Phonological Regularities and Spoken Production: Evidence from Speech Errors

Matt Goldrick
Department of Cognitive Science
Johns Hopkins University
Phonological Regularities and Speech Production Processes

• Out of the wide range of phonological regularities, what particular types are encoded by the language processing system?

• Focus here: Speech production processes.
Outline of the Talk

• What types of regularities could be encoded?
  – Typology of phonological regularities.
  – Three independent dimensions of variation in phonological regularities.

• What types of phonological regularities are encoded in spoken production processes?
  – Use issues arising in linguistic theories to generate specific questions.

• Performance in implicit learning task to help resolve some of these issues.

• Implications for spoken production system.
3 Dimensions: Phonological Regularity Types

Absolute or Graded?

Variability

Within-Language or Cross-Linguistic?

Granularity

Segment or Sub-Segment?
Example: Within-Language, Sub-Segmental, Absolute

- **German**: Word-final devoicing.
  - Word-finally, voiceless stops are permitted, while voiced stops are not.
    - \[h\text{Ant}] ‘hand’ \*\[h\text{And}].

- **Scope**: Within-Language; applies to German, not to English.

- **Granularity**: Sub-segmental; statement about class of segments.

- **Variability**: Absolute; no exceptions in German lexicon.
Example: German Devoicing
Within-Language, Sub-Segmental, Absolute

Variability

Granularity

Scope
**Example**: Cross-Linguistic, Segmental, Graded

- **Inventory status**: /f/ vs. /v/
  - If a language uses /v/, it will tend to use /f/.

- **Scope**: Cross-Linguistic; statement about distribution across world’s languages.

- **Granularity**: Segmental; statement about distribution of particular segments.

- **Variability**: Graded; holds for 78.5% of languages in Maddieson (1984).
Example: Inventory status, /f/ vs. /v/
Cross-Linguistic, Segmental, Graded

Variability

Granularity

Scope
What Types of Phonological Regularities are Encoded in Speech Production Processes?
What Types of Phonological Regularities are Encoded in Speech Production Processes?

• Use linguistic theories to guide the search along 3 dimensions.
  – Particular theories: Characterize some regularities but not others.

  – Portion of space not characterized = types of regularities that are not important.
    • Contrast between different types of linguistic theories.
What Types of Phonological Regularities are Encoded in Speech Production Processes?

• Assume processing theories make similar contrasts along each dimension of regularities as linguistic theories.

† Types of regularities that are not important = claims about the types of regularities that are not directly encoded by the spoken production system.

– N.B.: Testing processing theories, not linguistic theories.
Cross-linguistic regularities are **not** encoded by the production system.

- **Source in Linguistic Theory:** Statistical Theories
  - Important regularities are those based on linguistic experience.
    - Distribution of phonological structures across words (i.e., type frequency; Coleman & Pierrehumbert, 1997).
    - Distribution of phonological structures across utterances (i.e., token frequency; Luce et al., 2000).
  - Cross-linguistic regularities emerge due to functional properties of human communication system.
Graded regularities are not encoded by the production system.

- Source in Linguistic Theory:
  
  **UG-Based Generative Theories**
  - e.g., Chomsky & Halle (1968); Prince & Smolensky (1993)
  - Important regularities are absolute.
  - Graded regularities emerge due to interaction between processes encoding regularities and other processes (e.g., memorial processes).
Sub-segmental regularities are not encoded by the production system.

• Source in Linguistic Theory:

  Some Statistical Proposals:
  – In some statistical theories, frequency is counted over segmental and supra-segmental representations only.
    • Coleman & Pierrehumbert (1997): Syllable constituents in particular contexts.
    • Luce et al. (2000): Segments and biphones.
  – Sub-segmental regularities emerge through distributional properties of segmental and supra-segmental representations.
What Types of Phonological Regularities Are Encoded?

Are graded regularities encoded?

Variability

Are cross-linguistic regularities encoded?

Scope

Are sub-segmental regularities encoded?

Granularity

Variability

Are sub-segmental regularities encoded?

Granularity

Are cross-linguistic regularities encoded?

Scope

Are graded regularities encoded?

Variability

Are sub-segmental regularities encoded?

Granularity

Are cross-linguistic regularities encoded?

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Scope

Are graded regularities encoded?

Variability

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Granularity

Are cross-linguistic regularities encoded?

Scope

Are graded regularities encoded?

Variability

Are sub-segmental regularities encoded?

Granularity

Are cross-linguistic regularities encoded?
What Types of Phonological Regularities Are Encoded?

Are graded regularities encoded?

Variability

Granularity

Are sub-segmental regularities encoded?

Syllable Segment Sub-segment Language X All Languages Scope
Encoding of Phonological Regularities

• Examine performance on an implicit learning task.
Learning New Phonological Regularities

• Regularity of English: /ng/—coda
  – feng: possible word of English.
  – *ngef: not a possible word.

• Regularity of Experiment: /f/—onset
  – fek: found in stimulus set.
  – *kef: not found in stimulus set.
Dell et al. (2000)

- Participants read aloud sets of four syllable sequences.
  - heng fek meg nes

- Sequences respect
  - Regularities of English
  - Experiment-specific regularities
  - Other consonants occur with equal frequency in both syllable positions.
Dell et al. (2000): Results

- Induce speech errors by having participants read sequences quickly.
- Speech errors respect regularities of English.
  - /ng/ errors:  feng kef † feng keŋ
    - /ng/ produced in incorrect syllable, but position within syllable is correct.
  - All /ng/ errors fit this pattern: 100% in coda
Dell et al. (2000): Results

• Speech errors respect regularities of experiment.

• Likely error:
  – gem fek † fem gek

• Unlikely error:
  – gem fek † gef mek
Dell et al. (2000): Results

- Speech errors respect regularities of experiment.

![Distribution of /f/ errors](chart)

- Percentage of Errors
- same syllable position as target (onset)
- different syllable position
Dell et al. (2000): Results

- Cannot be explained solely by tendency to preserve syllable position.
Encoding of Phonological Regularities

• Participants can extract new phonological regularities.

• Is learning influenced by sub-segmental similarity?

• Are graded regularities encoded?
Current Study

• Participants read aloud sets of four syllable sequences.
  \[
  \text{heng fey meg kes}
  \]

• Sequences respect
  – Regularities of English
  – Experiment-specific regularities
  – One restricted consonant (/f/) highly similar to one unrestricted consonant (/v/).
Current Study

Analysis

heng fev meg kes

Effect of similarity
– /s/: Restricted control segment vs.
– /f/: Restricted test segment

Learning of Regularity
– /f/: Restricted test segment vs.
– /k,g,m/: Unrestricted control segments
Method

- Four different consonant pairs:
  /f/-/v/; /s/-/z/; /t/-/d/; /k/-/g/  
- For each pair, two conditions:
  - Restricted test: voiceless.  
    Unrestricted similar: voiced.  
    (e.g., /f/ restricted to onset, /v/ unrestricted).  
    heng fev meg kes  
  - Restricted test: voiced.  
    Unrestricted similar: voiceless.  
    (e.g., /v/ restricted to onset, /f/ unrestricted).  
    heng vef meg kes
Method

- 10 participants per consonant pair.
- 192 random sequences per participant.
- Each consonant appears once per sequence.
- Four syllables shown on computer screen.
- Read once slowly (1 syllable/second), three times quickly (2.5 syllables/second).
  - Sequence visible during all four repetitions.
- Voicing errors excluded.
Predictions: Sub-Segmental Similarity

• If sub-segmental regularities are not encoded, learning with an unrestricted highly similar segment should be no different than learning with unrelated segments.

  – Restricted test vs. Restricted control
    • No difference.
Predictions: Sub-Segmental Similarity

• If sub-segmental regularities are encoded, learning with an unrestricted highly similar segment should be different than learning with unrelated segments.
  – Restricted test vs. Restricted control
    • Significant difference.
Results

• Speech errors respect regularities of English.
  – /ng/ errors: 100% in coda
  – /h/ errors: 100% in onset
Restricted Control Segment: No Unrestricted Similar Segment Present

- In absence of unrestricted similar segment, participants extract regularity.

![Graph showing percentage of errors for 'Same syllable position as target' and 'Different syllable position'. The graph indicates a significant difference with an asterisk (*) for 'Same syllable position as target'.]
Restricted Test Segment: Unrestricted Similar Segment Present

- In presence of unrestricted similar segment, participants have more difficulty extracting regularity (all contrasts).

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% Errors Not Preserving Target Syllable Position

0% 2% 4% 6% 8% 10%

Restricted Control Segment Restricted Test Segment

*`

Difference between Restricted Test & Control Segments?

- Same segment: performance varies as a function of whether an unrestricted similar segment is present.
What Types of Phonological Regularities Are Encoded?

Yes. More difficult to extract regularities in presence of unrestricted similar segment.

Are sub-segmental regularities encoded?
Pure segmental account of these data?

- Could sub-segmental similarity emerge through distributional similarities?
- Within experiment: No. Distribution of segments does not reveal similarity.
- ex.: /f/-onset: /f/ and /v/ have dissimilar distributions.
  - Onset only: /h/, /f/
  - Onset and Coda: /y, k, g, m/

† Within experiment, participants are encoding distribution of sub-segmental representations.
Pure segmental account of these data?

- Could sub-segmental similarity emerge through distributional similarities?
- Across English lexicon: No. Distribution of segments does not reveal similarity.
- ex.: /s/-coda: /s/ and /z/ have dissimilar distributions in English.
  - Distribution = type frequency of word-final segments following each vowel.
  - Distribution of /s/ most similar to that of /m/.

† Distribution is inadequate; sub-segmental representations are required to encode similarity.
What Types of Phonological Regularities Are Encoded?

Are graded regularities encoded?

Variability

Granularity

Scope

All Languages

Language X

Syllable

Segment

Sub-segment

0%

25%

50%

75%

100%
Restricted Test vs. Unrestricted Controls

- Interference with learning is not total.
What Types of Phonological Regularities Are Encoded?

Are graded regularities encoded?

Variability

Yes. Errors can obey regularity at less than absolute levels.
What Types of Phonological Regularities Are Encoded?

Variability

Granularity

Are cross-linguistic regularities encoded?
Results & Implications

• More difficult for processing system to extract segment restrictions in presence of an unrestricted highly similar segment.
  – Sub-segmental regularities are encoded by the spoken production system.

• Sub-segmental interference does not eliminate learning.
  – The spoken production system can encode phonological regularities in a graded fashion.
Discussion

- Encoding of sub-segmental regularities is broadly consistent with other results.
  - Sub-segmental representations have played a prominent role in most linguistic theories.
  - Questions about status of sub-segmental representations in spoken production system.
- Likelihood of two segments interacting in a speech error is related to their sub-segmental similarity (e.g., Shattuck-Hufnagel & Klatt, 1979; Frisch, 1996).
- …but “pure” sub-segmental errors are extremely rare (e.g., Fromkin, 1971; but see Pouplier et al., 1999; Guest, 2001).
Discussion

• Encoding of graded regularities consistent with other studies of language processing.
  – Well-formedness judgements reflect graded regularities (e.g., Frisch & Zawaydeh, 2001; Zuraw, 2000).
  – Graded regularities affect spoken production accuracy/speed (e.g., Munson, 2001; Treiman et al., 2000; Vitevitch & Luce, 1999).

• Consistent with evolution of computational assumptions in linguistic theory.
  – Derivational? Constraint-Based
  – Further enriching computational mechanisms to include probabilistic computation.
Discussion

• Many theories encoding graded regularities do not make use of complex representations.

• Not a necessary assumption: Enriching computational mechanisms does not require impoverishing representations.
  – Orthogonal questions about types of phonological regularities; complex representations are not incompatible with graded regularities.
Discussion

- **Independent dimensions of variation.**
  - No necessary theoretical relationship between granularity, scope and variability.
  - **Granularity & Variability:**
    - Above: Complex representations are not incompatible with graded regularities.
    - Statistical approaches are not incompatible with abstract variables (Pierrehumbert, 2001, in press).
  - **Scope & Variability:**
    - UG-Based approaches are not incompatible with variability.
Conclusion

• Understanding phonological regularities is an important part of understanding spoken production processes:
  – Processing attempts to maximize phonological regularity;
  – Processing system adapts itself to many different types of regularities in the linguistic environment.
Collaborators at JHU

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• Daisy Bang
References


References


Contact

goldrick@cogsci.jhu.edu

http://www.cog.jhu.edu/grad-students/goldrick