Reconsidering pseudowords in morphological research

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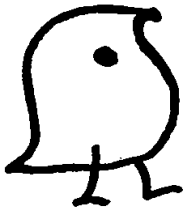
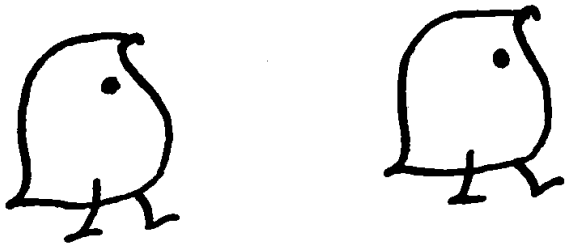
In the beginning there was a Wug…

- Berko Gleason (1958) created the 'Wug Test' to investigate whether children already have productive knowledge of morphophonological rules



THIS IS A WUG.



NOW THERE IS ANOTHER ONE.

THERE ARE TWO OF THEM.

THERE ARE TWO _____.

… and many more Wugs followed

Pseudoword are used in studies on…

- morphology / morpho-phonology (e.g. Albright 2002; Albright & Hayes 2003; Dabrowska 2008; Gouskove & Becker 2013; Kawahara 2012; Krämer 2009; Pierrehumbert 2006; Schmitz, Plag & Baer-Henney 2020)
- the mental lexicon (e.g. Anshen & Aronoff 1988; Eddington 2000; Meunier & Longtin 2007; Prasada & Pinker 1993; Rubenstein, Garfield & Millikan 1970; Shatzman & McQueen 2006; Vitevitch & Luce 1998, 2005; Wurm 2000)
- language acquisition (e.g. Dollaghan 1985; Friedrich & Fiederici 2005; Singson, Mahony & Mann 2000; van de Vijver & Baer-Henney 2014)
- phonetics / phonology (e.g. Schmitz, Cho & Niemann 2018; Turcsan & Herment 2015)
- reading (e.g. Burani et al. 1999; McKay et al. 2008)
- spoken word recognition (e.g. Marslen-Wilson 1984)
- semantics (e.g. Ozubko & Joordens 2011)
- memory performance (Hulme et al. 1995)

Pseudowords as Items/Stimuli

- Pseudowords are assumed to have the advantage of removing
  - storage effects (e.g. Caselli et al. 2016)
  - lexical relatedness effects (e.g. Schriefers et al. 1998)
- Such effects might interfere with the productive morphological capacity of speakers
- Along the same lines, pseudowords are commonly assumed to be semantically 'empty shells' (e.g. Frisch et al. 2000; Günther 1983; Turcsan & Herment 2015)

Semantically ‘Empty Shells’?

- Ample evidence to challenge the assumption of a semantically ‘empty shell’

1. **onomatopoeia** (e.g. Pratha et al. 2016)

   using sound to imitate sound

2. **phonaesthemes** (e.g. Kwon & Round 2015)

   sound-meaning pairings

3. **sound symbolism** (e.g. Maurer et al. 2006)

   vowel qualities associated with forms

individual sounds and certain combinations of sounds apparently can bear meaning, i.e. contribute to semantics

Semantically ‘Empty Shells’?

- Ample evidence to challenge the assumption of a semantically ‘empty shell’

4. **Pokémon** (e.g. Kawahara et al. 2018)

   interaction of names and appearance

5. **fiction literature** (e.g. Elsen 2008)

   villain names sound harsher

6. **nicknames** (e.g. Shih & Rudin 2020)

   taller baseball players have longer nicknames

words can code properties of what they describe, i.e. semantics are somewhat reflected in form

Semantically ‘Empty Shells’?

- Ample evidence to challenge the assumption of a semantically ‘empty shell’

7. **resonance with the lexicon** (Chuang et al., 2020)
   - the phonological form of pseudowords resonates with the words in the lexicon
   - measures derived from the computational modelling of such resonance, i.e. from the semantics of pseudowords, successfully predict reaction times and acoustic durations

The Present Study

- Following the general methodological approach by Chuang et al. (2020), we investigate the **hypothesis**:

  The resonance of morphologically simplex and complex pseudowords with the words in the mental lexicon influences the processing of these pseudowords.

The Present Study

- This effect is measured by investigating the duration of word-final /s/ in pseudowords
- It has been repeatedly shown (e.g. Plag et al. 2017; Schmitz et al. 2020) that

non-morphemic /s/ > plural /s/ > clitic /s/

- **Question**

  Can the duration of word-final /s/ be predicted by means of measures derived from the **semantics** of the pseudowords?

Linear Discriminative Learning

- Linear Discriminative Learning (LDL) networks are simple two-layer networks which are linguistically transparent and interpretable (e.g. Baayen et al. 2019)
- LDL makes use of five high-dimensional numeric matrices; two of which are important for the present study
  - **form matrix C**

    contains triphone cues of words

	#kæ	kæt	æt#	#bæ
cat	1	1	1	0
bat	0	0	1	1
bus	0	0	0	0

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- LDL makes use of five high-dimensional numeric matrices; two of which are important for the present study
  - **form matrix C**

    contains triphone cues of words
  - **semantic matrix S**

    contains the semantic vectors of words

	cat	bat	bus	animal
cat	1	0.01	0.003	0.7
bat	0.003	1	0.0001	0.4
bus	0.04	0.007	1	0.05

Linear Discriminative Learning

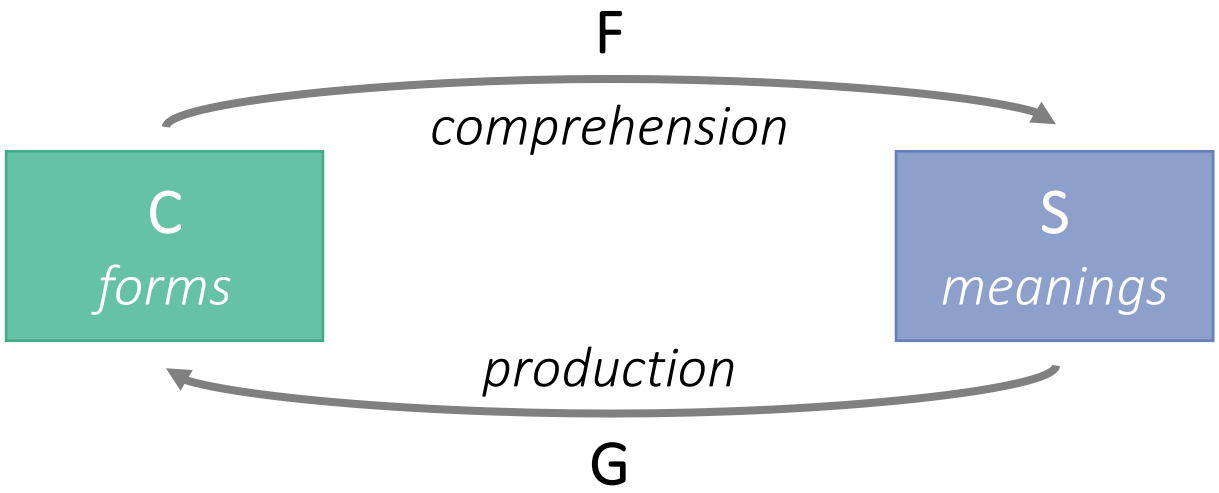

Illustration of mapping between form and meaning, and vice versa.

Linear Discriminative Learning

- The LDL implementation predicts
  - **meaning** from **forms** → **comprehension**
  - **forms** from **meanings** → **production**
- Following the approach by Chuang et al. (2020), we can estimate pseudoword **semantics** based on their **phonological** similarity with real words in the lexicon
- Using the *WpmWithLdl* (Baayen et al. 2019) and the *LDLConvFunctions* (Schmitz 2021) packages in R (R Core Team 2020), a combined implementation for real words and pseudowords then enables one to extract a variety of measures
  → *measures derived from the semantics of pseudowords*

Linear Discriminative Learning

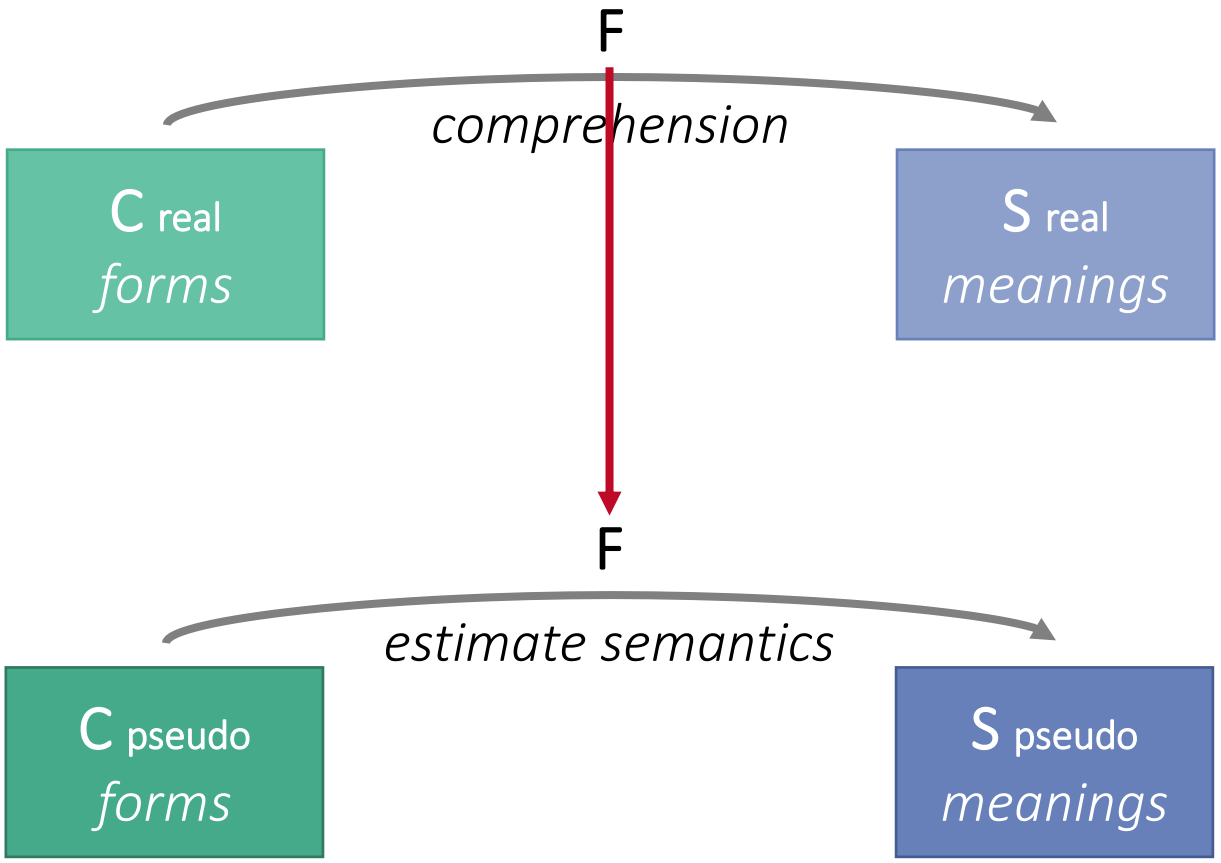

Illustration of a part of the combined implementation for real words and pseudowords.

Analysis

- Most of the derived LDL measures undergo a Principal Component Analysis (PCA) as they show high correlation coefficients (e.g. Venables & Ripley 2002)
- Then, linear mixed-effects regression is implemented using the *lme4* package (Bates et al. 2015) in R
  - dependent variable: duration of word-final /s/
  - independent variables: components retained from PCA
    LDL measures not considered in the PCA
    covariates not accounted for in LDL (e.g. speaking rate)
  - random variables: speaker

Results

- The final model contains LDL measures of

phonological uncertainty	**semantic activation diversity**
close semantic neighbourhood	**general semantic neighbourhood**

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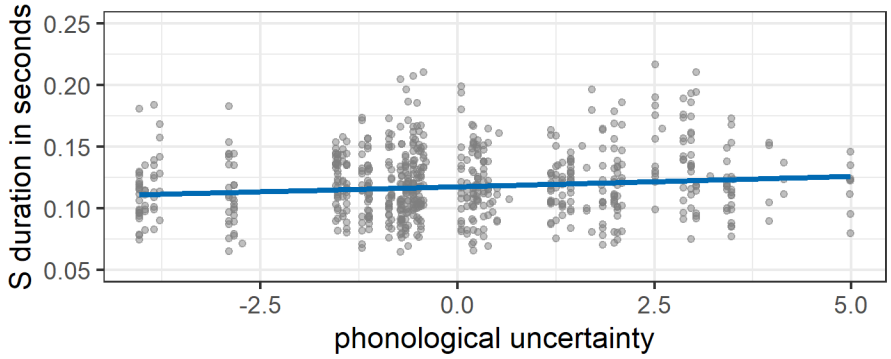
phonological uncertainty	semantic activation diversity
	
close semantic neighbourhood	**general semantic neighbourhood**

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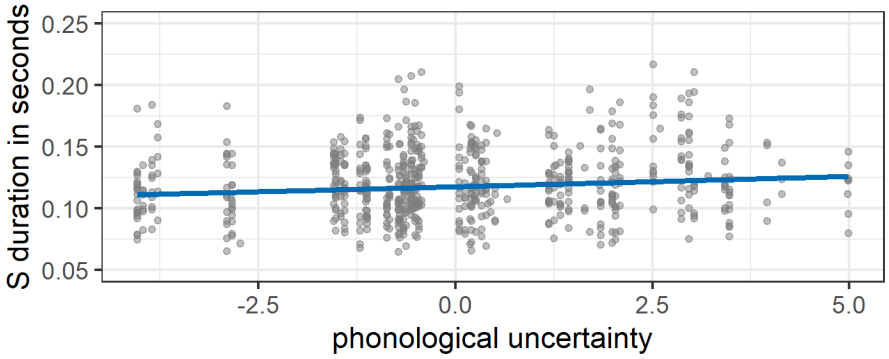
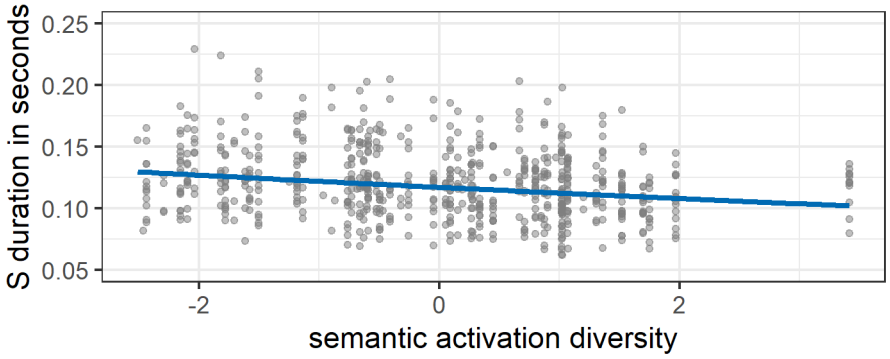


semantic activation diversity



close semantic neighbourhood

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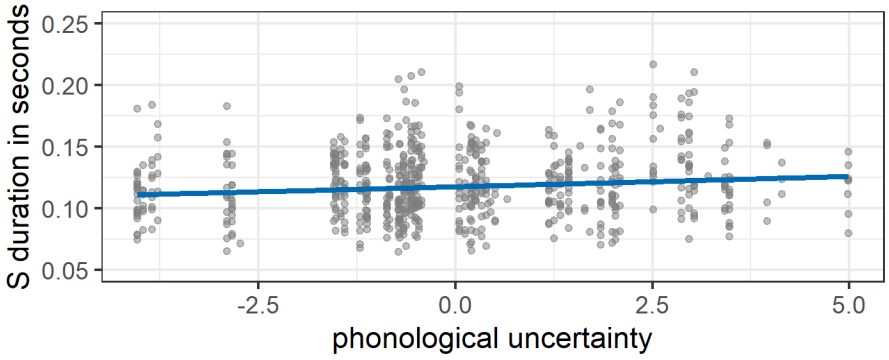
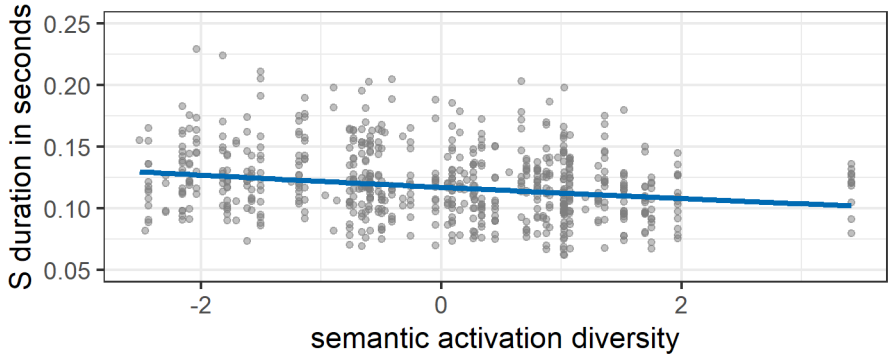
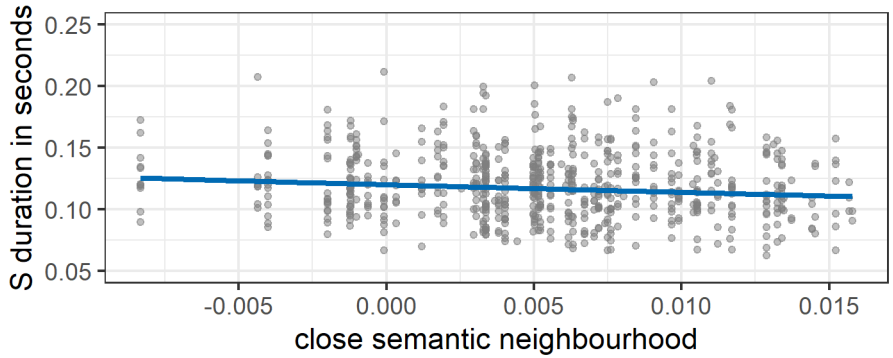


semantic activation diversity



close semantic neighbourhood



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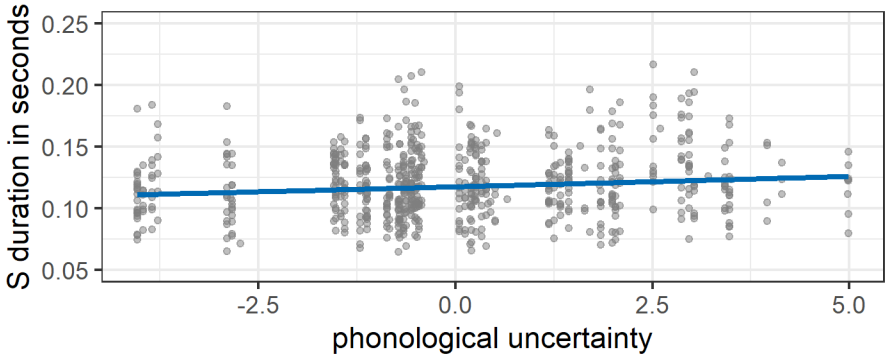
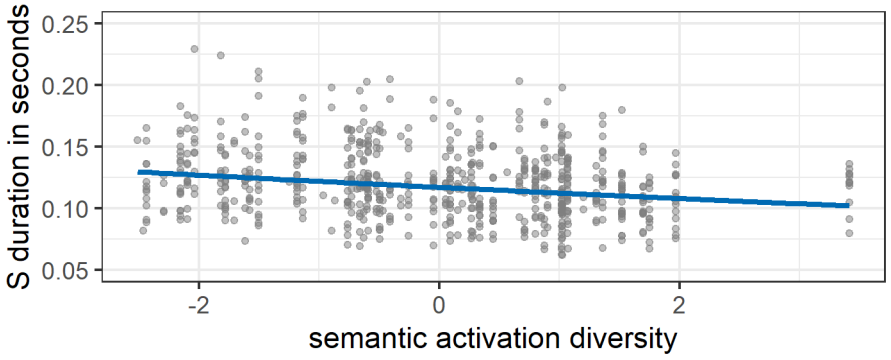
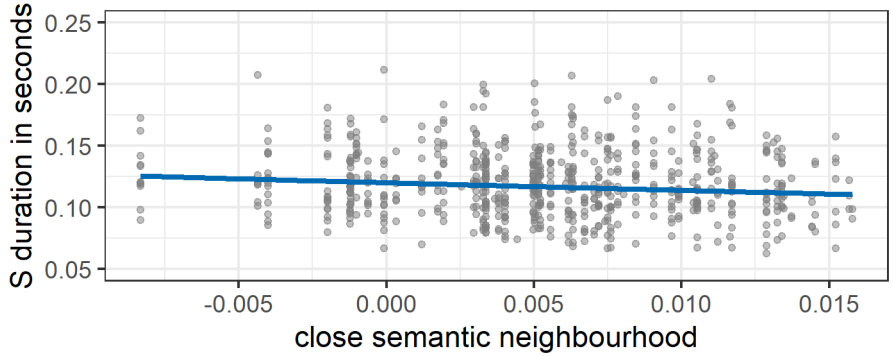


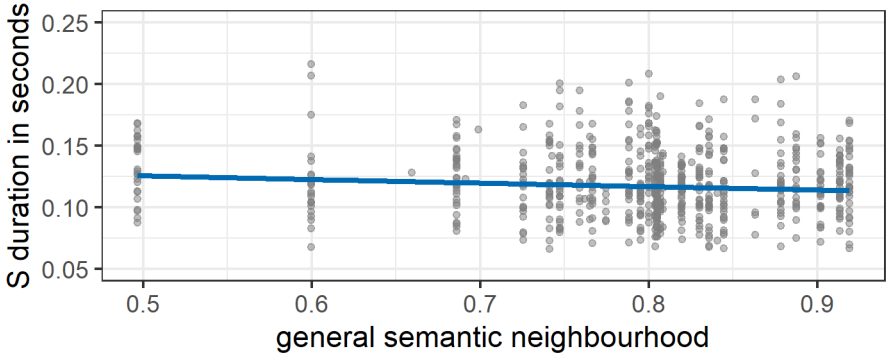
semantic activation diversity



close semantic neighbourhood



general semantic neighbourhood



Results

- How do these results translate to previous findings?

non-morphemic /s/ > plural /s/

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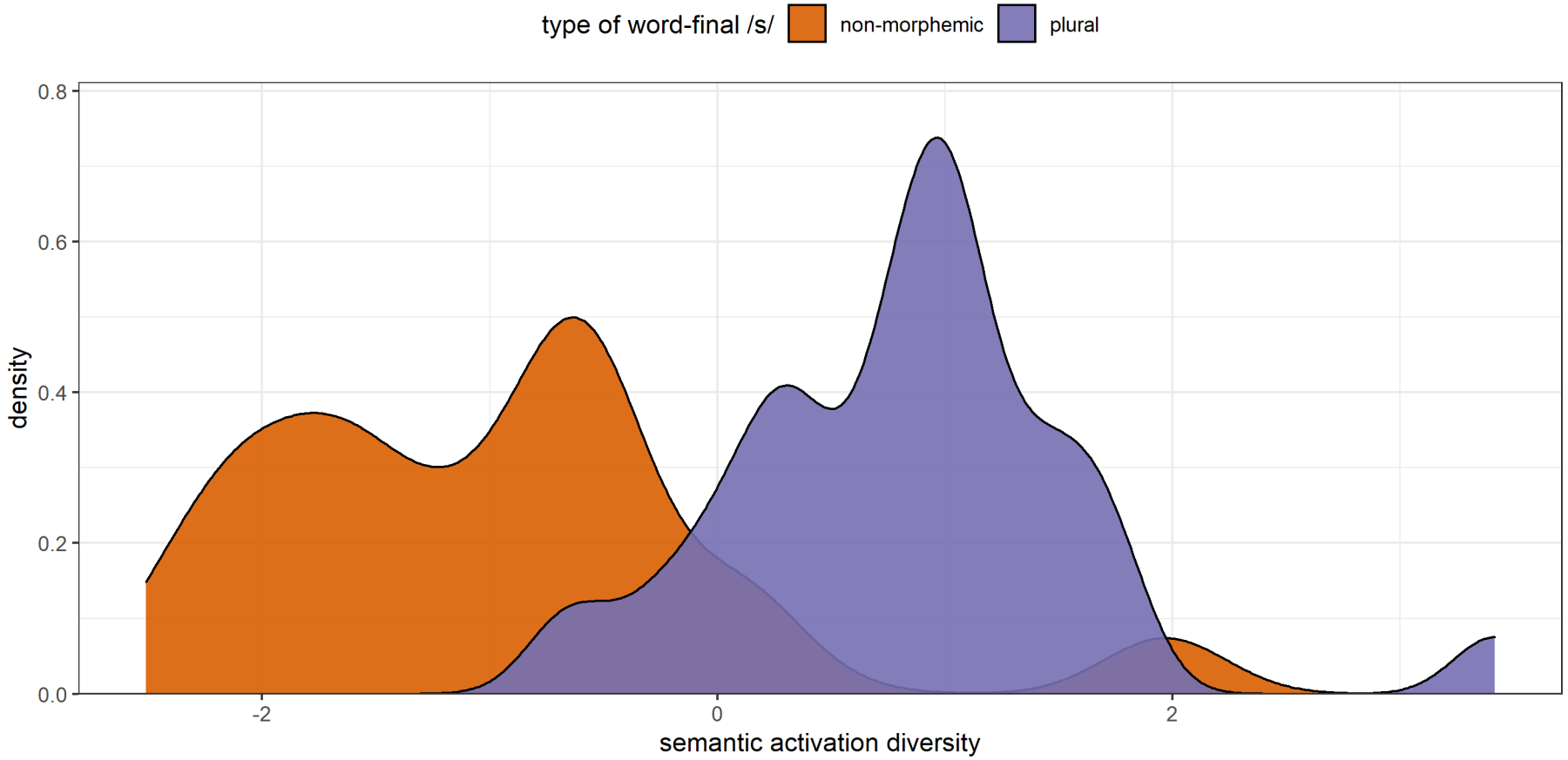


Discussion

- **Question**

  Can the duration of word-final /s/ be predicted by means of measures derived from the **semantics** of the pseudowords?

- Yes, word-final /s/ duration in pseudowords can successfully be modelled by measures derived from their semantics
  - Higher levels of **semantic activation diversity** and denser **semantic neighbourhoods** of pseudowords lead to shorter /s/ durations

Discussion

- The results suggests that the morpho-phonetic properties of pseudowords are dependent on their resonance with the existing lexicon
- Hence, pseudowords do not live in their own world, only interacting with 'grammar'
- The assumption of semantically 'empty shells' appears to be a fallacy

Consequences

1. **Past Studies**

   There might be a potential influence of pseudoword semantics on reported results.

2. **Future Studies**

   Experimental design and analyses should take potential semantics effects into account.

3. **General Notion**

   The very notion of ‘pseudoword’ and the dichotomy of ‘pseudoword vs. real word’ needs to be reconsidered.

Thank you!

References I

Albright, A. (2002). Islands of Reliability for Regular Morphology: Evidence from Italian. *Language, 78(4),* 684–709.

Albright, A., & Hayes, B. (2003). Rules vs. analogy in English past tenses: A computational/experimental study. *Cognition, 90(2),* 119–161. https://doi.org/10.1016/S0010-0277(03)00146-X

Anshen, F., & Aronoff, M. (1988). Producing morphologically complex words. *Linguistics, 26(4),* 641–656. https://doi.org/10.1515/ling.1988.26.4.641

Baayen, R. H., Chuang, Y.-Y., & Hitmeier, M. (2019). WpmWithLdl: Implementation of Word and Paradigm Morphology with Linear Discriminative Learning. R package version 1.3.17.1.

Baayen, R. H., Chuang, Y.-Y., Shafaei-Bajestan, E., & Blevins, J. P. (2019). The Discriminative Lexicon: A Unified Computational Model for the Lexicon and Lexical Processing in Comprehension and Production Grounded Not in (De)Composition but in Linear Discriminative Learning. *Complexity*, 2019. https://doi.org/10.1155/2019/4895891

Bates, D., Mächler, M., Bolker, B. M., & Walker, S. C. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67(1)*. https://doi.org/10.18637/jss.v067.i01

Berko, J. (1958). The Child's Learning of English Morphology. *WORD, 14(2–3),* 150–177. https://doi.org/10.1080/00437956.1958.11659661

Burani, C., Dovetto, F. M., Spuntarelli, A., & Thornton, A. M. (1999). Morpholexical access and naming: The semantic interpretability of new root-suffix combinations. *Brain and Language, 68(1–2),* 333–339. https://doi.org/10.1006/brln.1999.2073

Caselli, N. K., Caselli, M. K., & Cohen-Goldberg, A. M. (2016). Inflected words in production: Evidence for a morphologically rich lexicon. *Quarterly Journal of Experimental Psychology, 69(3),* 432–454. https://doi.org/10.1080/17470218.2015.1054847

Chuang, Y.-Y., Vollmer, M. L., Shafaei-Bajestan, E., Gahl, S., Hendrix, P., & Baayen, R. H. (2020). The processing of pseudoword form and meaning in production and comprehension: A computational modeling approach using linear discriminative learning. *Behavior Research Methods, 49*. https://doi.org/10.3758/s13428-020-01356-w

Dabrowska, E. (2008). The effects of frequency and neighbourhood density on adult speakers' productivity with Polish case inflections: An empirical test of usage-based approaches to morphology. *Journal of Memory and Language, 58(4)*, 931–951. https://doi.org/10.1016/j.jml.2007.11.005

Dollaghan, C. (1985). Child meets word: "Fast Mapping" in preschool children. *Journal of Speech and Hearing Research, 28*, 449–454.

Eddington, D. (2000). Analogy and the dual-route model of morphology. *Lingua, 110(4),* 281–298. https://doi.org/10.1016/s0024-3841(99)00043-1

Elsen, H. (2008). *Phantastische Namen: Die Namen in Science Fiction und Fantasy zwischen Arbitrarität und Wortbildung*. Narr Francke Attempto.

Friedrich, M., & Friederici, A. D. (2005). Phonotactic knowledge and lexical-semantic processing in one-year-olds: Brain responses to words and nonsense words in picture contexts. *Journal of Cognitive Neuroscience, 17(11),* 1785–1802. https://doi.org/10.1162/089892905774589172

Gouskova, M., & Becker, M. (2013). Nonce words show that Russian yer alternations are governed by the grammar. *Natural Language and Linguistic Theory, 31(3),* 735–765. https://doi.org/10.1007/s11049-013-9197-5

Günther, H. (1983). The Role of Meaning and Linearity in Reading. In F. Coulmas & E. Konrad (Eds.), *Writing in Focus*. Walter de Gruyter.

References II

Hulme, C., Roodenrys, S., Brown, G., & Mercer, R. (1995). The role of long-term memory mechanisms in memory span. *British Journal of Psychology, 86(4),* 527–536. https://doi.org/10.1111/j.2044-8295.1995.tb02570.x

Kawahara, S. (2012). Lyman's Law is active in loanwords and nonce words: Evidence from naturalness judgment studies. *Lingua, 122(11),* 1193–1206. https://doi.org/10.1016/j.lingua.2012.05.008

Kawahara, S., Noto, A., & Kumagai, G. (2018). Sound symbolic patterns in Pokémon names. *Phonetica, 75(3),* 219–244. https://doi.org/10.1159/000484938

Krämer, M. (2009). Main stress in italian nonce nouns. *Romance Languages and Linguistic Theory*, 127–142.

Kwon, N., & Round, E. R. (2015). Phonaesthemes in morphological theory. *Morphology, 25(1),* 1–27. https://doi.org/10.1007/s11525-014-9250-z

Marslen-Wilson, W. (1984). Function and Process in Spoken Word Recognition: A Tutorial Review. In H. Bouma & D. Bouwhuis (Eds.), *Attention & Performance X*. Lawrence Erlbaum Associates.

Maurer, D., Pathman, T., & Mondloch, C. J. (2006). The shape of boubas: Sound-shape correspondences in toddlers and adults. *Developmental Science, 9(3),* 316–322. https://doi.org/10.1111/j.1467-7687.2006.00495.x

McKay, A., Davis, C., Savage, G., & Castles, A. (2008). Semantic Involvement in Reading Aloud: Evidence From a Nonword Training Study. *Journal of Experimental Psychology: Learning Memory and Cognition, 34(6),* 1495–1517. https://doi.org/10.1037/a0013357

Meunier, F., & Longtin, C. M. (2007). Morphological decomposition and semantic integration in word processing. *Journal of Memory and Language, 56(4),* 457–471. https://doi.org/10.1016/j.jml.2006.11.005

Ozubko, J. D., & Joordens, S. (2011). The Similarities (and Familiarities) of Pseudowords and Extremely High-Frequency Words: Examining a Familiarity-Based Explanation of the Pseudoword Effect. *Journal of Experimental Psychology: Learning Memory and Cognition, 37(1),* 123–139. https://doi.org/10.1037/a0021099

Pierrehumbert, J. B. (2006). The statistical basis of an unnatural alternation. In L. Goldstein, D. H. Whalen, & C. T. Best (Eds.), *Laboratory Phonology* (Issue 8). De Gruyter Mouton. https://doi.org/10.1515/9783110197211.1.81

Plag, I., Homann, J., & Kunter, G. (2017). Homophony and morphology: The acoustics of word-final S in English. *Journal of Linguistics, 53(1),* 181–216. https://doi.org/10.1017/S0022226715000183

Prasada, S., & Pinker, S. (1993). Generalisation of regular and irregular morphological patterns. *Language and Cognitive Processes, 8(1),* 1–56. https://doi.org/01690969308406948

Pratha, N. K., Avunjian, N., & Cohn, N. (2016). Pow, Punch, Pika, and Chu: The Structure of Sound Effects in Genres of American Comics and Japanese Manga. *Multimodal Communication, 5(2),* 93–109. https://doi.org/10.1515/mc-2016-0017

R Core Team. (2020). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. https://www.r-project.org/

Rubenstein, H., Garfield, L., & Millikan, J. A. (1970). Homographic Entries in the Internal Lexicon. *Journal of Verbal Learning and Verbal Behavior, 9*, 487–494.

Schmitz, D. (2021). LDLConvFunctions: Functions for measure computation, extraction, and other handy stuff. R package version 1.2. URL: https://github.com/dosc91/LDLConvFunctions

References III

Schmitz, D., Baer-Henney, D., & Plag, I. (2020). The duration of word-final /s/ differs across morphological categories in English: Evidence from pseudowords [*Manuscript submitted for publication*].

Schmitz, D., Cho, H.-E., & Niemann, H. (2018). Vowel shortening in German as a function of syllable structure. *Proceedings 13. Phonetik Und Phonologie Tagung (P&P13),* 181–184.

Schriefers, H., Friederici, A. D., & Rose, U. (1998). Context effects in visual word recognition: Lexical relatedness and syntactic context. *Memory and Cognition, 26(6),* 1292–1303. https://doi.org/10.3758/BF03201201

Shatzman, K. B., & McQueen, J. M. (2006). Segment duration as a cue to word boundaries in spoken-word recognition. *Perception and Psychophysics, 68(1),* 1–16. https://doi.org/10.3758/BF03193651

Shih, S. S., & Rudin, D. (2020). On Sound Symbolism in Baseball Player Names. *Names*, 1–18. https://doi.org/10.1080/00277738.2020.1759353

Singson, M., Mahony, D., & Mann, V. (2000). The relation between reading ability and morphological skills: Evidence from derivational suffixes. *Reading and Writing, 12(3),* 219–252. https://doi.org/10.1023/a:1008196330239

Turcsan, G., & Herment, S. (2015). Making Sense of Nonce Word Stress in English. In J. A. Mompean & J. Fouz-González (Eds.), *Investigating English Pronunciation: Trends and Directions* (pp. 23–46). Palgrave MacMillan.

van de Vijver, R., & Baer-Henney, D. (2014). Developing biases. *Frontiers in Psychology, 5(JUN),* 1–9. https://doi.org/10.3389/fpsyg.2014.00634

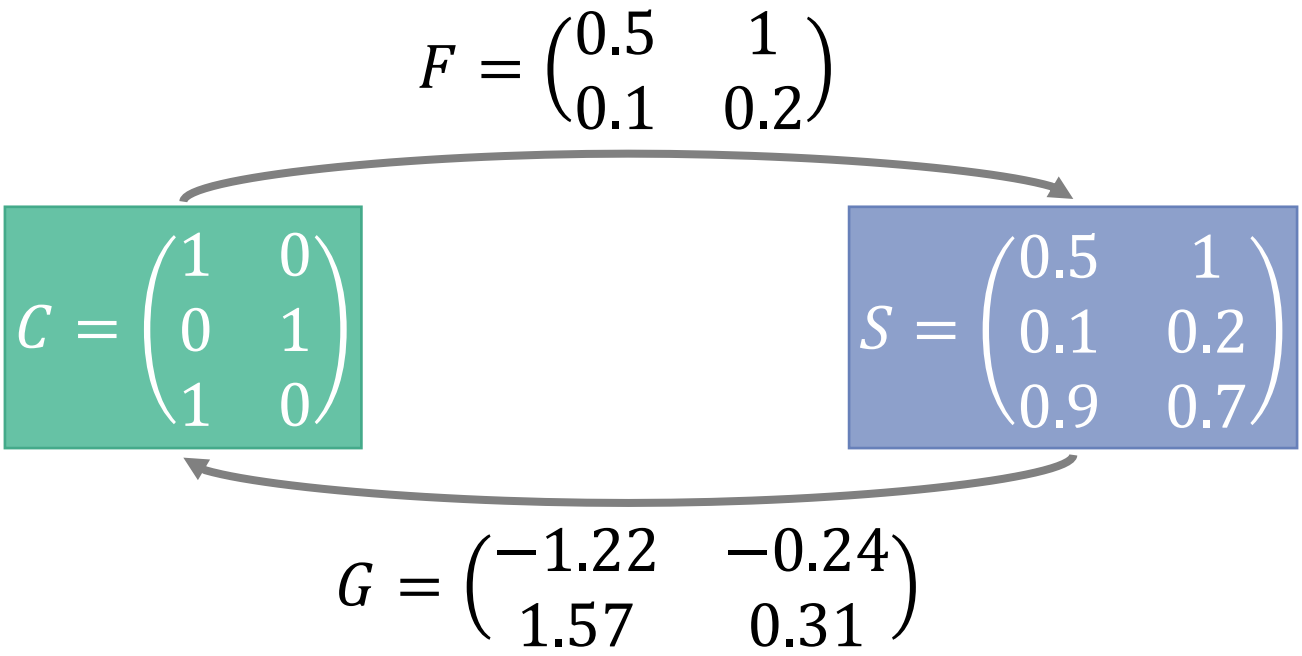
Venables, W. N., & Ripley, B. D. (2002). *Modern Applied Statistics with S*. Springer New York. https://doi.org/10.1007/978-0-387-21706-2

Vitevitch, M. S., & Luce, P. A. (1998). When words compete: Levels of Processing in Perception of Spoken Words. *Psychological Science, 9(4),* 325–329. https://doi.org/10.1111/1467-9280.00064

Vitevitch, M. S., & Luce, P. A. (2005). Increases in phonotactic probability facilitate spoken nonword repetition. *Journal of Memory and Language, 52(2),* 193–204. https://doi.org/10.1016/j.jml.2004.10.003

Wurm, L. H. (2000). Auditory Processing of Polymorphemic Pseudowords. *Journal of Memory and Language, 42(2),* 255–271. https://doi.org/10.1006/jmla.1999.2678

Linear Discriminative Learning



Toy example of mapping between form and meaning, and vice versa.