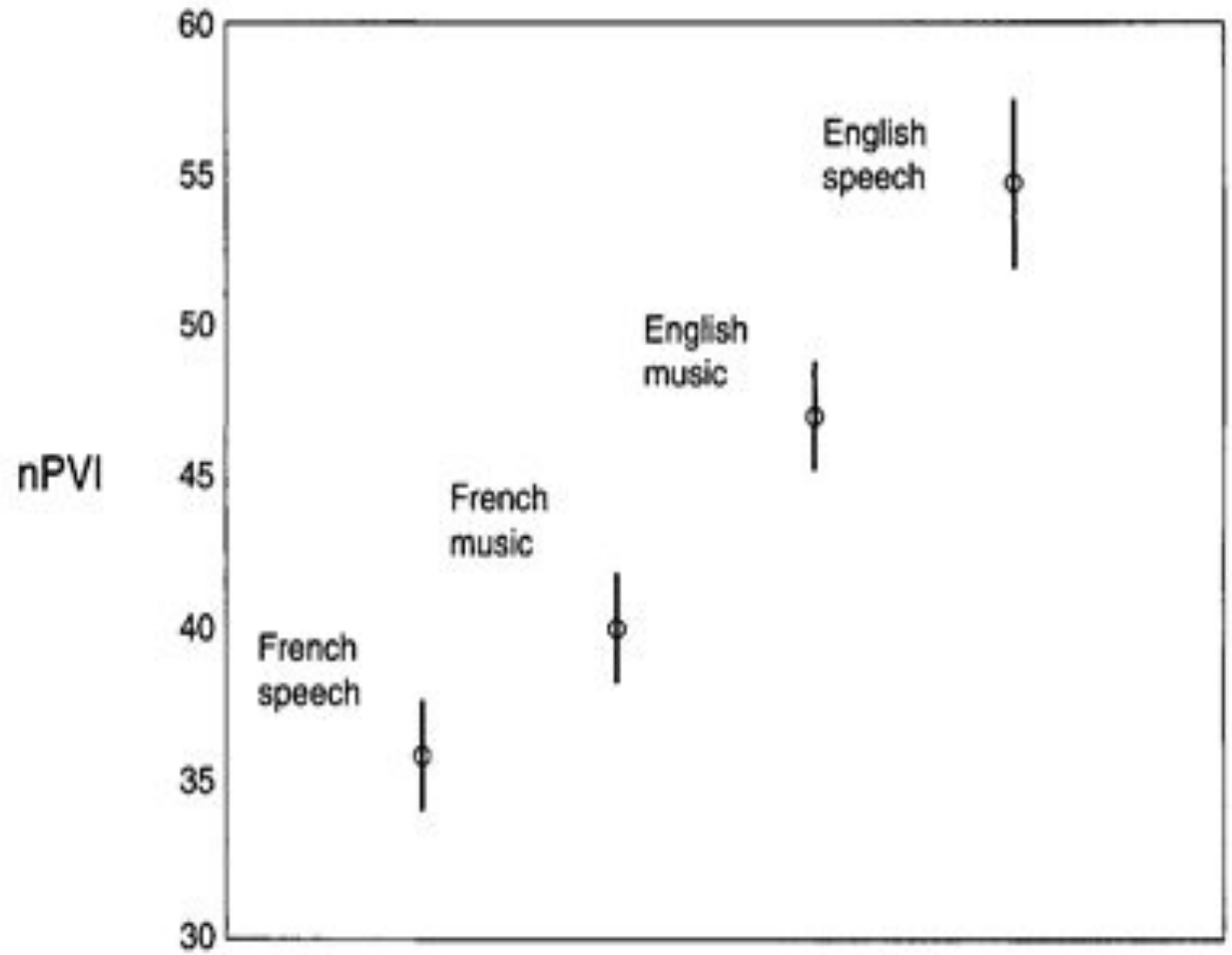

Figure 3.17 The nPVI of British English and French musical themes. Error bars show +/- 1 standard error. Data from Patel & Daniele, 2003a, and Patel, Iversen, & Rosenberg, 2006.

Relations between musical structure and linguistic rhythm cont.

- Thus there is empirical evidence that speech rhythm is reflected in musical rhythm.
- How is this connection between language and music mediated?
  - The perceptual system is sensitive to rhythmic patterns in language from a very early age.
  - Composers internalize these patterns as they learn to speak, perhaps through statistical learning.
  - As they write music, these patterns are "in their ears" and they consciously or unconsciously draw on them.
  - This link is likely greater during historical epochs where composers seek a national character for their music.

Relations between musical structure and linguistic rhythm cont.

- Would the musical nPVI difference be observed if a broader sample of English and French themes and composers were studied?
- Would the result generalize to other cultures in which stress- versus syllable-timed languages are spoken?
- Huron & Ollen 2003 compared 2000 English and French musical themes, composed between the mid-1500s and the mid-1900s.
  - They found a significant difference, although it was smaller than that found by Patel & Daniele.

Relations between musical structure and linguistic rhythm cont.

- They also compared almost 8000 themes from 12 nationalities over more than 3 centuries
  - Four out of five nations with stress-timed languages do indeed have higher musical nPVI values than do the three nations with syllable-timed languages.
    - American, Austrian, English, Swedish compared to French, Italian and Spanish.

Table 3.1 Musical nPVI Values for Eight Different Nationalities

	Musical nPVI	
	Mean	S.E.
Nationalities With Stress-Timed Languages		
American	46.7	1.0
Austrian	45.1	0.6
English	45.6	0.9
German	43.2	0.6
Swedish	50.0	2.4
Nationalities With Syllable-Timed Languages		
French	43.4	0.7
Italian	41.4	1.0
Spanish	42.5	1.9

Relations between musical structure and linguistic rhythm cont.

- Only German has a low nPVI despite being a stress-timed language with a high nPVI for speech.
  - This may be due to the influence of Italian music on German music.
  - Patel & Daniele 2003b, 2004 examined themes from 14 German composers historically by birth year.
  - Over the course of 250 years, nPVI almost doubled.
  - This likely reflects historical changes in musical style, perhaps including a waning influence of Italian music on German period over this period
    - From the Baroque era (1600-1750), through the Classical era (1750-1825), and into the Romantic era (1825-1900).

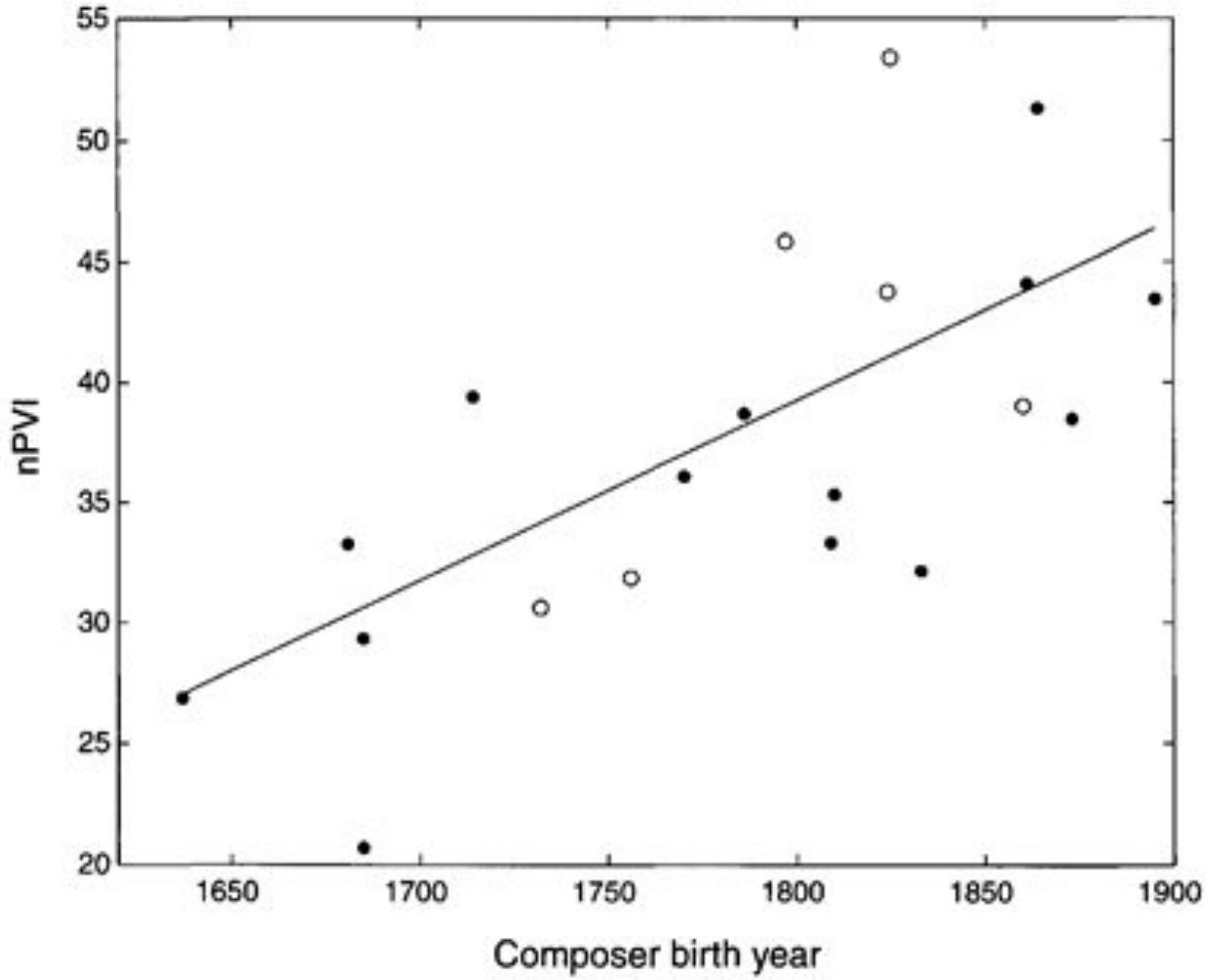

Figure 3.18 nPVI as a function of composer birth year for 20 composers. (Solid dots = German composers; open dots = Austrian composers.) The best-fitting linear regression line is shown. From Patel & Daniele, 2003b.

Relations between nonlinguistic rhythm perception and speech rhythm

- Jakobson, Fant & Halle 1952 suggested that Czech, French and Polish hear a series of knocks differently due to lexical stress patterns in the language.
  - X x x X x x X… (X x x) Czech
(x x X) French
(x X x) Polish
- Stobart & Cross 2000 documented a form of music from the Viacha people of the Bolivian highlands
  - They clap or tap on the shorter of two events.
  - This may be related to the lexical stress patterns in Quechua.
  - Sound example.

Relations between nonlinguistic rhythm perception and speech rhythm cont.

- Are there cultural differences in non-linguistic rhythm perception that are influenced by linguistic rhythms?
- It is known that native language segmentation or grouping strategies are applied even when listening to a foreign language.
- Yet, it is widely believed that elementary grouping strategies reflect general auditory biases not influenced by culture.
  - 1. A louder sound tends to mark the beginning of a group.
  - 2. A lengthened sound tends to mark the end of a group.
- But these studies were done with American, Dutch and French subjects.

Relations between nonlinguistic rhythm perception and speech rhythm cont.

- Iverson, Patel & Ohgushi 2008
  - Native speakers of Japanese vs. American English
  - Listened to sequences of tones, which alternated in loudness ("amplitude") or in duration.
    - Sound examples.
  - Both groups agreed that the louder sound begins a group.
  - But only the English speakers perceived the "universal" short-long grouping.
  - Many Japanese speakers perceived repeating long-short groups.

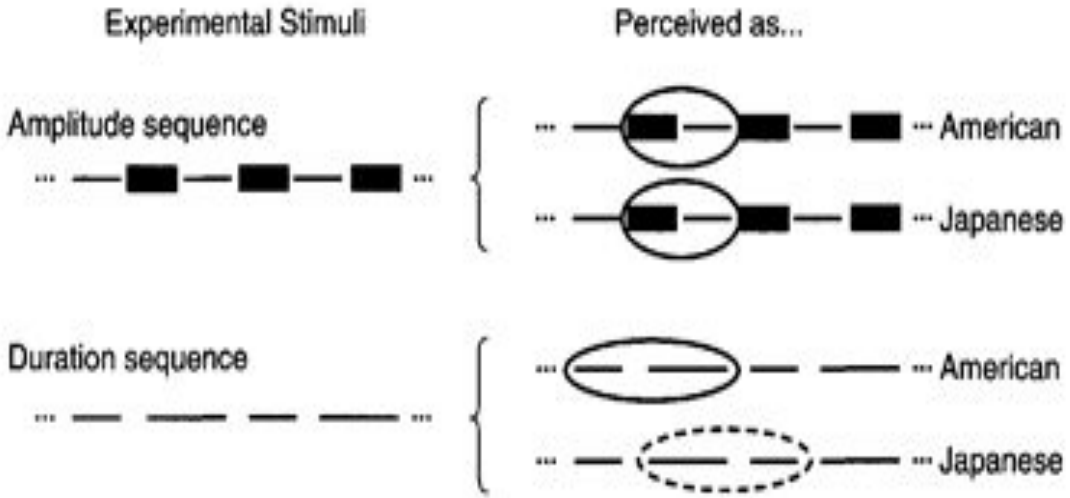

Figure 3.19 *Left side:* Schematic of sound sequences used in the perception experiment. These sequences consist of tones alternating in loudness ("amplitude sequence," top), or duration ("duration sequence," bottom). In the amplitude sequence, thin bars correspond to softer sounds and thick bars correspond to louder sounds. In the duration sequence, short bars correspond to briefer sounds and long bars correspond to longer sounds. The dots before and after the sequences indicate that only an excerpt of a longer sequence of alternating tones is shown. *Right side:* Perceived rhythmic grouping by American and Japanese listeners, indicated by ovals. Solid black ovals indicate preferences that follow "universal" principles of perception, while the dashed black oval indi-

Relations between nonlinguistic rhythm perception and speech rhythm cont.

- Why would native English and Japanese speakers differ in this way?
  - Might the temporal rhythm of these chunks differ for music or speech in the two cultures?
  - If so, then learning these patterns might influence auditory segmentation generally.
- Iversen et al. examined 50 children's songs per culture, computed the duration ratio of the first to the second note and then counted how often phrases started with short-long, long-short, or equal.
  - American songs show no bias to start with short-long.
  - Japanese songs did show a bias to start with long-short.

Relations between nonlinguistic rhythm perception and speech rhythm cont.

- English places function words at the beginning of a syntactic phrase, and function words are typically reduced:
  - [*The* cat] wants [*to* eat] [*a* big fish].
- Japanese places function words at the ends of phrases, e.g. case markers:
  - John-san-*ga* Mari-san-*ni* hon-*wo* agemashita.
    'John gave a book to Mary'.

Relations between nonlinguistic rhythm perception and speech rhythm cont.

- Iversen et al. measured the duration of the two syllables of the 50 most common disyllabis words in English from a corpus of spontaneous speech.
  - Common words with stress on the first syllable did not have a strong bias towards long-short.
  - But common words with stress on the second syllable had a very strong short-long duration pattern.
  - Thus, the average duration pattern for common two-syllable words in English was short-long.
- The 50 most common disyllabic words in Japanese showed an average duration pattern of long-short.

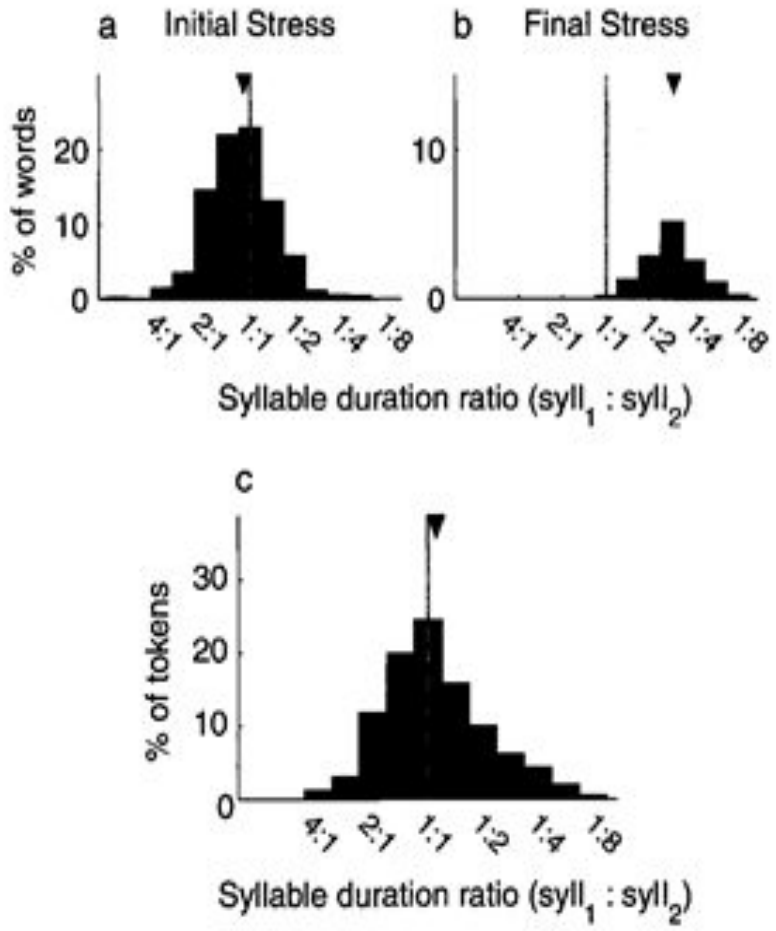

Figure 3.20 Distribution of syllable duration ratios for common two-syllable words in spontaneous speech in American English. Separate histograms are shown for initial-stress versus final-stress words in (a) and (b), and combined data are shown in (c), weighted by word frequency. Averages indicated by arrowheads. The overall distribution in (c) has a significant short-long bias (average ratio = 1 : 1.11). From Iversen et al. (submitted).

Relations between nonlinguistic rhythm perception and speech rhythm cont.

- Thus, perception of rhythmic grouping, long thought to be universal, actually varies by culture.
- This difference may well be based on the rhythms of speech.
- Learning the typical rhythmic shape of phrases and words in the native language may have a deep effect on rhythm perception in general.
- Rhythmic grouping preferences should be predictable from the temporal structure of small linguistic units (phrases and words) in a language.

Neural relationships between rhythm in speech and music

- Is there neural evidence that some aspects of rhythm in music and speech are handled by similar brain systems, whereas other aspects show little neural overlap?
- There is some evidence for overlap in brain processing of phrase boundaries in language and music.
  - Steinhauer et al. 1999: The perception of phrase boundaries in language is associated with a particular ERP component termed the "closure positive shift (CPS):
    - A centro-parietal positivity of a few hundred milliseconds that starts soon after the end of an intonational phrase.
  - Knösche et al. 2005 found a similar component in musicians to the ends of musical phrases.
    - Using MEG, they identified brain areas likely to be involved.
    - Cingulate cortex and posterior hippocampus.
    - The musical CPS does not reflect the detection of a phrase boundary per se, but memory and attention processes associated with shifting focus from one phrase to another.

Neural relationships between rhythm in speech and music cont.

- One would predict neural dissociations between linguistic rhythmic abilities and the ability to keep or follow a beat in music.
  - Studies of acquired arrythmia show that rhythmic abilities can be selectively disrupted leaving pitch processing skills relatively intact.
  - Liégois-Chauvel et al. 1998 found that patients with lesions in the anterior left or right superior temporal gyrus were much more impaired on a metrical task than on a temporal discrimination task.
    - Identifying a passage as a waltz or a march vs. same different judgment on short melodic sequences differing only in duration.

Neural relationships between rhythm in speech and music cont.

- None of these studies compare music and speech, so the field is wide open for comparative work.
- Studies could be done of patients with "foreign accent syndrome".
- Or of people with "congenital amusia" (tone-deafness).
  - Can't discriminate small pitch changes or determine the direction of small pitch changes.
  - Aren't impaired in discriminating simple temporal patterns, and can synchronize to a simple metronome (although they have difficulty synchronizing to the beat of music).
- One could look for people who claim to be "beat deaf" and test them on language.
- Patel: future research will likely find little relationship between speech rhythmic abilities and musical rhythmic abilities involving periodicity.