Prefixal Gemination in English: An experimental study on un- and in-

Sonia Ben Hedia
Heinrich-Heine-Universität Düsseldorf

Spoken Morphology: Phonetics and Phonology of Complex Words
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(De-)Gemination in English

• Sequence of two identical consonants across a morphological boundary

  \textit{un-} \quad \textit{un-natural}

  \textit{in-} \quad \textit{in-numerous, im-material, il-logical, ir-resistable}

  \textit{dis-} \quad \textit{dis-satisfied}

  \textit{-ly} \quad \textit{sole-ly, technical-ly}

• Phonetic correlates
  
  o Gemination: Longer duration than a singleton
  
  o Degemination: Same duration as a singleton

• Theoretical assumption: Degemination is affix- or stratum-dependent
## Predictions: Lexical Phonology

<table>
<thead>
<tr>
<th></th>
<th>Level 1</th>
<th>Level 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morphological Process</td>
<td>in + numerous</td>
<td></td>
</tr>
<tr>
<td>Phonological Process</td>
<td>i/n/umerous</td>
<td></td>
</tr>
<tr>
<td>Phonetic Outcome</td>
<td>i[n]umerous</td>
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</tr>
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</table>

**Degemination**
# Predictions: Lexical Phonology

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Morphological Process</td>
<td>in + numerous</td>
<td>un + natural</td>
</tr>
<tr>
<td>Phonological Process</td>
<td>i/n/umerous</td>
<td>u/nn/atural</td>
</tr>
<tr>
<td>Phonetic Outcome</td>
<td>i[n]umerous</td>
<td>u[n:]atural</td>
</tr>
</tbody>
</table>

- **Degemination**
- **Gemination**
Predictions: Morphological Separability

- Phonetic realization is dependent on morphological separability
- more separable $\rightarrow$ less reduction
  
  (e.g. Hay 2003, Smith et al. 2012, Ben Hedia & Plag 2016, Plag 2016)

More separable complex words geminate.
Less separable complex words degeminate.

- Separability:
  - Semantic Transparency: opaque vs. transparent
  - Type of Root: bound root vs. word
  - Relative Frequency: relative frequency of base and derivative
Empirical evidence?

- Only few studies empirically investigated gemination in English

- Corpus Study (Ben Hedia & Plag 2016)
  - *dis-* geminates
  - *-ly* degeminates

- *un-* geminates (Kaye 2005, Oh and Redford 2013, Ben Hedia & Plag 2016)

- *in-* can geminate
  - Type-dependent (Oh and Redford 2013)
  - speaker-dependent (Kaye 2005)
  - *in-* geminates (Ben Hedia and Plag 2016)

- Problems: Only very small set of types
  Contradictory results
This study

- Reading experiment
- 2 affixes: *un-* and *in-*
- Comparison of nasal duration in 3 different environments

<table>
<thead>
<tr>
<th></th>
<th>Morphological geminate</th>
<th>Singleton in base</th>
<th>Singleton in complex word</th>
</tr>
</thead>
<tbody>
<tr>
<td>un</td>
<td>unnatural (n#n)</td>
<td>natural (#n)</td>
<td>uneven (n#V)</td>
</tr>
<tr>
<td>im</td>
<td>immature (m#m)</td>
<td>mature (#m)</td>
<td>impossible (m#p)</td>
</tr>
<tr>
<td>in</td>
<td>innumerous (n#n)</td>
<td>numerous (#n)</td>
<td>intolerant (n#t)</td>
</tr>
</tbody>
</table>
Experiment

• 183 types
• Items are put in carrier sentences

John said *UNNATURAL* again.
John tells me *NATURAL* again.
It is John who said *unnatural* again, NOT HENRY.
Experiment

• 183 types
• Items are put in carrier sentences

John said **UNNATURAL** again.
John tells me **NATURAL** again.
It is John who said **unnatural** again, NOT HENRY.

unaccented position
Experiment

- 29 participants (native speakers of British English) read the sentences
- Separability Rating
## Separability Rating

### Complex words

*Please rate on a scale from 1 to 4 how difficult you find it to divide the word into its first two letters (un-, in- or im-) and the rest of the word. I don't know this word.*

<table>
<thead>
<tr>
<th>I don't know this word.</th>
<th>1 - Very easy to break into parts in/im/un + rest of word</th>
<th>2 - Easy to break into parts in/im/un + rest of word</th>
<th>3 - Difficult to break into parts in/im/un + rest of word</th>
<th>4 - Very difficult to break into parts in/im/un + rest of word</th>
</tr>
</thead>
<tbody>
<tr>
<td>inexpressive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>unnoteworthy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>improve</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ineliminable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>impotence</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>inimitable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>unnoticed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>unnerve</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>immature</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>impanel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Experiments

- 29 participants (native speakers of British English) read the sentences
- Separability Rating
- Items were manually segmented
- Acoustic measurements
- Items were coded (frequencies, stress...
Data Overview

<table>
<thead>
<tr>
<th></th>
<th>Morphological geminate</th>
<th>Singleton in base</th>
<th>Singleton in complex word</th>
</tr>
</thead>
<tbody>
<tr>
<td>un</td>
<td>535</td>
<td>549</td>
<td>676</td>
</tr>
<tr>
<td>im</td>
<td>490</td>
<td>458</td>
<td>610</td>
</tr>
<tr>
<td>in</td>
<td>88</td>
<td>77</td>
<td>422</td>
</tr>
</tbody>
</table>
Statistical Modelling

- Multiple regression with **nasal duration** as dependent variable
- Speaker and Item as random effects
Variables:

- Environment
- Preceding Segment Duration
- Following Segment
- Following Segment Duration
- Local Speech Rate
- Global Speech Rate
- Stress
- Accentuation
- Word Form Frequency
- Order
- Affix
- Semantic Transparency
- Rating
- Relative Frequency
- Type of Root
Statistical Modelling

• Variables:
  • Environment
  • Preceding Segment Duration
  • Following Segment
  • Following Segment Duration
  • Local Speech Rate
  • Global Speech Rate
  • Stress
  • Accentuation
  • Word Form Frequency
  • Order
  • Affix
  • Semantic Transparency
  • Rating
  • Relative Frequency
  • Type of Root
Morphological Separability

<table>
<thead>
<tr>
<th>Affix</th>
<th>uncool</th>
<th>impossible</th>
<th>import</th>
</tr>
</thead>
<tbody>
<tr>
<td>un-</td>
<td>negative in-</td>
<td>locative in-</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Semantic Transparency</th>
<th>transparent</th>
<th>opaque</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Root</td>
<td>word as a root</td>
<td>bound root</td>
</tr>
<tr>
<td>Relativ Freq.</td>
<td>base more frequent</td>
<td>derivative more frequent</td>
</tr>
<tr>
<td>Rating</td>
<td>easy to segment</td>
<td>difficult to segment</td>
</tr>
</tbody>
</table>
Results: Overview
Results: Overview

- **im-**
  - #m
  - m#m
  - m#p

- **in-**
  - #n
  - n#n
  - n#t
  - n#V

- **un-**
  - #n
  - n#n
  - n#V
Results \textit{in-}: m#m vs. m#p

- $R^2 = 0.56$
- Covariates show expected effects
- Primary stress on base: Doubles are 11 ms longer than singles
- Unstressed base: Doubles are as long as singles
Results *in-*: m#m vs. m#p

- Speaker: 165.8
- Local Speech: 89.8
- Item: 45.2
- Interaction: 29.2
- Stress: 27.6
- Global Speech: 16.6
- Environment: 16.6

AIC increase in im-model
Results *in-*: m#m vs. #m

- $R^2 = 0.58$
- Covariates show expected effects
- NoPause: Doubles and singles are of the same duration
- Pause: Doubles are 10 ms longer than singles
Results *in*-: m#m vs. #m

AIC increase in im-model

- Speaker: 131.5
- Local Speech: 76.8
- PrePause: 41.2
- Stress: 37.7
- Item: 27.8
- Interaction: 25.8
- Environment: 23.8
- Accentuation: 8.7
- Global Speech: 3.2
Results *in-*: n#n vs. n#t vs. n#V

- $R^2 = 0.74$
- Covariates show expected effects
- Doubles are as long as singles with a following stop
- Doubles are 27 ms longer than singles with a following vowel
**Results in-: n#n vs. n#t vs. n#V**

- $R^2 = 0.74$
- Covariates show expected effects
- Doubles are 53 ms shorter than singles with a following stop
- Doubles are 8 ms longer than singles with a following vowel
Results *in-*: n#n vs. n#t vs. n#V
Summary: *in-*

For *im-*:
- Only if there is stress on base: Doubles are slightly longer than singles with a following stop
- Only after a pause: Doubles are slightly longer than singles in base words
- Environment is not a powerful predictor

For *in-*:
- Stressed base: Doubles are longer than singles with a following vowel
- Unstressed base: Doubles are slightly longer than singles with a following vowel
- Doubles are never longer than singles with a following stop
- Environment is a powerful predictor
Results $un-$: n#$n$ vs. n#$V$

- $R^2 = 0.90$
- Covariates show expected effects
- Accented doubles are 98 ms longer than accented singles
- Unaccented doubles are 78 ms longer than unaccented singles
Results *un-*: n#n vs. n#V
Results *un*-: n#n vs. #n

- $R^2 = 0.74$
- Covariates show expected effects
- Doubles are 36 ms longer than singles
Results $un$: n#n vs. #n
Summary

• No effect of separability

• *un*- clearly geminates:
  • doubles are always longer than singles

• *in*- does not clearly geminate
  • For *im*-: doubles are never clearly longer than singles
  • For *in*-: only when base is stressed, doubles are clearly longer than singles with a following vowel

*un*- and *in*- differ in their gemination pattern
Discussion

Does *in*- geminate? Does stress play an important role?

*i*-n-

- Experiment:
  - Stressed base: doubles slightly longer than singletons
  - Unstressed base: doubles as long as singletons

- Corpus: Doubles always longer than singletons

*i*-

- Stressed base:
  - doubles longer than singletons with following vowel
  - doubles as long as singletons with following stop

- Unstressed base:
  - doubles slightly longer than singletons with following vowel
  - doubles shorter than singletons with following stop
Why do the experimental results deviate from the results of the corpus study?

<table>
<thead>
<tr>
<th>Corpus</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>• <em>un</em>- geminates (n#n= 90, n#V= 43)</td>
<td>• <em>un</em>- geminates (n#n=148/132, n#V= 51/54)</td>
</tr>
<tr>
<td>• <em>in</em>- geminates (m#m= 96, m#p= 69)</td>
<td>• <em>in</em>- does not clearly geminate (m#m= 99/ 76, m#p= 87/83)</td>
</tr>
<tr>
<td>• Difference in duration between negative and locative <em>in</em>-</td>
<td>• No difference in duration between negative and locative <em>in</em>-</td>
</tr>
<tr>
<td>• Natural conversational speech</td>
<td>• Read speech</td>
</tr>
<tr>
<td>• American English</td>
<td>• British English</td>
</tr>
<tr>
<td>• Less types</td>
<td>• More types</td>
</tr>
</tbody>
</table>
Discussion

Does separability play a role?

• No direct effect of separability on gemination

• *un-* more separable than *in-*

• Could the different gemination behavior of *un-* and *in-* be explained with a “categorical” difference in their separability?
Thank you very much for your attention!

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- Phonetics Lab, Department of Theoretical and Applied Linguistics, University of Cambridge

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- Grant PL151/8-1 ‘Morpho-phonetic Variation in English’
- Grant PL151/7-1 ‘FOR 2737 Spoken Morphology: Central Project’
References


## Discussion

Does *in-* geminate?

<table>
<thead>
<tr>
<th></th>
<th>(\text{im}) m#m vs m#p</th>
<th>(\text{im}) m#m vs.#m</th>
<th>(\text{in}) n#n vs. n#t</th>
<th>(\text{in}) n#n vs. n#V</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experiment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>unstressed base:</td>
<td>Pause before word:</td>
<td>unstressed base:</td>
<td>unstressed base:</td>
</tr>
<tr>
<td></td>
<td>double = single</td>
<td>double = single</td>
<td>double &lt; single</td>
<td>double &gt; single</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>53 ms</td>
<td>8 ms</td>
</tr>
<tr>
<td></td>
<td>stressed base:</td>
<td>No pause before word:</td>
<td>stressed base:</td>
<td>stressed base:</td>
</tr>
<tr>
<td></td>
<td>double &gt; single 11 ms</td>
<td>double &gt; single 10 ms</td>
<td>double = single</td>
<td>double &gt; single 27 ms</td>
</tr>
<tr>
<td><strong>Corpus</strong></td>
<td>double &gt; single 27 ms</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Data Overview: types

<table>
<thead>
<tr>
<th>prefix</th>
<th>Morphological geminate (n#n)</th>
<th>Base (Base)</th>
<th>Singletons (n#V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>un</td>
<td>20</td>
<td>20</td>
<td>26</td>
</tr>
<tr>
<td>im</td>
<td>19</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>in</td>
<td>4</td>
<td>3</td>
<td>19</td>
</tr>
</tbody>
</table>
Decomposability of affixes

Type of Root per Affix

- un: 89%
- Neg: 66%
- Loc: 54%

Decomposability Rating per Affix

- un: 98%
- Neg: 86%
- Loc: 47%
Decomposability of affixes

Semantic Transparency per Affix

- un: 98%
- Neg: 97%
- Loc: 39%

Log Relative Frequency per Affix
**un-model: unV vs. unn**

Fixed effects:

| Estimate | Std. Error | df    | t value | Pr(>|t|) |
|----------|------------|-------|---------|----------|
| (Intercept) | 9.154e-01 | 3.055e-03 | 4.524e+02 | 299.662 | < 2e-16 *** |
| FirstSyllBaseStressunstressed | -3.628e-03 | 1.202e-03 | 4.580e+01 | -3.018 | 0.00414 ** |
| LocSpeech | -1.326e-03 | 1.992e-04 | 5.746e+02 | -6.655 | 6.62e-11 *** |
| GlobalSpeechRate | -4.481e-03 | 9.369e-04 | 8.215e+02 | -4.782 | 2.06e-06 *** |
| PrecSegDur | -2.997e-02 | 1.289e-02 | 1.150e+03 | -2.325 | 0.02024 * |
| TypeOfRootword | 3.191e-03 | 1.612e-03 | 3.880e+01 | 1.981 | 0.05476 . |
| CategoryunV | -5.645e-02 | 1.278e-03 | 5.800e+01 | -44.164 | < 2e-16 *** |
| AccentuationUnaccented | -6.328e-03 | 1.049e-03 | 1.144e+03 | -6.033 | 2.17e-09 *** |
| CategoryunV:AccentuationUnaccented | 9.942e-03 | 1.160e-03 | 1.119e+03 | 8.571 | < 2e-16 *** |
Results 1: un#n vs. un#V

- **Local speech rate**
  - The duration in milliseconds decreases as the speech rate increases.
  - The trend is consistent across different speech rates.

- **Global speech rate**
  - Similar trend to local speech rate, with duration decreasing with increasing speech rate.

- **Primary vs. unstressed**
  - The duration is relatively constant for both primary and unstressed conditions.

- **Stress**
  - The duration decreases slightly with increasing stress levels.

- **Preceding segment duration**
  - The duration decreases linearly with increasing preceding segment duration.
Results 1: un♯n vs. un♯V
**un-model: Base vs. unn**

Fixed effects:

|                      | Estimate | Std. Error | df   | t value | Pr(>|t|) |
|----------------------|----------|------------|------|---------|----------|
| (Intercept)          | 5.601e-01| 1.306e-02  | 1.814e+02| 42.874  | < 2e-16 *** |
| Categoryunn          | 4.953e-02| 6.868e-03  | 3.170e+01| 7.211   | 3.64e-08 *** |
| AccentuationUnaccented| -1.445e-02| 3.072e-03 | 1.016e+03| -4.706  | 2.88e-06 *** |
| logWordFormFreq      | -2.615e-03| 1.117e-03  | 3.060e+01| -2.341  | 0.02591 *    |
| FirstSyllBaseStressunstressed | -3.798e-02| 1.141e-02 | 3.120e+01| -3.327  | 0.00226 **   |
| LocSpeech            | -1.237e-02| 7.235e-04  | 7.480e+02| -17.099 | < 2e-16 ***  |
| GlobalSpeechRate     | -9.715e-03| 3.833e-03  | 9.771e+02| -2.535  | 0.01141 *    |
| PrePausePause        | -1.160e-02| 2.798e-03  | 1.029e+03| -4.145  | 3.68e-05 ***  |
| PostPausePause       | -6.070e-03| 3.111e-03  | 1.029e+03| -1.951  | 0.05130 .     |
un-model: Base vs. unn

- Local speech rate
- Global speech rate
- Accentuation
- Primary vs. unstressed
- No Pause vs. Pause
- Word form frequency

(duration in milliseconds)
**im-model: m#m vs. m#p**

Fixed effects:  

|                          | Estimate | Std. Error | df   | t value | Pr(>|t|) |
|--------------------------|----------|------------|------|---------|----------|
| (Intercept)              | 7.792e-01| 4.280e-03  | 2.870e+02 | 182.045  | < 2e-16 *** |
| Categorymp               | -1.251e-02| 2.695e-03  | 3.780e+01 | -4.644   | 4.06e-05 *** |
| FirstSyllBaseStressunstressed | -2.563e-02| 3.915e-03  | 3.690e+01 | -6.548   | 1.15e-07 *** |
| LocSpeech                | -3.561e-03| 3.576e-04  | 6.775e+02 | -9.956   | < 2e-16 *** |
| GlobalSpeechRate         | -7.102e-03| 1.507e-03  | 9.530e+02 | -4.713   | 2.81e-06 *** |
| Categorymp:FirstSyllBaseStressunstressed | 2.090e-02 | 5.145e-03  | 3.690e+01 | 4.063    | 0.000243 *** |
**im-model: m#m vs. m#p**

- **Local speech rate** vs. duration in milliseconds
- **Global speech rate** vs. duration in milliseconds
im-model: m#m vs. base

Fixed effects:

| Term                        | Estimate | Std. Error | df  | t value | Pr(>|t|)  |
|-----------------------------|----------|-----------|-----|---------|-----------|
| (Intercept)                 | 0.4884   | 0.0101    | 4097| 48.141  | < 2e-16 ***|
| Environment m#m             | -0.0010  | 0.0050    | 4520| -1.994  | 0.05223 . |
| PrePausePause               | -0.0278  | 0.0041    | 9004| -6.713  | 3.38e-11 ***|
| Accentuation Unaccented     | -0.0105  | 0.0032    | 8888| -3.279  | 0.00108 **|
| FirstSyllBaseStress Unstressed | -0.0462 | 0.0054    | 2900| -8.578  | 1.88e-09 ***|
| LocSpeech                   | -0.0064  | 0.0007    | 4939| -9.423  | < 2e-16 ***|
| GlobalSpeechRate            | -0.0086  | 0.0038    | 8283| -2.264  | 0.02381 *  |
| Environment m#m:PrePausePause | 0.0259  | 0.0049    | 8799| 5.283   | 1.61e-07 ***|
*im*-model: m#m vs. base

- **Accentuation**
  - Duration in milliseconds
  - Accented: 120 ms
  - Unaccented: 100 ms

- **Global Speech**
  - Duration in milliseconds
  - Range: 120 to 100 ms

- **Local Speech**
  - Duration in milliseconds
  - Range: 200 to 100 ms

- **Stress on Base**
  - Duration in milliseconds
  - Primary: 120 ms
  - Unstressed: 100 ms
**in-model: n#n vs. n#V vs. n#t**

Fixed effects:

| Term                                      | Estimate | Std. Error | df   | t value | Pr(>|t|) |
|-------------------------------------------|----------|------------|------|---------|----------|
| (Intercept)                               | 8.951e-01 | 4.690e-03  | 3.342e+02 | 190.844 | < 2e-16 *** |
| Category n#t                              | 3.165e-03 | 2.827e-03  | 4.270e+01 | 1.120   | 0.269147 |
| Category n#V                              | -2.085e-02| 3.047e-03  | 4.270e+01 | -6.841  | 2.26e-08 *** |
| FirstSyllBaseStressunstressed             | -2.068e-02| 5.220e-03  | 4.710e+01 | -3.961  | 0.000252 *** |
| LocSpeech                                 | -1.872e-03| 2.136e-04  | 8.757e+02 | -8.763  | < 2e-16 *** |
| GlobalSpeechRate                          | -2.559e-03| 9.416e-04  | 1.020e+03 | -2.718  | 0.006683 ** |
| PostPausePause                            | -2.138e-03| 8.926e-04  | 1.083e+03 | -2.395  | 0.016799 *  |
| PrecSegDur                                | -4.885e-02| 1.743e-02  | 1.079e+03 | -2.803  | 0.005157 ** |
| FollSegDur                                | -3.029e-02| 1.175e-02  | 1.075e+03 | -2.579  | 0.010047 *  |
| Category n#t:FirstSyllBaseStressunstressed| 2.637e-02  | 5.668e-03  | 4.660e+01 | 4.652   | 2.73e-05 *** |
| Category n#V:FirstSyllBaseStressunstressed| 1.194e-02  | 5.599e-03  | 4.740e+01 | 2.133   | 0.038118 *  |
in-model: n#n vs. n#V vs. n#t
Oh and Redford: difference between un- and in-
un- and in- : Corpus vs. Experiment
un- and in- : Corpus vs. Experiment

![Graph showing duration in milliseconds for accented and unaccented n#n and n#V in different environments.](image-url)