Stress patterns of German cardinal numbers

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Aim: To create an algorithm for assigning stress to German numbers
Introduction

- Motivation
- Structure of numbers in German
- Default stress and variability
- English stress: eurhythm
- Wagner: prominence
- Varga: rhythmical variation in Hungarian
- Contrastive stress
- Outlook
Motivation

- Natural sounding synthesis
- Many applications for numbers in synthesis
- What is a number?
  - Part of speech?
- Variation
Structure of numbers in German

- Single lexical items up to 12
  
e.g. vier, neun

- 13–19: Lexical item plus -zehn
  
e.g. vierzehn, achtzehn

- Decades: Lexical item plus -zig
  
e.g. vierzig, achtzig

- 21–99: Unit “und” Decade
  
e.g. achttundzwanzig, zweiundvierzig

- Three digits: Unit “hundert” Unit “und” Decade
  
e.g. dreihundertvierundsechzig

- Grouping: in threes from right to left as in English
  
e.g. 438 676
Default stress

- Citation form
  - Phrase-like stress
    * Primary stress: first syllable of the lexeme identifying the decade
    * Secondary stress: first syllable of the lexeme identifying the unit
    * “und” is unstressed

e.g.
Ich bin vierundZWANzig.
I am four and TWENty.

*I am twenty-four.*
The Main Question

- Metrical well-formedness

  Ich bin VIERundzwanzig JAHre alt.
  I am FOUR and twenty YEARS old.
  *I am twenty-four years old.*

- Contrastive stress

  Ich bin VIERundzwanzig, nicht DREIundzwanzig.
  I am FOUR and twenty, not THREE and twenty.
  *I am twenty-four, not twenty-three.*

- What conditions the reversal?

- How reliable are the triggers?
Eurhythmgy

- German has a preference for an alternating stress pattern (Jessen 1993)

- Rhythmic adjustment in English is to achieve a rhythmical target of eurhythm (Hayes 1984)

  Ideal eurhythmic metrical grid
  \[\begin{array}{cccc}
  x & x & x & x \\
  x & x & x & x \\
  x & x & x & x & x & x & x \\
  x & x & x & x & x & x & x & x & x & x & x & x \\
  \end{array}\]

- Three rhythmical targets
  - Level of scansion: 4 syllables apart
  - A level dividing the level of scansion in half
  - A level higher giving the initial beat of the level of scansion precedence

- Language universal?
Prediction 1

- Reversal of stress:
  - When a number is followed by any word where primary stress precedes secondary stress.
Wagner: 2000

- Stress patterns depend on the strategy of the speaker to achieve eurhythm

- Theory developed on German read data in terms of prominence

- Prominence defined as a measurement of the perceptual markedness in relation to the surrounding phonetic environment
Predictions 2: Wagner

- Reversal of stress:
  - When a number is immediately followed by a word with the same prominence value: numeral, noun or proper name, whose primary stress precedes any secondary stress
  - In syntactic terms:
    * Reversal occurs if the leftmost constituent of the numeral’s sister node is a noun, proper name or numeral and that is the head of the phrase in which the numeral occurs

21 Kinder

21 kleine Kinder
Varga: 1998

- Hungarian
  - Fixed primary stress on first syllable
  - Primary stress is cued by pitch-accent

- RV words
  - Double accented compound words
  - Phrase-like stress
  - Lexical process (limited scope)

'tizenhárom → 'pont tizenhárom
thirteen exactly thirteen
'tizenhárom → 'tizenhárom 'pont
thirteen thirteen points
Varga: 1998

- Final Weakening
  \[ * \rightarrow \emptyset / X_P (P_C (\ast \_ \_ \_ ) P_C \ast \_ \_ \_ ) X_P \]

  - Where \( X_P \) is a syntactic constituent starting with a double accented phrasal compound
  - Postlexical rule
  - Only applied if it leads to an interval of no more than four syllables between two consecutive primary stresses
Predictions 3: Varga

- If the lexeme identifying the unit has two syllables
  - Reversal of stress:
    * If the following word belongs to the same syntactic phrase as the numeral and has a pitch accent on the first syllable

- If the lexeme identifying the unit has one syllable
  - Reversal of stress:
    * If the following word belongs to the same syntactic phrase as the numeral and has a pitch accent on the first or second syllable
Contrastive stress

Ich bin VIERundzwanzig, nicht DREIundzwanzig.
I am FOUR and twenty, not THREE and twenty.
I am twenty-four, not twenty-three.

• Prominence for contrastive stress (Wagner 1999):
  – H*
    – Increase in duration

• Effects on numbers of the following environments
  and contrastive stress

• Interaction of focus and eurhythmy
Outlook

● Production experiment
  – Compare the predictions of well-formedness effects
  – Investigate their interactions with eurhythmy

● Preliminary results from pilot
  – F0 effects

● Phonetic measurement of stress
  – Backed up with perception experiment

● Result
  – Algorithm for assigning stress to German numbers