

The Role of Morphology in Auditory Word Recognition

Exploring Dutch and English Massive Databases

by Hanno Müller, Louis ten Bosch, Mirjam Ernestus

March 18, 2021

Agenda

- 1 Introduction
- 2 Experiment
- 3 Discussion
- 4 Outlook

Agenda

1 Introduction

2 Experiment

3 Discussion

4 Outlook

Visual vs. Auditory

- *Visual* word recognition well studied, *auditory* word recognition not

Visual vs. Auditory

- *Visual* word recognition well studied, *auditory* word recognition not
- Visual processing studies are inadequate for understanding auditory processing e.g. **Neighborhood Density (ND)**,

Visual vs. Auditory

- *Visual* word recognition well studied, *auditory* word recognition not
- Visual processing studies are inadequate for understanding auditory processing e.g. **Neighborhood Density (ND)**,
 - Visual: orthographic and phonological ND facilitative (Yates et al., 2004)

Visual vs. Auditory

- *Visual* word recognition well studied, *auditory* word recognition not
- Visual processing studies are inadequate for understanding auditory processing e.g. **Neighborhood Density (ND)**,
 - Visual: orthographic and phonological ND facilitative (Yates et al., 2004)
 - Auditory: orthographic ND facilitative (Ziegler et al., 2003), phonological ND inhibitive (Luce & Pisoni, 1998)

Visual vs. Auditory

- *Visual* word recognition well studied, *auditory* word recognition not
- Visual processing studies are inadequate for understanding auditory processing e.g. **Neighborhood Density (ND)**,
 - Visual: orthographic and phonological ND facilitative (Yates et al., 2004)
 - Auditory: orthographic ND facilitative (Ziegler et al., 2003), phonological ND inhibitive (Luce & Pisoni, 1998)
- Additionally, contradictory findings in auditory lexical decision disable strong conclusions e.g. **Stem Frequency**:

Visual vs. Auditory

- *Visual* word recognition well studied, *auditory* word recognition not
- Visual processing studies are inadequate for understanding auditory processing e.g. **Neighborhood Density (ND)**,
 - Visual: orthographic and phonological ND facilitative (Yates et al., 2004)
 - Auditory: orthographic ND facilitative (Ziegler et al., 2003), phonological ND inhibitive (Luce & Pisoni, 1998)
- Additionally, contradictory findings in auditory lexical decision disable strong conclusions e.g. **Stem Frequency**:
 - Facilitative (Baayen et al., 1997; Caramazza et al., 1988)

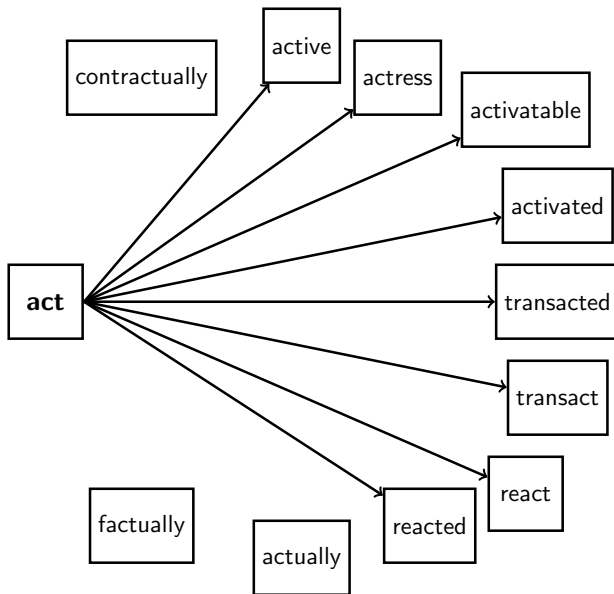
Visual vs. Auditory

- *Visual* word recognition well studied, *auditory* word recognition not
- Visual processing studies are inadequate for understanding auditory processing e.g. **Neighborhood Density (ND)**,
 - Visual: orthographic and phonological ND facilitative (Yates et al., 2004)
 - Auditory: orthographic ND facilitative (Ziegler et al., 2003), phonological ND inhibitive (Luce & Pisoni, 1998)
- Additionally, contradictory findings in auditory lexical decision disable strong conclusions e.g. **Stem Frequency**:
 - Facilitative (Baayen et al., 1997; Caramazza et al., 1988)
 - No effect (Bertram et al., 2000; Wurm et al., 2006)

Family Size

- **Family Size** = type frequency of words sharing the stem

Family Size



Family Size

- **Family Size** = type frequency of words sharing the stem
- Idea: Activation is spread across morphological relationships
→ Co-activated candidates activate target or compete

Family Size

- **Family Size** = type frequency of words sharing the stem
- Idea: Activation is spread across morphological relationships
→ Co-activated candidates activate target or compete
- Visual lexical decision:
 - Facilitative for monomorphemic (Schreuder & Baayen, 1997; Baayen et al., 2011), suffixed (Bertram et al., 2000; De Jong IV et al., 2000), prefixed, suffixed and monomorphemic words (del Prado Martín et al., 2005)

Family Size

- **Family Size** = type frequency of words sharing the stem
- Idea: Activation is spread across morphological relationships
→ Co-activated candidates activate target or compete
- Visual lexical decision:
 - Facilitative for monomorphemic (Schreuder & Baayen, 1997; Baayen et al., 2011), suffixed (Bertram et al., 2000; De Jong IV et al., 2000), prefixed, suffixed and monomorphemic words (del Prado Martín et al., 2005)
- Auditory lexical decision:

Family Size

- **Family Size** = type frequency of words sharing the stem
- Idea: Activation is spread across morphological relationships
→ Co-activated candidates activate target or compete
- Visual lexical decision:
 - Facilitative for monomorphemic (Schreuder & Baayen, 1997; Baayen et al., 2011), suffixed (Bertram et al., 2000; De Jong IV et al., 2000), prefixed, suffixed and monomorphemic words (del Prado Martín et al., 2005)
- Auditory lexical decision:
 - Facilitative for prefixed (Wurm et al., 2006), suffixed and monomorphemic (Winther Balling & Harald Baayen, 2008)

Family Size

- **Family Size** = type frequency of words sharing the stem
- Idea: Activation is spread across morphological relationships
→ Co-activated candidates activate target or compete
- Visual lexical decision:
 - Facilitative for monomorphemic (Schreuder & Baayen, 1997; Baayen et al., 2011), suffixed (Bertram et al., 2000; De Jong IV et al., 2000), prefixed, suffixed and monomorphemic words (del Prado Martín et al., 2005)
- Auditory lexical decision:
 - Facilitative for prefixed (Wurm et al., 2006), suffixed and monomorphemic (Winther Balling & Harald Baayen, 2008)
 - Inhibitive for prefixed and suffixed words (Balling & Baayen, 2012)

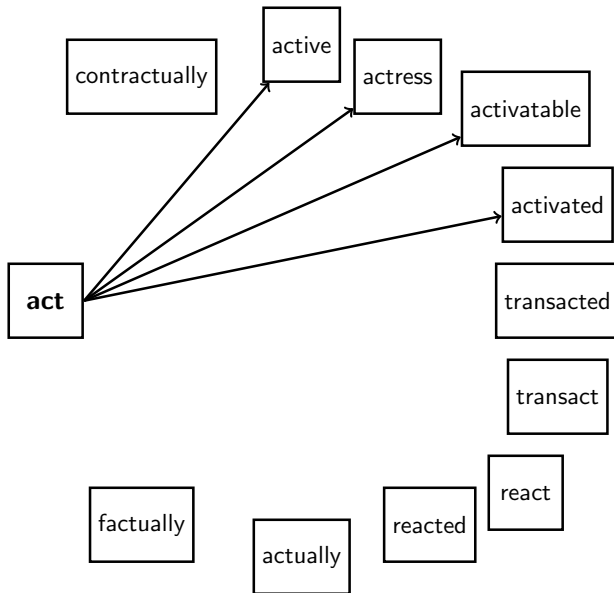
Family Size

- **Family Size** = type frequency of words sharing the stem
- Idea: Activation is spread across morphological relationships
→ Co-activated candidates activate target or compete
- Visual lexical decision:
 - Facilitative for monomorphemic (Schreuder & Baayen, 1997; Baayen et al., 2011), suffixed (Bertram et al., 2000; De Jong IV et al., 2000), prefixed, suffixed and monomorphemic words (del Prado Martín et al., 2005)
- Auditory lexical decision:
 - Facilitative for prefixed (Wurm et al., 2006), suffixed and monomorphemic (Winther Balling & Harald Baayen, 2008)
 - Inhibitive for prefixed and suffixed words (Balling & Baayen, 2012)
 - No effect for prefixed and suffixed words (Baayen et al., 2007)

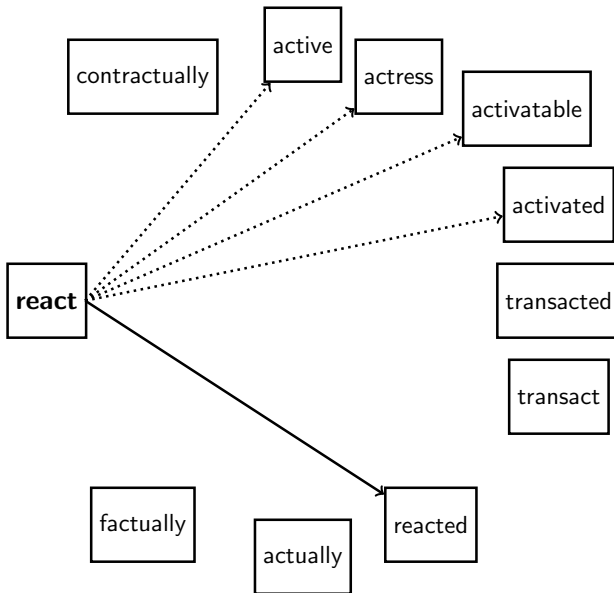
Onset-Aligned Family Size

- **Onset-Aligned Family Size** = type frequency of words sharing the stem (and possibly a prefix)

Onset-Aligned Family Size



Onset-Aligned Family Size



Onset-Aligned Family Size

- **Onset-Aligned Family Size** = type frequency of words sharing the stem (and possibly a prefix)
- Idea: the acoustic signal unfolds over time. Only those words that are onset-aligned with the target influence processing

Onset-Aligned Family Size

- **Onset-Aligned Family Size** = type frequency of words sharing the stem (and possibly a prefix)
- Idea: the acoustic signal unfolds over time. Only those words that are onset-aligned with the target influence processing
- Visual lexical decision:
 - Facilitative for monomorphemic (Baayen et al., 2011), prefixed, suffixed and monomorphemic words (del Prado Martín et al., 2005)

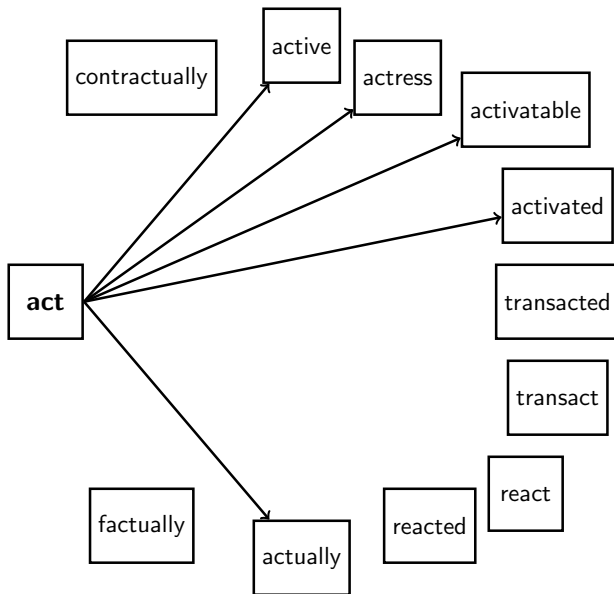
Onset-Aligned Family Size

- **Onset-Aligned Family Size** = type frequency of words sharing the stem (and possibly a prefix)
- Idea: the acoustic signal unfolds over time. Only those words that are onset-aligned with the target influence processing
- Visual lexical decision:
 - Facilitative for monomorphemic (Baayen et al., 2011), prefixed, suffixed and monomorphemic words (del Prado Martín et al., 2005)
- Auditory lexical decision:
 - Inhibitive for prefixed and suffixed words (Balling & Baayen, 2012)

Continuation Forms

- **Continuation Forms** = type frequency of words that left embed the target acoustically

Continuation Forms



Continuation Forms

- **Continuation Forms** = type frequency of words that left embed the target acoustically
- Idea: candidates that match with the bottom-up acoustic signal become activated and influence processing
- Auditory lexical decision:

Continuation Forms

- **Continuation Forms** = type frequency of words that left embed the target acoustically
- Idea: candidates that match with the bottom-up acoustic signal become activated and influence processing
- Auditory lexical decision:
 - Facilitative for prefixed (Wurm et al., 2006), prefixed words and compounds (Balling & Baayen, 2012)

Continuation Forms

- **Continuation Forms** = type frequency of words that left embed the target acoustically
- Idea: candidates that match with the bottom-up acoustic signal become activated and influence processing
- Auditory lexical decision:
 - Facilitative for prefixed (Wurm et al., 2006), prefixed words and compounds (Balling & Baayen, 2012)
 - No effect for monomorphemic and suffixed words (Winther Balling & Harald Baayen, 2008)

Research Question

- Effect of Family Size inconsistent in auditory lexical decision:

Research Question

- Effect of Family Size inconsistent in auditory lexical decision:
 - Is Family Size predictive in auditory lexical decision?

Research Question

- Effect of Family Size inconsistent in auditory lexical decision:
 - Is Family Size predictive in auditory lexical decision?
- Onset-Aligned Family Size inhibitive in one auditory lexical decision study mixing prefixed and suffixed words:

Research Question

- Effect of Family Size inconsistent in auditory lexical decision:
 - Is Family Size predictive in auditory lexical decision?
- Onset-Aligned Family Size inhibitive in one auditory lexical decision study mixing prefixed and suffixed words:
 - Does the effect show up when word classes are separated?

Research Question

- Effect of Family Size inconsistent in auditory lexical decision:
 - Is Family Size predictive in auditory lexical decision?
- Onset-Aligned Family Size inhibitive in one auditory lexical decision study mixing prefixed and suffixed words:
 - Does the effect show up when word classes are separated?
- Effects of number of Continuation Forms facilitative for prefixed and inhibitive for monomorphemic and suffixed words

Research Question

- Effect of Family Size inconsistent in auditory lexical decision:
 - Is Family Size predictive in auditory lexical decision?
- Onset-Aligned Family Size inhibitive in one auditory lexical decision study mixing prefixed and suffixed words:
 - Does the effect show up when word classes are separated?
- Effects of number of Continuation Forms facilitative for prefixed and inhibitive for monomorphemic and suffixed words
 - Same for auditory recognition?

Agenda

- 1 Introduction
- 2 Experiment
- 3 Discussion
- 4 Outlook

- Dutch Database: **BALDEY** (Ernestus & Cutler, 2015)

- Dutch Database: **BALDEY** (Ernestus & Cutler, 2015)
 - 2.780 words & 2.761 pseudowords
 - 110.820 decisions from 20 listeners

- Dutch Database: **BALDEY** (Ernestus & Cutler, 2015)
 - 2.780 words & 2.761 pseudowords
 - 110.820 decisions from 20 listeners
- English Database: **MALD** (Tucker et al., 2019)

- Dutch Database: **BALDEY** (Ernestus & Cutler, 2015)
 - 2.780 words & 2.761 pseudowords
 - 110.820 decisions from 20 listeners
- English Database: **MALD** (Tucker et al., 2019)
 - 26.793 word & 9.592 pseudowords
 - 227.179 decisions from 231 listeners

- Dutch Database: **BALDEY** (Ernestus & Cutler, 2015)
 - 2.780 words & 2.761 pseudowords
 - 110.820 decisions from 20 listeners
- English Database: **MALD** (Tucker et al., 2019)
 - 26.793 word & 9.592 pseudowords
 - 227.179 decisions from 231 listeners
- Both databases contain words of different morphological complexity

Method

- 1 Creation of *baseline*-model including most important factors that explain variance away

- ① Creation of *baseline*-model including most important factors that explain variance away
 - Previous RT
 - Word Duration
 - Trial
 - Phonological Uniqueness Point (PhonUP)

- ① Creation of *baseline*-model including most important factors that explain variance away
 - Previous RT
 - Word Duration
 - Trial
 - Phonological Uniqueness Point (PhonUP)
 - (only MALD: Phonological Neighborhood Density (PhonND))

Method

- ① Creation of *baseline*-model including most important factors that explain variance away
 - Previous RT
 - Word Duration
 - Trial
 - Phonological Uniqueness Point (PhonUP)
 - (only MALD: Phonological Neighborhood Density (PhonND))
- ② Not significant predictors were removed stepwisely

- ① Creation of *baseline*-model including most important factors that explain variance away
 - Previous RT
 - Word Duration
 - Trial
 - Phonological Uniqueness Point (PhonUP)
 - (only MALD: Phonological Neighborhood Density (PhonND))
- ② Not significant predictors were removed stepwisely
- ③ Random-Structure fitted following parsimonious account

(Bates et al., 2015)

Method

- ① Creation of *baseline*-model including most important factors that explain variance away
 - Previous RT
 - Word Duration
 - Trial
 - Phonological Uniqueness Point (PhonUP)
 - (only MALD: Phonological Neighborhood Density (PhonND))
- ② Not significant predictors were removed stepwisely
- ③ Random-Structure fitted following parsimonious account
(Bates et al., 2015)
- ④ Hypothesis testing: predictor of interest added to *baseline*
→ Does resulting model improve on *baseline*?

BALDEY - Results

Subset	N	Predictor	Direction
mono	8.798	Family Size***	facilitative
mono	8.798	Onset Aligned Family Size	
mono	8.798	Continuation Forms	
suffixed	11.050	Family Size	facilitative
suffixed	11.050	Onset Aligned Family Size***	
suffixed	11.050	Continuation Forms	
prefixed	6.709	Family Size	
prefixed	6.709	Onset Aligned Family Size	
prefixed	6.709	Continuation Forms	

Table: Comparison of subsets

MALD - Results

Subset	N	Predictor	Direction
mono	49.195	Family Size***	facilitative
mono	49.195	Onset Aligned Family* Size	inhibitive
mono	49.195	Continuation Forms*	inhibitive
suffixed	20.010	Family Size	
suffixed	20.010	Onset Aligned Family Size	
suffixed	20.010	Continuation Forms***	inhibitive
prefixed	116	-	-
prefixed	116	-	-
prefixed	116	-	-

Table: Comparison of subsets

Overview

	Family Size		O.-Aligned Family Size		Continuations	
Structure	BALD	MALD	BALD	MALD	BALD	MALD
Mono.	+***	+***		_*		_*
Suffixed			+***			_***
Prefixed		NA		NA		NA

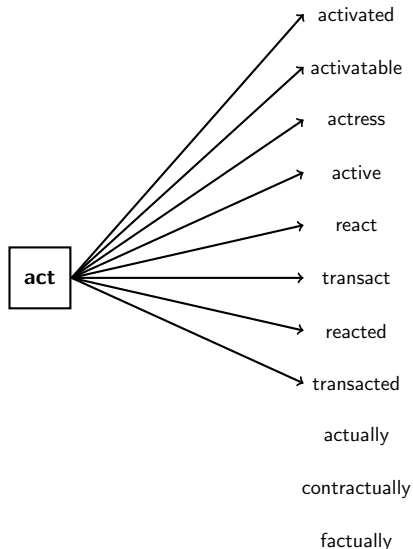
Table: Effects per words of differing morphological complexity in BALDEY (BALD) and MALD: '+' = facilitativ; '-' = inhibitive

Agenda

- 1 Introduction
- 2 Experiment
- 3 Discussion**
- 4 Outlook

Family Size

- **Family Size** is facilitative for monomorphemic words; in line with visual lexical decision studies



Family Size

- **Family Size** is facilitative for monomorphemic words; in line with visual lexical decision studies
- No effect for complex words

react

activated

activatable

actress

active

react

transact

reacted

transacted

actually

contractually

factually

Family Size

- **Family Size** is facilitative for monomorphemic words; in line with visual lexical decision studies
- No effect for complex words

activate

activated

activatable

actress

active

react

transact

reacted

transacted

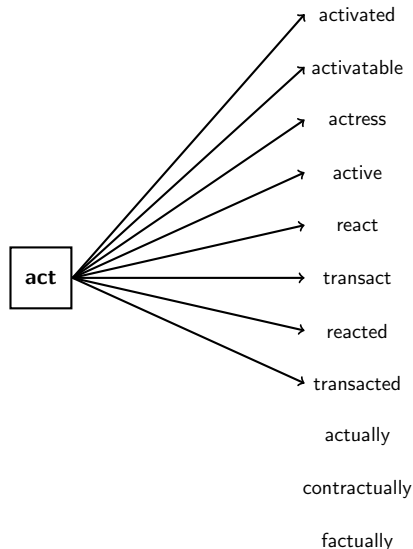
actually

contractually

factually

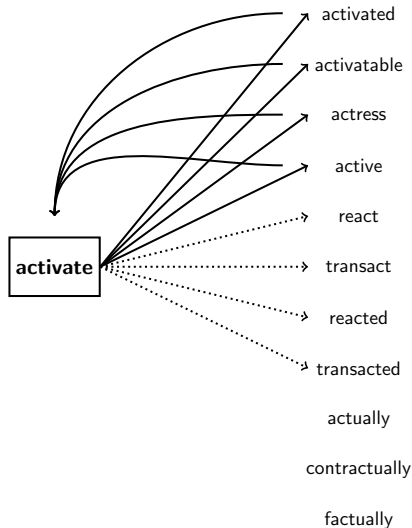
Family Size

- **Family Size** is facilitative for monomorphemic words; in line with visual lexical decision studies
- No effect for complex words
- Hypothesis: Activation not spread between target and words deviating from target



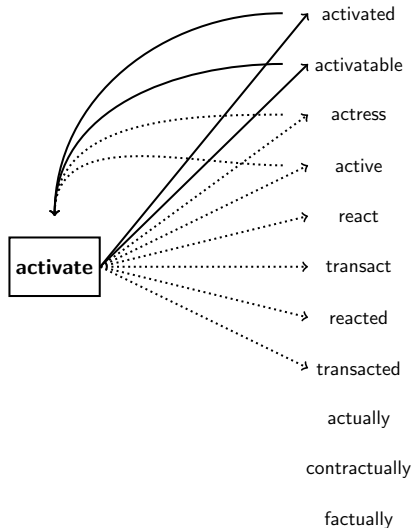
Family Size

- **Family Size** is facilitative for monomorphemic words; in line with visual lexical decision studies
- No effect for complex words
- Hypothesis: Activation not spread between target and words deviating from target
 - Morphological deviation:
→ Onset-Aligned Family Size facilitative



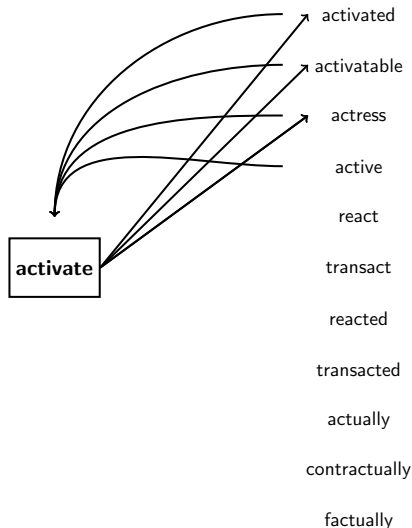
Family Size

- **Family Size** is facilitative for monomorphemic words; in line with visual lexical decision studies
- No effect for complex words
- Hypothesis: Activation not spread between target and words deviating from target
 - Morphological deviation:
 - Onset-Aligned Family Size facilitative
 - Acoustic deviation:
 - Continuations facilitative



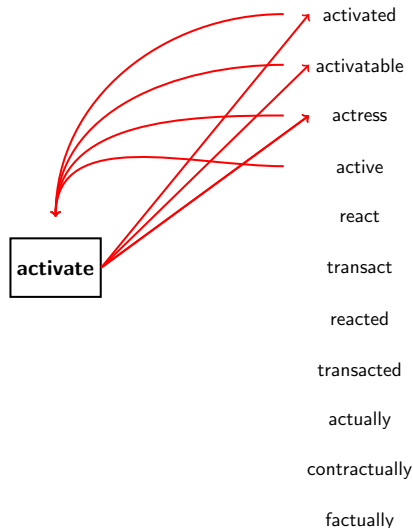
Onset-Aligned Family Size

- **Onset-Aligned Family Size** is facilitative for Dutch suffixed words ...



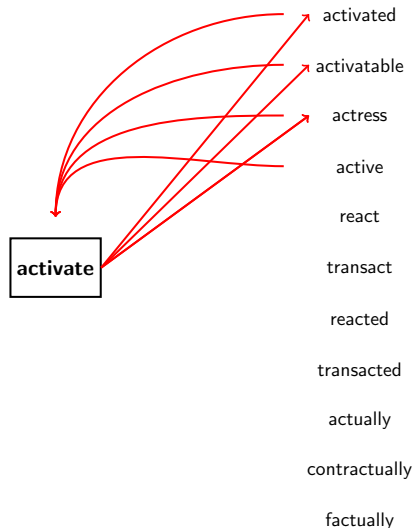
Onset-Aligned Family Size

- **Onset-Aligned Family Size** is facilitative for Dutch suffixed words ...
- ... but inhibitive for English monomorphemic and suffixed words



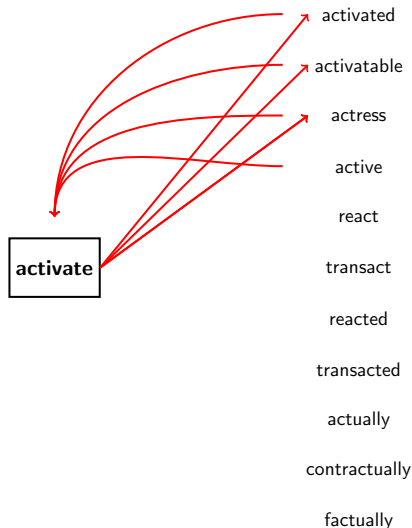
Onset-Aligned Family Size

- **Onset-Aligned Family Size** is facilitative for Dutch suffixed words ...
- ... but inhibitive for English monomorphemic and suffixed words
- Indication of differences across languages:



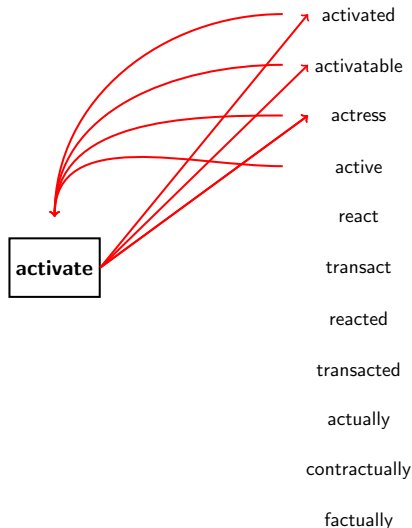
Onset-Aligned Family Size

- **Onset-Aligned Family Size** is facilitative for Dutch suffixed words ...
- ... but inhibitive for English monomorphemic and suffixed words
- Indication of differences across languages:
 - ① distributional properties: Entropy, Surprisal, Frequency, ...



Onset-Aligned Family Size

- **Onset-Aligned Family Size** is facilitative for Dutch suffixed words ...
- ... but inhibitive for English monomorphemic and suffixed words
- Indication of differences across languages:
 - 1 distributional properties: Entropy, Surprisal, Frequency, ...
 - Further investigation necessary



Continuations

- **Continuations** inhibit responses (MALD)

act

activation

activatable

actress

active

react

transact

reacted

transacted

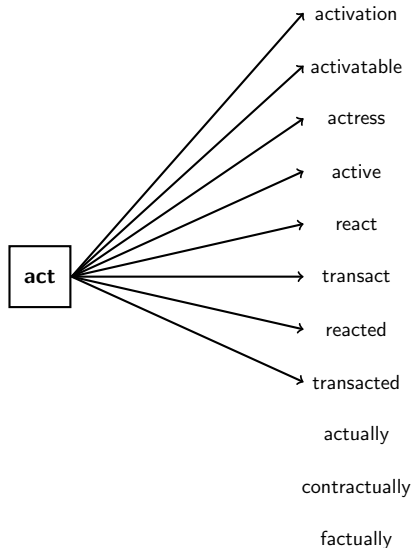
actually

contractually

factually

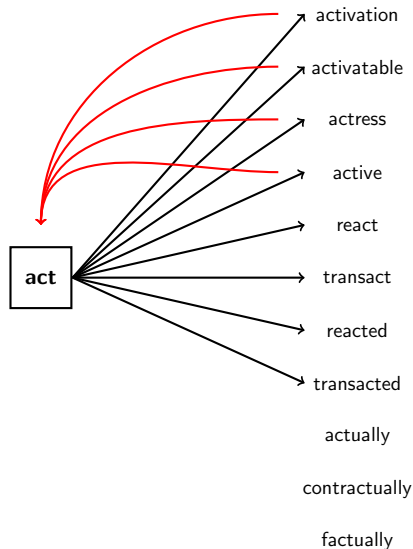
Continuations

- **Continuations** inhibit responses (MALD)
- Monomorphemic words:
 - Family Size facilitative



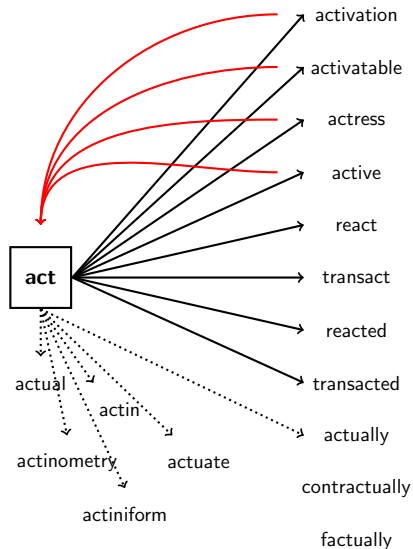
Continuations

- **Continuations** inhibit responses (MALD)
- Monomorphemic words:
 - Family Size facilitative
 - Inhibitive effect Onset-Aligned Family Size



Continuations

- **Continuations** inhibit responses (MALD)
- Monomorphemic words:
 - Family Size facilitative
 - Inhibitive effect Onset-Aligned Family Size
 - Continuations inhibitive



Continuations

- **Continuations** inhibit responses (MALD)

- Monomorphemic words:

- Family Size facilitative
- Inhibitive effect Onset-Aligned Family Size
- Continuations inhibitive

activate

- Suffixed words:

activation

activatable

actress

active

react

transact

reacted

transacted

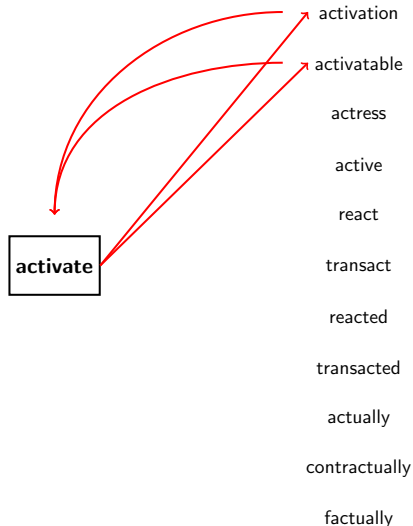
actually

contractually

factually

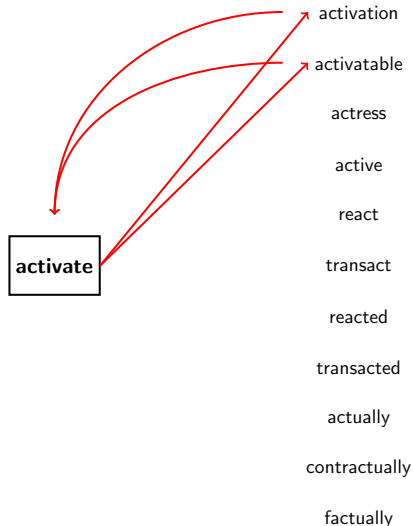
Continuations

- **Continuations** inhibit responses (MALD)
- Monomorphemic words:
 - Family Size facilitative
 - Inhibitive effect Onset-Aligned Family Size
 - Continuations inhibitive
- Suffixed words:
 - Continuation Forms equal Onset-Aligned Family



Continuations

- **Continuations** inhibit responses (MALD)
- Monomorphemic words:
 - Family Size facilitative
 - Inhibitive effect Onset-Aligned Family Size
 - Continuations inhibitive
- Suffixed words:
 - Continuation Forms equal Onset-Aligned Family
- Absence in Dutch
 - Interlingual differences



Agenda

- 1 Introduction
- 2 Experiment
- 3 Discussion
- 4 Outlook

Outlook

- Source of interlingual differences?

- Source of interlingual differences?
- Inclusion of other predictors to explain e.g., Surprisal, Entropy, Frequency, ...

Outlook

- Source of interlingual differences?
- Inclusion of other predictors to explain e.g., Surprisal, Entropy, Frequency, ...



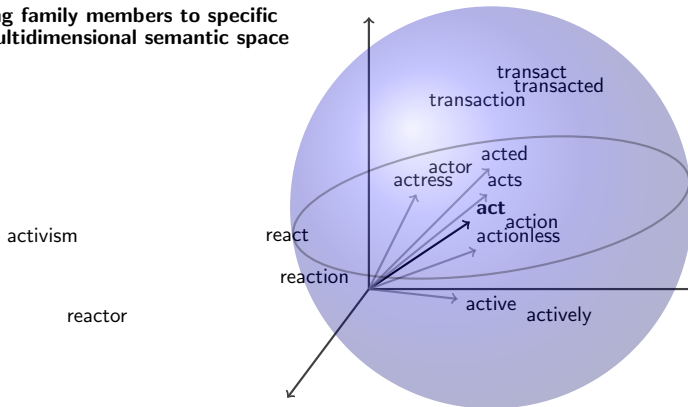
Outlook

- Source of interlingual differences?
- Inclusion of other predictors to explain e.g., Surprisal, Entropy, Frequency, ...
- Do semantic transparency or regularity shape the family?



Outlook

Resitricting family members to specific
area in multidimensional semantic space



- Baayen, R. H., Dijkstra, T., & Schreuder, R. (1997). Singulars and plurals in Dutch: Evidence for a parallel dual-route model. *Journal of Memory and Language*, 37(1), 94–117.
- Baayen, R. H., Milin, P., Durdević, D. F., Hendrix, P., & Marelli, M. (2011). An amorphous model for morphological processing in visual comprehension based on naive discriminative learning. *Psychological review*, 118(3), 438.
- Baayen, R. H., Wurm, L. H., & Ayccock, J. (2007). Lexical dynamics for low-frequency complex words: A regression study across tasks and modalities. *The mental lexicon*, 2(3), 419–463.
- Balling, L. W., & Baayen, R. H. (2012). Probability and surprisal in auditory comprehension of morphologically complex words. *Cognition*, 125(1), 80–106.
- Bates, D., Kliegl, R., Vasishth, S., & Baayen, H. (2015). Parsimonious mixed models. *arXiv preprint arXiv:1506.04967*.
- Bertram, R., Schreuder, R., & Baayen, R. H. (2000). The balance of storage and computation in morphological processing: The role of word formation type, affixal homonymy, and productivity. *Journal of experimental psychology: Learning, memory, and cognition*, 26(2), 489.
- Caramazza, A., Laudanna, A., & Romani, C. (1988). Lexical access and inflectional morphology. *Cognition*, 28(3), 297–332.
- De Jong IV, N. H., Schreuder, R., & Harald Baayen, R. (2000). The morphological family size effect and morphology. *Language and cognitive processes*, 15(4-5), 329–365.
- del Prado Martín, F. M., Deutsch, A., Frost, R., Schreuder, R., De Jong, N. H., & Baayen, R. H. (2005). Changing places: A cross-language perspective on frequency and family size in dutch and hebrew. *Journal of Memory and Language*, 53(4), 496–512.
- Ernestus, M., & Cutler, A. (2015). Baldey: A database of auditory lexical decisions. *Quarterly Journal of Experimental Psychology*, 68(8), 1469–1488.
- Luce, P. A., & Pisoni, D. B. (1998). Recognizing spoken words: The neighborhood activation model. *Ear and hearing*, 19(1), 1.
- Schreuder, R., & Baayen, R. H. (1997). How complex simplex words can be. *Journal of memory and language*, 37(1), 118–139.
- Tucker, B. V., Brenner, D., Danielson, D. K., Kelley, M. C., Nenadić, F., & Sims, M. (2019). The massive auditory lexical decision (mald) database. *Behavior research methods*, 51(3), 1187–1204.
- Winther Balling, L., & Harald Baayen, R. (2008). Morphological effects in auditory word recognition: Evidence from danish. *Language and Cognitive Processes*, 23(7-8), 1159–1190.
- Wurm, L. H., Ernestus, M. T., Schreuder, R., & Baayen, R. H. (2006). Dynamics of the auditory comprehension of prefixed words: Cohort entropies and conditional root uniqueness points. *The Mental Lexicon*, 1(1), 125–146.
- Yates, M., Locker, L., & Simpson, G. B. (2004). The influence of phonological neighborhood on visual word perception. *Psychonomic Bulletin & Review*, 11(3), 452–457.
- Ziegler, J. C., Muneaux, M., & Grainger, J. (2003). Neighborhood effects in auditory word recognition: Phonological competition and orthographic facilitation. *Journal of Memory and Language*, 48(4), 779–793.