Incomplete Neutralization and the Blueprint Model of Production

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Overview of Presentation

- Motivation/Background
- Architecture and design of the BLUEPRINT MODEL OF PRODUCTION
- Comparison with (some) other accounts of incomplete neutralization

Motivation/Background

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- Phonetics on the other hand deals with the continuous manifestation of segments.
- Viewing the phonetics-phonology interface as a serial operation (Phonology→Phonetics) has caused considerable problems when trying to account for certain facts such as incomplete phonetic neutralization.
- We present a reinterpretation of the phonetics-phonology interface that provides an abstract characterization for how a discrete phonology and continuous phonetics may interact.

Phonological Neutralization

- German final-devoicing (Dinnsen and Garcia-Zamor, 1971)

(1)
a. /bad+en/ → [baden] ‘to bathe’
b. /bad/ → [bat] ‘bath’
c. bat+en/ → [baten] ‘asked’
d. /bat/ → [bat] ‘ask’

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- Notably, both types of grammars are *extensionally* equivalent when considering the phonological *mappings* (i.e., the underlying and surface form pairs).

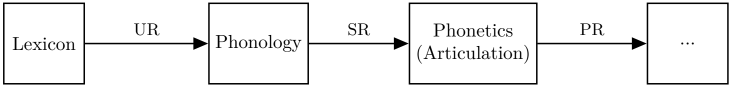
Incomplete Phonetic Neutralization

- Laboratory experiments on final devoicing have shown time and time again that phonologically neutralized segments are not fully neutralized in the phonetics.
  - German (Port et al., 1981; Fourakis and Iverson, 1984; Port and O'Dell, 1985; Port and Crawford, 1989).
  - Polish (Slowiaczek and Dinnsen, 1985; Jassem and Richter, 1989).
  - Russian (Dmitrieva et al., 2010; Shrager, 2012; Kharlamov, 2014).
  - Dutch (Warner et al., 2004, 2006).
  - Catalan (Dinnsen and Charles-Luce, 1984).
  - Afrikaans (Van Rooy et al., 2003).
- Many other neutralization processes shown to be incomplete as well...

Incomplete Phonetic Neutralization

- Furthermore...
  1. It is often a subset of cues that appear incomplete.
  2. The incompleteness regularly appears to be in the direction of the underlying form (Port et al., 1981; Port and O'Dell, 1985).
  3. Speakers have at least some control over the level of incompleteness which is influenced by pragmatic factors (Port and Crawford, 1989).

Modular feedforward model



- Pierrehumbert (2002) refers to this as a "modular feedforward model".
- Phonology maps UR to SR and Phonetics maps SR to PR.
- Phonetics module is blind to UR form so how does it know to differentiate phonologically neutralized forms?

The blueprint model of production

Function types

- General form of a function:
  - $f :: A \to B$
  - "f is a function that maps A-type arguments to B-type arguments."
- Example of *Phonology* function:
  - $P :: UR \to SR$
  - "The *Phonology* function maps *UR*s to *SR*s."

Higher order functions

- A higher order function is a function that either takes another function in its input, or a function that returns another function in its output.
- One example is the `map()` function.
  - Input: list of objects, a function
  - Output: function applied elementwise to list
- `map(plus_one`$(), [-23, 1, 9, 307]) = [-22, 2, 10, 308]$

Function application

- Function application is itself a higher order function.
- Assuming abstract types A and B, function application is a function that takes something of type A and a function from A types to B types as its input, and outputs something of type B.
  - $A \to (A \to B) \to B$
  - Everything to the left of the rightmost arrow is an argument and everything to the right of the rightmost (non-bracketed) arrow is the output.

Observation

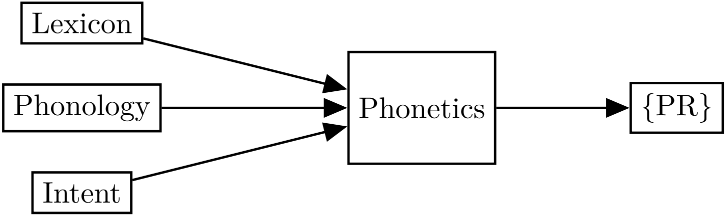
In a system where we know all B type things are derived from A type things, and that there is some function g that implements this mapping, then we also know that every B is equivalent to $g(a)$ for some $a \in A$.

Abbreviations

Functions	
Lexicon	L
Phonology	P
Phonetics$_{\text{MFF}}$	A_{MFF}
Phonetics$_{\text{BLUEPRINT}}$	$A_{\text{BLUEPRINT}}$
Non-Functions	
Underlying Representation	UR
Surface Representation	SR
Phonetic Representation	PR
Intent[1]	I

[1] Following Gafos and Benus (2006), we use the term Intent to model the effect of pragmatic context.

The blueprint model of production



- Phonetics is a higher order function that takes the phonology function, the lexicon, and an Intent value as its input.

Deriving the blueprint model

Our claim

The blueprint model can be derived directly from the modular feed-forward model

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Derivation

$$A_{\mathrm{MFF}} :: SR \to PR$$

- First we start with the phonetics function for the modular feed-forward model

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The blueprint model can be derived directly from the modular feed-forward model

Derivation

$$A_{\text{MFF}} :: SR \rightarrow PR$$

$$A :: UR \rightarrow (UR \rightarrow SR) \rightarrow PR$$

- From the definition of function application we can fortuitously decompose SR into $UR \rightarrow (UR \rightarrow SR)$

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Derivation

$$A_{\text{MFF}} :: SR \rightarrow PR$$
$$A :: UR \rightarrow (UR \rightarrow SR) \rightarrow PR$$
$$A :: UR \rightarrow P \rightarrow PR$$

- $UR \rightarrow SR$ is equivalent to the phonology function P

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$$A_{\text{MFF}} :: SR \rightarrow PR$$

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$$A :: UR \rightarrow P \rightarrow PR$$

$$A_{\text{BLUEPRINT}} :: L \rightarrow P \rightarrow \{PR\}$$

- We can generalize over the entire lexicon rather than a specific UR

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- Finally, we add the intent value I as an input to account for pragmatic effects

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- The phonetics module is therefore a higher-order function with three arguments: the lexicon, the entire phonology module (a function), and an intent value

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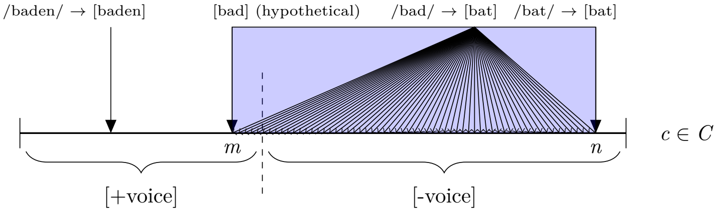
- The addition of the Intent value allows us to scale how much influence the UR has on the final Phonetic Representation.
- Incomplete neutralization is therefore the result of this scaling process.

Scaling UR/SR

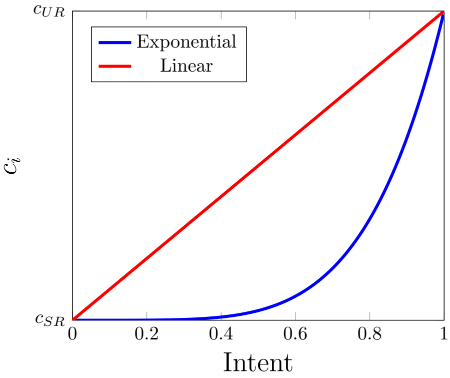


- [voice] feature maps to different values for cue $c \in C$ depending on position.
- [-voice] in final position maps to value n.
- [+voice] in final position maps to value m.
- The phonetic realization of /bad/→[bat] is therefore some value v where $m \leq v \leq n$.

Scaling UR/SR

- What might a scaling formula include?
  - c_{UR} = cue value based on UR (m)
  - c_{SR} = cue value based on SR (n)
  - $i \in [0, 1]$ = intent to maintain underlying contrast
- Example scaling formulae.
  - Linear: $c = c_{UR} \times i + c_{SR} \times (1 - i)$
  - Exponential: $c = c_{UR} \times i^{\alpha} + c_{SR} \times (1 - i)^{\alpha}$

Scaling UR/SR



- Exponential scaling accounts for the small phonetic differences.
- It also allows for speakers to potentially produce UR-like tokens, but only in extreme circumstances.

Comparison

Previous Explanation of Incomplete Neutralization

- Interleaving phonological and phonetic rules (Dinnsen and Charles-Luce, 1984; Slowiaczek and Dinnsen, 1985).

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- Scalar phonetic-based constraints (Braver, 2019).

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- With the blueprint model of production, we provide an abstract characterization of the production process that fits their guidelines, while also being applicable to other theories of phonology.

Conclusion

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- This model can also account for at least a subset of near merger data as well (e.g. Yu (2007)).
- Future work can use this model to explore other facts about the phonetics-phonology interface that relate to the phonetic realization of phonological processes involving segmental changes (e.g. epenthetic vowel duration, phonetic evidence of deleted segments, absolute neutralization).

Thank You!

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Bibliography

Braver, A. (2019). Modelling incomplete neutralisation with weighted phonetic constraints. *Phonology*, 36(1):1–36.
Dinnsen, D. and Garcia-Zamor, M. (1971). The three degrees of vowel length in German. *Research on Language & Social Interaction*, 4(1):111–126.
Dinnsen, D. A. and Charles-Luce, J. (1984). Phonological neutralization, phonetic implementation and individual differences. *Journal of phonetics*, 12(1):49–60.
Dmitrieva, O., Jongman, A., and Sereno, J. (2010). Phonological neutralization by native and non-native speakers: The case of Russian final devoicing. *Journal of phonetics*, 38(3):483–492.
Ernestus, M. and Baayen, R. H. (2006). The functionality of incomplete neutralization in Dutch: The case of past-tense formation. *Laboratory phonology*, 8(1):27–49.
Fourakis, M. and Iverson, G. K. (1984). On the 'incomplete neutralization' of German final obstruents. *Phonetica*, 41(3):140–149.
Gafos, A. I. and Benus, S. (2006). Dynamics of phonological cognition. *Cognitive science*, 30(5):905–943.
Jassem, W. and Richter, L. (1989). Neutralization of voicing in Polish obstruents. *Journal of Phonetics*, 17(4):317–325.
Kharlamov, V. (2014). Incomplete neutralization of the voicing contrast in word-final obstruents in Russian: Phonological, lexical, and methodological influences. *Journal of Phonetics*, 43:47–56.
Kleber, F., John, T., and Harrington, J. (2010). The implications for speech perception of incomplete neutralization of final devoicing in German. *Journal of Phonetics*, 38(2):185–196.
Pierrehumbert, J. (2002). Word-specific phonetics. *Laboratory phonology*, 7.
Port, R. and Crawford, P. (1989). Incomplete neutralization and pragmatics in German. *Journal of phonetics*, 17:257–282.
Port, R., Mitleb, F., and O'Dell, M. (1981). Neutralization of obstruent voicing in German is incomplete. *The journal of the Acoustical Society of America*, 70(S1):S13–S13.
Port, R. F. and Leary, A. P. (2005). Against formal phonology. *Language*, 81(4):927–964.
Port, R. F. and O'Dell, M. L. (1985). Neutralization of syllable-final voicing in German. *Journal of phonetics*.
Röettger, T. B., Winter, B., Grawunder, S., Kirby, J., and Grice, M. (2014). Assessing incomplete neutralization of final devoicing in German. *Journal of Phonetics*, 43:11–25.
Shrager, M. (2012). Neutralization of word-final voicing in Russian. *Journal of Slavic linguistics*, pages 71–99.
Slowiaczek, L. M. and Dinnsen, D. A. (1985). On the neutralizing status of Polish word-final devoicing. *Journal of phonetics*.
Van Oostendorp, M. (2008). Incomplete devoicing in formal phonology. *Lingua*, 118(9):1362–1374.
Van Rooy, B., Wissing, D., and Paschall, D. D. (2003). Demystifying incomplete neutralisation during final devoicing. *Southern African Linguistics and Applied Language Studies*, 21(1-2):49–66.
Warner, N., Good, E., Jongman, A., and Sereno, J. (2006). Orthographic vs. morphological incomplete neutralization effects. *Journal of Phonetics*, 34(2):285–293.
Warner, N., Jongman, A., Sereno, J., and Kemps, R. (2004). Incomplete neutralization and other sub-phonemic durational differences in production and perception: Evidence from Dutch. *Journal of phonetics*, 32(2):251–276.
Winter, B. and Röettger, T. (2011). The nature of incomplete neutralization in German: Implications for laboratory phonology. *Grazer Linguistische Studien*, 76:55–74.
Yu, A. C. (2007). Understanding near mergers: The case of morphological tone in Cantonese. *Phonology*,