Acoustic prominence and phonological head-dependent structure

Kuniya Nasukawa
Tohoku Gakuin University
Sendai, Japan
Introduction

• In terms of the roles of heads and dependents, there is a mismatch between phonology and syntax.

• Phonology: heads are structurally and informationally important.

• Syntax: heads are structurally important but their informational role is relatively unimportant.
Introduction

• This talk proposes a reassessment of the roles of heads and dependents in phonology.
• It is argued that heads in phonology are structurally important but lexically unimportant whereas dependents are structurally unimportant but lexically important: phonology = syntax
• This view is supported not only by segmental distribution patterns but also by the size of the modulated carrier signal.
Roadmap

• How syntactic head-dependent structure is reflected in the acoustic properties of its phonetic realisation.

• The sonority scale and carrier signal modulations as ways of measuring stress and segmental salience.

• The differences between syntax and phonology with regard to the phonetic salience of head-dependent structure.
Roadmap

• The primary role of heads is structural and the primary role of dependents is informational.
• Compared with heads, dependents show a wider modulated form of carrier signal when they are phonetically realised.
Head-Dependency (H-D)

- A linguistically significant expression typically consists of multiple units, rather than just a single unit.
- When units combine, asymmetric relations are established between them.
- The unit which exerts control is the head of a combined set while the unit under the control of the head is a dependent.
H-D in syntax

a. ‘can drink …’
   - TP
     - T
       - can
     - VP
       - V
         - drink
     - DP
       - coffee

b. ‘the backyard’
   - DP
     - D
       - the
     - NP
       - backyard

c. ‘in the backyard’
   - PP
     - P
       - in
     - DP
       - D
         - the
       - NP
         - backyard
H-D in syntax

a. ‘can drink …’  
b. ‘the backyard’  
c. ‘in the backyard’

```
TP
  T
  can
  V
  drink
  DP
  N
  coffee

DP
  D
  the
  NP
  backyard

PP
  P
  in
  DP
  the
  NP
  backyard
```
Constituent heads are important structurally but have a low informational load, while dependents are not so important structurally but they are rich in terms of information (Nasukawa and Backley 2015a: 68).
Phrasal stress pattern in syntax

a. ‘can drink …’  
b. ‘the backyard’  
c. ‘in the backyard’

```
TP
  T can
  VP
    V drink
    DP
      N coffee

DP
  D the
  NP
    N backyard

PP
  P in
  DP
    D the
    NP
      N backyard
```
Stress pattern in syntax

\[ [\text{John} \ [\text{kissed} \ [\text{Mary}]]] \]
Defining the notion of prominence

Harris (2006, 2009)

a. All energy in the speech signal is used for delivering linguistic messages.

b. Only the energy in the modulated carrier signal contains linguistic messages, while the carrier signal itself is linguistically insignificant and merely allows linguistic messages to be audible.
Sonority scale

less sonorous       more sonorous
plosives > fricatives > liquids > glides > vowels

e.g. a syllable must consist of a sonority peak
(usually V) flanked by Cs.
  Rising shape (e.g., play, try, tweet)
  Falling shape (e.g., hel.per, par.ty, win.ter, cus.tom)
Sonority scale

less sonorous / more sonorous
plosives > fricatives > liquids > glides > vowels

The degree of sonority at the phrasal level

<table>
<thead>
<tr>
<th>less sonorous</th>
<th>more sonorous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heads</td>
<td>&lt;</td>
</tr>
<tr>
<td>Dependents</td>
<td></td>
</tr>
</tbody>
</table>

14
The modulated carrier-signal


a. The carrier signal:
   allows linguistic information (the message) to be heard.

b. Modulations:
   allows linguistic information (the message) to be understood.
The modulated carrier-signal

Acoustic attributes of modulations of the carrier signal (Harris 2009, 2012)

• Periodicity
• Amplitude
• Spectral shape
• Fundamental frequency
• Duration/timing
The modulated carrier-signal

Modulations of the carrier signal

a. Periodicity
b. Amplitude ←
c. Spectral shape
d. Fundamental frequency
e. Duration/timing ←

The size of modulations at the phrasal level

\[
\begin{array}{|c|c|}
\hline
\text{smaller} & \text{bigger} \\
\text{Heads} & < & \text{Dependents} \\
\hline
\end{array}
\]
The modulated carrier-signal

• Degree of sonority

\[
\begin{array}{cc}
\text{smaller} & \text{bigger} \\
\text{Consonants} < & \text{Vowels}
\end{array}
\]

• Size of modulation from the carrier signal

\[
\begin{array}{cc}
\text{smaller} & \text{bigger} \\
\text{Vowels} < & \text{Consonants} \\
\text{son Cs} < & \text{fricatives} < \text{plosives}
\end{array}
\]
H-D relations between syllable constituents

Syllable structure

```
O R
|
|
C N V
```

Dep    Head
Phonetic saliency

a. Degree of sonority at the syllable level

b. The size of modulation at the syllable level

- less son more son
- smaller bigger

Dep < Head

Dep > Head
Phonetic saliency

a. Degree of sonority at the syllable level

b. The size of modulation at the syllable level

The size of modulation at the phrasal level
H-D relations in the foot

a. ‘water’

b. ‘cooler’
H-D relations in the foot

Prominence at the foot level

\[
\begin{array}{c}
\text{Ft} \\
\sigma & \sigma \\
...V... > ...V...
\end{array}
\]

The size of modulation at the foot level

\textit{smaller} \qquad \textit{bigger} (prominent)

Dependents \quad < \quad Heads
Roles of heads/dependents and their modulation in syntax and the foot

<table>
<thead>
<tr>
<th></th>
<th>SYNTAX</th>
<th>FOOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEADS</td>
<td>structure-building</td>
<td>structure-building</td>
</tr>
<tr>
<td></td>
<td>information-poor</td>
<td>information-rich</td>
</tr>
<tr>
<td></td>
<td><em>smaller</em> modulation</td>
<td><em>bigger</em> modulation</td>
</tr>
<tr>
<td>DEPENDENTS</td>
<td>non-structure-building</td>
<td>non-structure-building</td>
</tr>
<tr>
<td></td>
<td>information-rich</td>
<td>information-poor</td>
</tr>
<tr>
<td></td>
<td><em>bigger</em> modulation</td>
<td><em>smaller</em> modulation</td>
</tr>
</tbody>
</table>

Two ways to account for this mismatch:
(i) by finding a reason for why the roles of heads and dependents in syntax are swapped when they apply at the foot level;
(ii) by investigating whether the head/dependent roles in phonology, or perhaps those in syntax, have been wrongly specified and must be reassigned in order to bring both modules into line with each other.
Roles of heads/dependents and their modulation in syntax, the syllable and the foot

<table>
<thead>
<tr>
<th></th>
<th>SYNTAX</th>
<th>FOOT</th>
<th>SYLLABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEADS</td>
<td>structure-building</td>
<td>structure-building</td>
<td>structure-building</td>
</tr>
<tr>
<td></td>
<td>information-<em>poor</em></td>
<td>information-<em>rich</em></td>
<td>information-<em>poor</em></td>
</tr>
<tr>
<td></td>
<td><em>smaller</em> modulation</td>
<td><em>bigger</em> modulation</td>
<td><em>smaller</em> modulation</td>
</tr>
<tr>
<td>DEPENDENTS</td>
<td>non-structure-building</td>
<td>non-structure-building</td>
<td>non-structure-building</td>
</tr>
<tr>
<td></td>
<td>information-<em>rich</em></td>
<td>information-<em>poor</em></td>
<td>information-<em>rich</em></td>
</tr>
<tr>
<td></td>
<td><em>bigger</em> modulation</td>
<td><em>smaller</em> modulation</td>
<td><em>bigger</em> modulation</td>
</tr>
</tbody>
</table>

Two ways to account for this mismatch:

(i) by finding a reason for why the roles of heads and dependents in syntax are swapped when they apply at the foot level;
(ii) by investigating whether the head/dependent roles in phonology, or perhaps those in syntax, have been wrongly specified and must be reassigned in order to bring both modules into line with each other.
Redefining H-D relations in the foot

a. ‘water’

b. ‘cooler’

The size of the modulated-carrier signal at the foot level,

*smaller*  <  *bigger* (prominent)

Heads  <  Dependents
Redefining H-D relations in the word

‘water cooler’ (proposed right-head structure)
Redefining H-D relations in the rhyme

The relative size of modulation in the rhyme

R
\[ \begin{array}{c}
  X & X \\
  V < & C \\
\end{array} \]

The size of modulation

smaller  \hspace{1cm} bigger

Heads  \hspace{1cm} Dependents
Redefining H-D relations in the nucleus

The left positions in (a) and (b) support a wider range of segmental contrasts than we find in the right positions.

- the left-hand positions are informationally rich
- the right-hand positions have limited scope for lexical contrasts.
Redefining H-D relations in the nucleus

c. The size of modulation

\textit{smaller} \quad \text{Heads} \quad \text{<} \quad \text{bigger} \quad \text{Dependents}
Redefining H-D relations in the onset

a. O
   x x
   p l

b. O
   x x
   t r
Redefining H-D relations in the onset

a. O
   x x
   p l

b. O
   x x
   t r

c. The size of modulation
   smaller
   Heads < bigger
   Dependents

The left positions in (a) and (b) support a wider range of segmental contrasts than we find in the right positions.

- the left-hand positions are informationally rich
- the right-hand positions have limited scope for lexical contrasts.
Redefining H-D relations in melody

Acoustic signatures of elements

<table>
<thead>
<tr>
<th>Label</th>
<th>Spectral Shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘mass’</td>
<td>mass of energy located in the centre of the vowel spectrum, with troughs at top and bottom</td>
</tr>
<tr>
<td>‘dip’</td>
<td>energy distributed to the top and bottom of the vowel spectrum, with a trough in between</td>
</tr>
<tr>
<td>‘rump’</td>
<td>marked skewing of energy to the lower half of the vowel spectrum</td>
</tr>
<tr>
<td>‘edge’</td>
<td>abrupt and sustained drop in overall amplitude</td>
</tr>
<tr>
<td>‘noise’</td>
<td>aperiodic energy</td>
</tr>
<tr>
<td>‘murmur’</td>
<td>broad resonance peak at lower end of the frequency range</td>
</tr>
</tbody>
</table>
Acoustic exponence of \( |A I U| \)


<table>
<thead>
<tr>
<th>element</th>
<th>spectral shape</th>
<th>schematic filter response</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (</td>
<td>A</td>
<td>) ‘mass’:</td>
</tr>
<tr>
<td>b. (</td>
<td>I</td>
<td>) ‘dip’:</td>
</tr>
<tr>
<td>c. (</td>
<td>U</td>
<td>) ‘rump’:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>element</th>
<th>spectral shape</th>
<th>stylised spectrographic frame</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(y-axis=frequency, x-axis=time)</td>
</tr>
</tbody>
</table>

a. |ʔ| ‘edge’: abrupt and sustained drop in overall amplitude

b. H ‘noise’: aperiodic energy

c. N ‘murmur’: broad resonance peak at lower end of the frequency range

d. |ʔ H| in occlusives

<table>
<thead>
<tr>
<th>element</th>
<th>spectral shape</th>
<th>stylised spectrographic frame</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(y-axis=frequency, x-axis=time)</td>
</tr>
</tbody>
</table>

| silence | noise | | silence | noise |
Precedence-free Phonology (PfP)


- elements still function as the building blocks of phonological structure, but they represent not only melodic but also prosodic properties.

- That is, they project onto higher levels as organizing units, where they concatenate to form prosodic constituents without referring to traditional prosodic labels such as nucleus, mora, rhyme, syllable and foot.
Precedence-free Phonology (PfP)

- This model assumes that the constituent regularly referred to as ‘nucleus’ must be one of the vowel elements |A|, |I| or |U|.

- When |A|/|I|/|U| appears in its minimal or most basic form (i.e., as a single element without dependent structure), it is realised as a central vowel [ə]/[ɨ]/[ɯ].

- The choice of default vowel is assumed to be determined by parameter: ə in English, i in Cilungu and u in Japanese. (For detailed discussion, see Nasukawa 2014.)
Precedence-free Phonology (PfP)

Typological variation: default vowels

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A′</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

They appear in loanwords, when the native phonology requires a nucleus to be pronounced even if there is no corresponding vowel in the original word.

- **English**: as in the place name ‘Gdansk’ [ˈɡɔdænsk].
- **Japanese**: as in loanwords such as ‘slim’ [ˈsuɾimu].
Precedence-free Phonology (PfP)

The phonetically weak realizations of |A|, |I| and |U|

a. [ə]  
   ![Graph](image1)

b. [ɪ]
   ![Graph](image2)

c. [ʊ]
   ![Graph](image3)

The phonetically strong realizations of |A|, |I| and |U|

a. [a]
   ![Graph](image4)

b. [i]
   ![Graph](image5)

c. [u]
   ![Graph](image6)
Default vowels vs. full vowels

a. [ə]  

b. [a]  

c. [i]  

d. [u]
More complex melodic compounds

In models such as standard ET and DP:

mid vowels have compound structures in which constituent elements enter into head-dependency relations.

|A|+|I|:

(a) [|A||I|] realised as [e] when |I| is headed
(b) [|A|]|I|] realised as [æ] when |A| is headed

in English
Iterative vowel concatenation

Further endocentric concatenation (deeper embedding)

a. [i]   b. [æ]   c. [e]
Iterative vowel concatenation

Phonetic interpretation depends
(i) on which elements are present and also
(ii) on the headedness of their concatenated structures.

Furthermore, successive levels of embedding can be introduced recursively until all the required vowel categories are uniquely represented.
Iterative consonant concatenation:
The phonological structure of [kʰi] in PfP

V domain

|A|

[ɪ]

|A|

[kʰ]

C domain

|H|

|U|

|?|

|?|

[H]

The source of aspiration
The phonological structure of $[k^h i]$ in PfP

(10)
The phonological structure of $[k^h i]$ in PfP

The source of aspiration
The phonological structure of \([k^h]i\) in PfP
The phonological structure of $[k^h i]$ in PfP

(10)
The phonological structure of \([k^h]i\) in PfP
The phonological structure of $[k^h i]$ in PfP
Summary

- In order to achieve a greater degree of uniformity between syntax and phonology, I have proposed a reassessment of the roles of heads and dependents in phonology.

- Contrary to the widespread view, it is not only in syntax but also at all levels of phonology (i.e., word, foot, syllable, rhyme, nucleus, onset, intra-segmental) that heads are structurally important but lexically recessive whereas dependents are structurally less important but richer in terms of lexical information.
Summary

- When a given head-dependent structure is phonetically realised, the relative prominence between heads and dependents is reflected in the acoustic signature of the whole expression.

- This means that dependents, which are not necessary for structural well-formedness, are phonetically more salient in terms of their modulated carrier signal (rather than the sonority scale) than heads, which are important for building structure.
References 1


Acknowledgement

This work was partially funded by a grant (no. 26284067) from the Japanese government (Grant-in-Aid for Scientific Research (B), Ministry of Education, Culture, Sports, Science and Technology (MEXT)).
Heavy Syllables

Heavy syllable = concatenation of two |X| constituents i.e. similar in prosodic terms: CVCV (city), CVV (see), CVC (sit)

bare |A| suppressed

in this position
Coda Consonants

Following the Strict CV approach (Szigetvári 1999, Scheer 2004), a coda consonant is a dependent of an unspecified nucleus, e.g. *think* [θɪŋk]

resonance element copying/
licensing suppresses
the realisation of bare |A|