Economy and invariance are unjustified assumptions in formal phonology

Mark VanDam
NAPhC5
10 May 2008
Montréal, QC
Traditional linguistic model

What is a FORM in competence?

- only performance is directly observed
- competence (then meaning) is inferred

How is a (possible) FORM identified?

-a minimal pair demands explicit formal representation in competence
### Minimal pair

<table>
<thead>
<tr>
<th></th>
<th>$b_{\Lambda g}$</th>
<th>$p_{\Lambda g}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>consonantal</td>
<td>+</td>
</tr>
<tr>
<td>—</td>
<td>continuant</td>
<td>—</td>
</tr>
<tr>
<td>—</td>
<td>sonorant</td>
<td>—</td>
</tr>
<tr>
<td>—</td>
<td>nasal</td>
<td>—</td>
</tr>
<tr>
<td>—</td>
<td>coronal</td>
<td>—</td>
</tr>
<tr>
<td>+</td>
<td>labial</td>
<td>+</td>
</tr>
<tr>
<td>—</td>
<td>strident</td>
<td>—</td>
</tr>
<tr>
<td>+</td>
<td>voice</td>
<td>—</td>
</tr>
</tbody>
</table>
Traditional linguistic model

1. How many forms?
   Greek, about 24
   Port-Royal, 25-30
   Jakobson-Fant-Halle, 12
   SPE, about 40
   Optimality Theory, assume SPE’s 40 or so
   no consensus, but features must be
   limited in number: economy
   Why? descriptive simplicity, computational tractability,
   typological universality, elegance, Occam, etc.

2. What is the nature of a form?
   timeless and perfective: invariance
   Why? perfectly recognizable, modular naivety, aut Caesar
   [Chomsky] aut nihil, perception depends on bi-directionality,
   Universal Grammar, "represent the phonetic capabilities of
   man" (SPE: 295), transmittable, etc.
Traditional linguistic model

Benefits of assuming economy and invariance:

1. tractable due to constrained resources (storage space, processing)

2. powerful: limited units of representation, unlimited output

Potential costs of assuming economy and invariance:

1. power is a function of economy: as more forms are admitted to the model (ie, less economy), theoretical power declines.
   
   **What evidence challenges the proposition of economy?**
   
   **ID minimal pairs, increasing # of necessary forms**

2. model has no way of dealing with variance. If variation is found, there is no apparent or obvious way out.

   **What evidence challenges the proposition of invariance?**
   
   **flexible linguistic representations (forms) over time**
Empirical research questions

Experiment 1: test economy
(1a) are there (new) minimal contrasts for words differing by lexical usage frequency?

(1b) are there (new) minimal contrasts for words versus non-words?

Experiment 2: test invariance
are linguistic categories (forms) flexible?
can experience easily affect representations (forms)?
Experiment 1a & 1b: economy

**DV:** VOT boundary (ms)

**IV:** lexical status

<table>
<thead>
<tr>
<th>LEX-STATUS</th>
<th>[d] non-word</th>
<th>[d] word</th>
</tr>
</thead>
<tbody>
<tr>
<td>[t] word</td>
<td>talc ~ dalc</td>
<td>teal ~ deal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>usage frequency</th>
<th>USAGE-FREQ</th>
<th>[d] low-freq</th>
<th>[d] high-freq</th>
</tr>
</thead>
<tbody>
<tr>
<td>[t] low-freq</td>
<td>tine ~ dine</td>
<td>ton ~ done</td>
<td></td>
</tr>
<tr>
<td>[t] high-freq</td>
<td>time ~ dime</td>
<td>town ~ down</td>
<td></td>
</tr>
</tbody>
</table>

**Task:** for 30 word pairs; presented with an acoustic token from VOT continuum, then identify "A for 'teal' B for 'deal'"

**Data:** 220k responses, 27k boundaries

**Analysis:** differences among voicing boundary locations
Voice-onset time (VoT):
Anatomy of a category boundary shift

- Proportion 'voiced' response
- Voicing lag (VoT) in milliseconds

Graph showing the proportion of voiced responses over time for 'dime' and 'time' categories, with 'time-2' and 'dime-2' indicating specific points on the graph.
Experiment 1a & 1b: economy

Are voicing boundaries different based on lexical status?

<table>
<thead>
<tr>
<th>LEX-STATUS</th>
<th>[d] non-word</th>
<th>[d] word</th>
</tr>
</thead>
<tbody>
<tr>
<td>[t] word</td>
<td>dalc ~ talc</td>
<td>deal ~ teal</td>
</tr>
</tbody>
</table>

Are voicing boundaries different based on lexical usage frequency?

<table>
<thead>
<tr>
<th>USAGE-FREQ</th>
<th>[d] low-freq</th>
<th>[d] high-freq</th>
</tr>
</thead>
<tbody>
<tr>
<td>[t] low-freq</td>
<td>dine ~ tine</td>
<td>done ~ ton</td>
</tr>
<tr>
<td>[t] high-freq</td>
<td>dime ~ time</td>
<td>down ~ town</td>
</tr>
</tbody>
</table>
Non-word bias over words

- diffs significant
- diffs small, 6.0ms
- bias only tested in voiced series
High usage-frequency bias, voiced only

- voiced
  - diffs signif
  - small, 2.7 ms

- voiceless
  - diffs not signif

usage-frequency

boundary, VoT (ms)

- LOW
- HIGH
- LOW
- HIGH
Formal invariance
Methodology, Experiment 2: formal invariance

**DV:** VOT boundary (ms)

**IV:** training exposure (control, lengthened)
- control targets = 80% VOT for 12 target words
- lengthened targets = 180% VOT for 12 target words

**Procedure:** pretest, training (5 days), posttest

**Task (pretest and posttest):** "press A for TEAL or B for DEAL"

**Task (training):** listen-and-repeat phrases from 4-minute/600 word story. 12 voiceless targets occur twice each in story.

eg: over the rusty keel section of the boat
    buy all the talc from the general store

**Analysis:** differences among voicing boundary locations
Results recap

Exp-1a. lexical status: word versus non-word?
non-word bias in the voiced series
ie, dope-taupe and dop-top have different structure
→ the two minimal pair contrasts differ
→ formal model demands unique form to represent lexical contrast

Exp-1b. usage frequency: high versus low frequency?
high-frequency bias, voiced series only
ie, done-ton and den-ten have different structure
→ the two minimal pair contrasts differ
→ formal model demands unique form to represent frequency contrast

Exp-2. category flexibility: controlled versus lengthened exposure?
lengthened exposure changed category boundary, control did not
ie, experience with longer tokens changed structure of category
→ linguistic voicing category is highly flexible
→ formal model cannot account for this data
Present results compatible with other work

(1) perceptual learning
   (Kraljic & Samuel 2005, 2006; Norris, McQueen, & Cutler 2003)

(2) listener sensitivity to variability

(3) exemplar-, episodic-, rich-memory language models
   (Goldinger 1997, 1998; Pierrehumbert 2001; Johnson 1997; Port 2007)

(4) usage-based models
   (Hooper 1976; Phillips 1984; Johnson 1997; Bybee 2002)
Formal-theoretic assumptions of economy and invariance are violated.

What sort of theory can account for the facts?
Abstract and detailed representation, Rich-memory approach

<table>
<thead>
<tr>
<th>p</th>
<th>Λ</th>
<th>g</th>
</tr>
</thead>
<tbody>
<tr>
<td>consonant</td>
<td>+</td>
<td>—</td>
</tr>
<tr>
<td>continuant</td>
<td>—</td>
<td>+</td>
</tr>
<tr>
<td>sonorant</td>
<td>—</td>
<td>+</td>
</tr>
<tr>
<td>nasal</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>coronal</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>labial</td>
<td>+</td>
<td>—</td>
</tr>
<tr>
<td>strident</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>voice</td>
<td>—</td>
<td>+</td>
</tr>
</tbody>
</table>

END