

Ultrasound evidence for gradient and categorical components of English /l/ lenition processes

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2 Methodology

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4 Conclusion

/l/-darkening

- The process whereby /l/ is realised with a delayed and/or reduced tongue-tip gesture.
- Generally stated that light [l] is found in onsets, e.g. *light, love*, and dark [ɫ] is found in codas, e.g. *dull, fall*.
- However, there is controversy over whether this allophonic distinction is the best way of categorising the variation.

[l]ight

du[ɫ]

Research Question

- 1 To what extent can articulatory data help us distinguish between gradient and categorical processes?

Research Question

- 1 To what extent can articulatory data help us distinguish between gradient and categorical processes?
- 2 What kind of variation do we find in different dialects of English?

Categorical vs. gradient interpretation

[I]

[{]}

Categorical vs. gradient interpretation

[l]

[{}

Categorical vs. gradient interpretation

[l]

light

[t̪]

dark

Categorical vs. gradient interpretation



Categorical vs. gradient interpretation



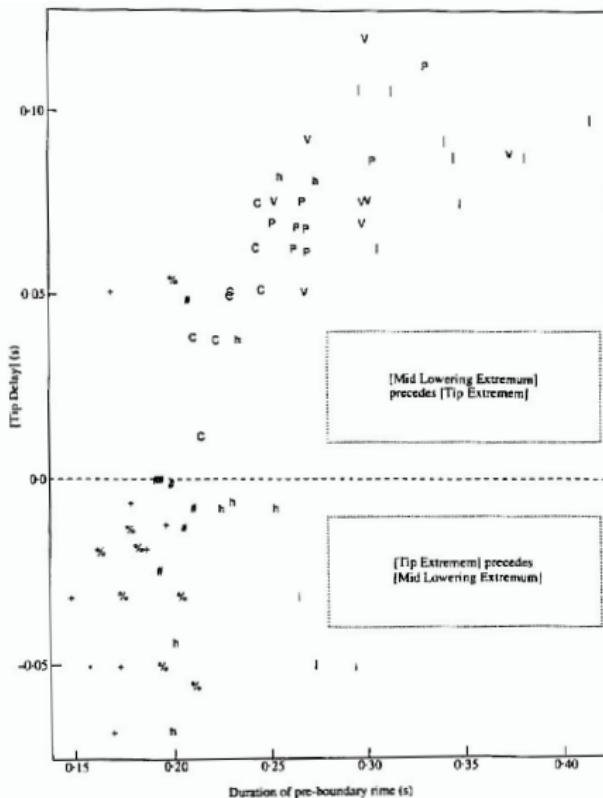
- **Gradient interpretation:** There is no categorical distinction between discrete light and dark allophones, i.e. [l] vs [t], but only a gradient continuum of darkness.

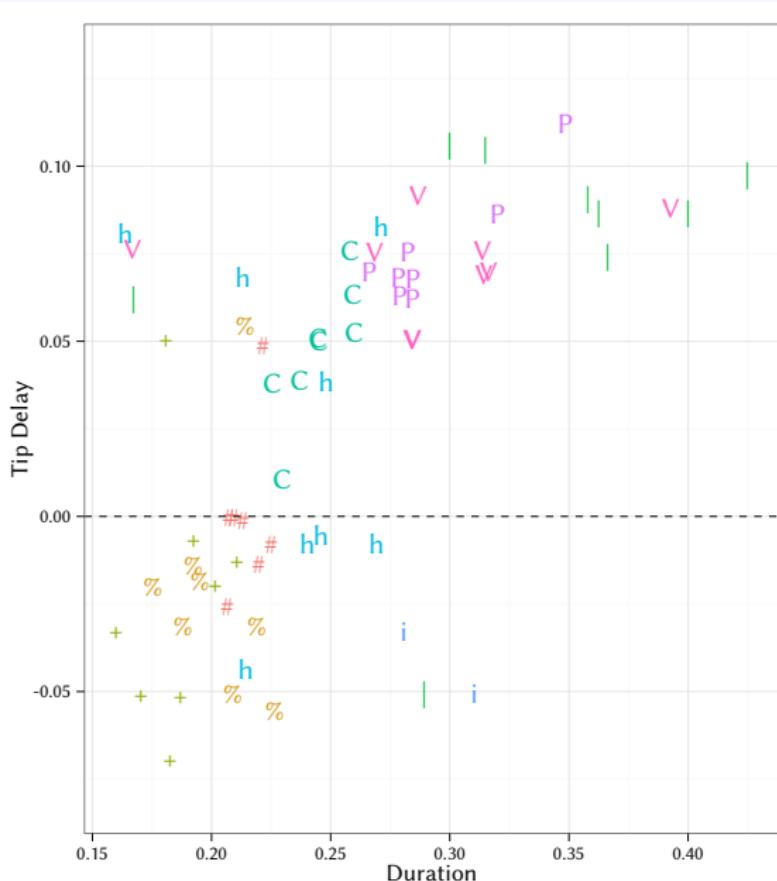
Categorical vs. gradient interpretation

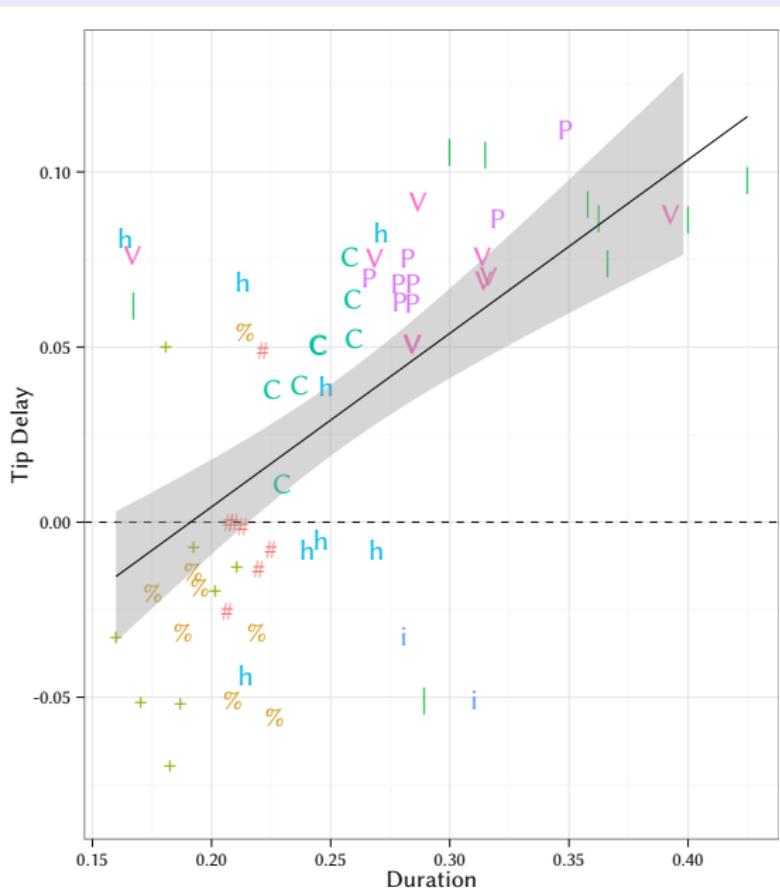


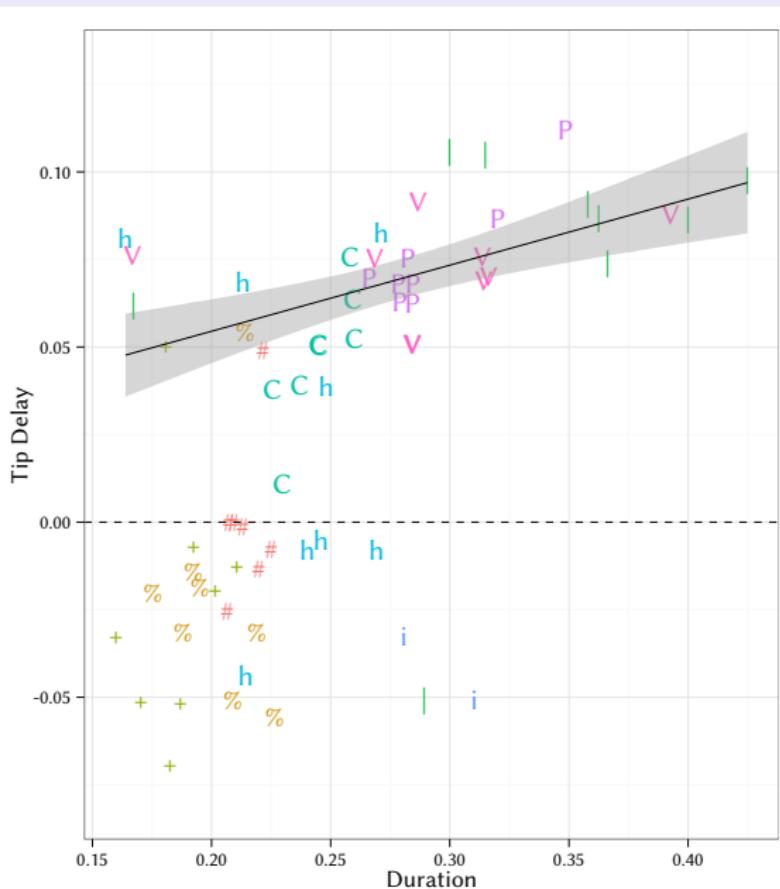
- **Gradient interpretation:** There is no categorical distinction between discrete light and dark allophones, i.e. [l] vs {, but only a gradient continuum of darkness.
- Most famous study:
 - Sproat and Fujimura (1993), who argue that darkness depends on duration: the longer the pre-boundary rime, the darker the /l/.
 - cf. Yuan and Liberman (2009, 2011) showed only dark /l/s exhibited a significant effect of duration.

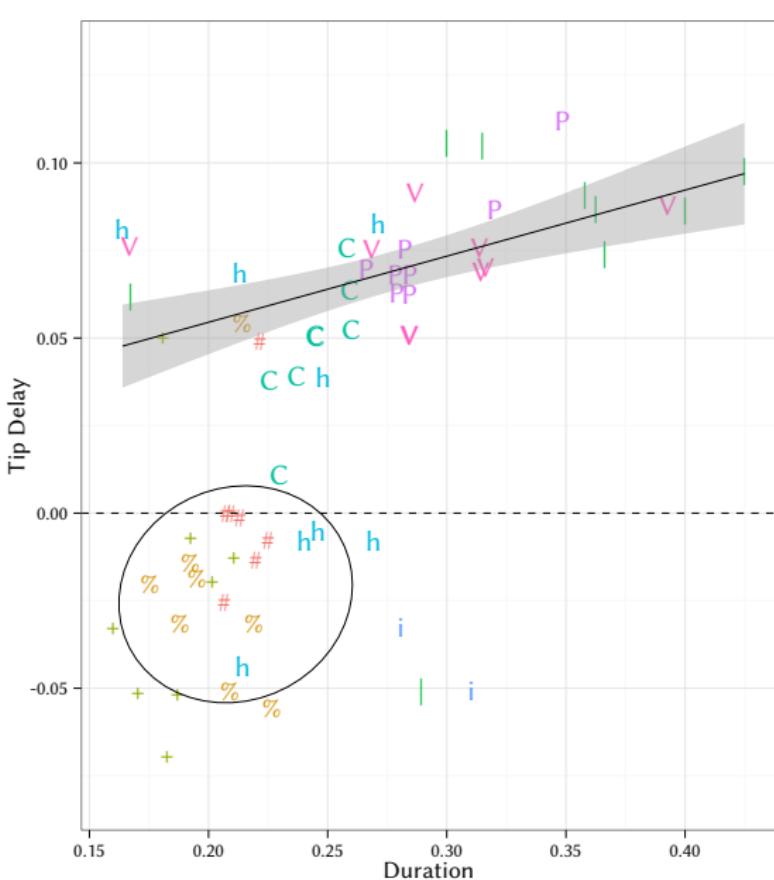
Sproat and Fujimura (1993:303)



t



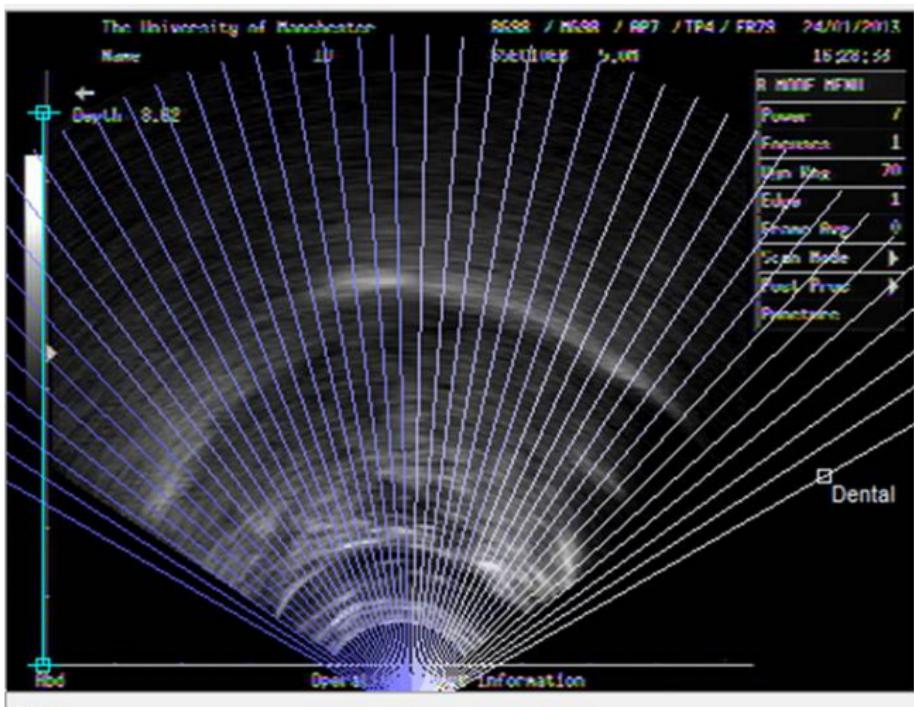




Interim Summary

- 1 The present study seeks to address questions arising from previous work on /l/-darkening, with the help of articulatory data using ultrasound tongue imaging.
- 2 /l/ seems to show both categorical and gradient effects. Can ultrasound data help investigate this?

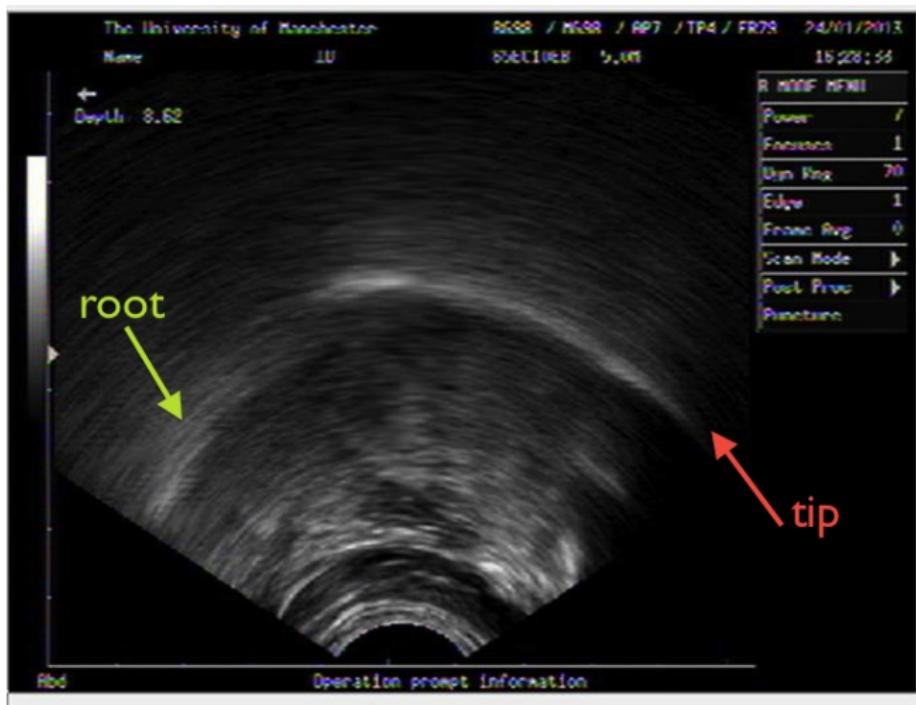
Ultrasound



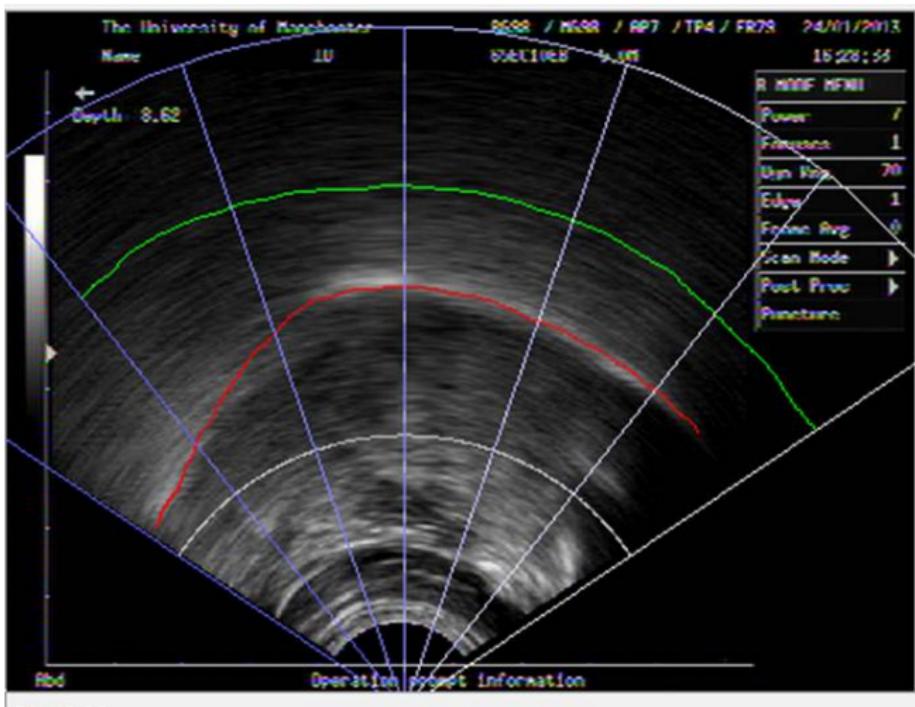
Ultrasound



Ultrasound



Ultrasound



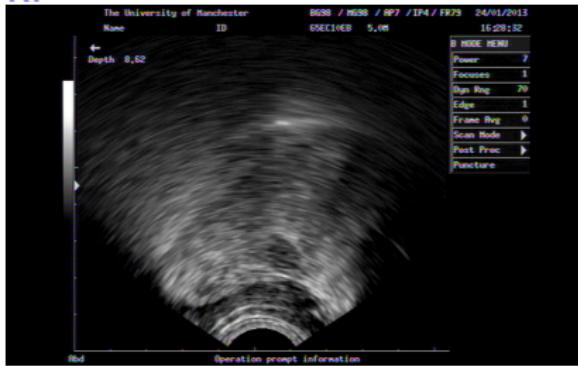
Challenge:

How do we distinguish between categorical and gradient processes?

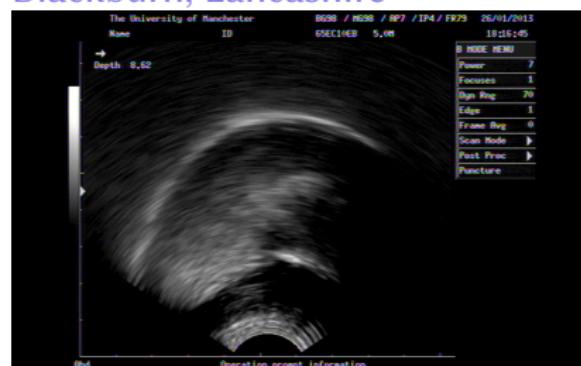


Some /l/s are darker than others...

RP



Blackburn, Lancashire



Methodology

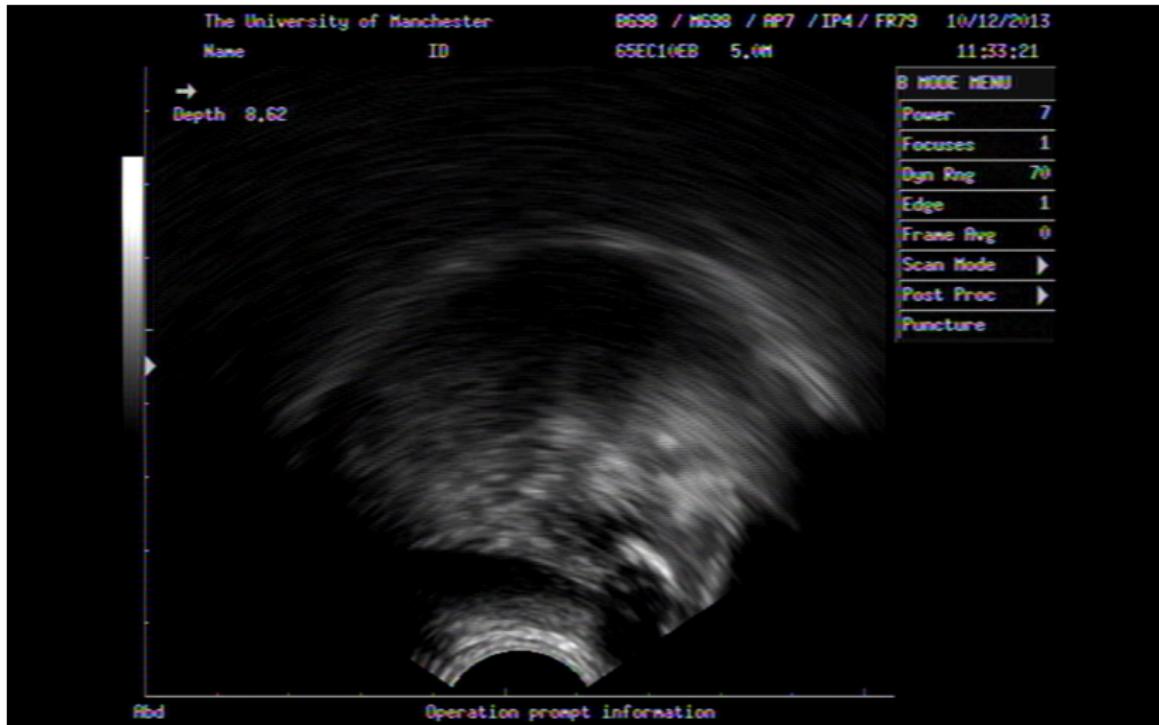
- Subjects read 5 repetitions per sentence, interspersed with distractors
- /l/s always flanked by high front vowels.
- Recorded on a Mindray DP2200 ultrasound machine (frame rate 60fps deinterlaced).
- /l/s segmented acoustically and splines hand-drawn for all frames within /l/ boundaries in Articulate Assistant Advanced (AAA; Articulate Instruments, 2010).
- Spline coordinates of midpoint plotted
- Non-overlapping loess confidence intervals taken as significant difference (similar to SS ANOVA, Davidson 2006).

Sentences

Speakers read 2 x 10 phonological contexts 5 times = 100 [l]s

Context	Example
1. word-initial	<i>leap</i>
2. foot-initial	<i>believe</i>
3. suffix	<i>free-ly</i>
4. foot-medial intervocalic	<i>helix</i>
5. morpheme boundary	<i>peel-ing</i>
6. internal boundary	<i>peel-instrument</i>
7. word-final internal boundary	<i>heal_{VP}</i>
8. word-final phrase boundary	<i>heal##..._{VP}</i>]
9. final	<i>peel</i>
10. word-final pre-consonantal	<i>peel bananas</i>

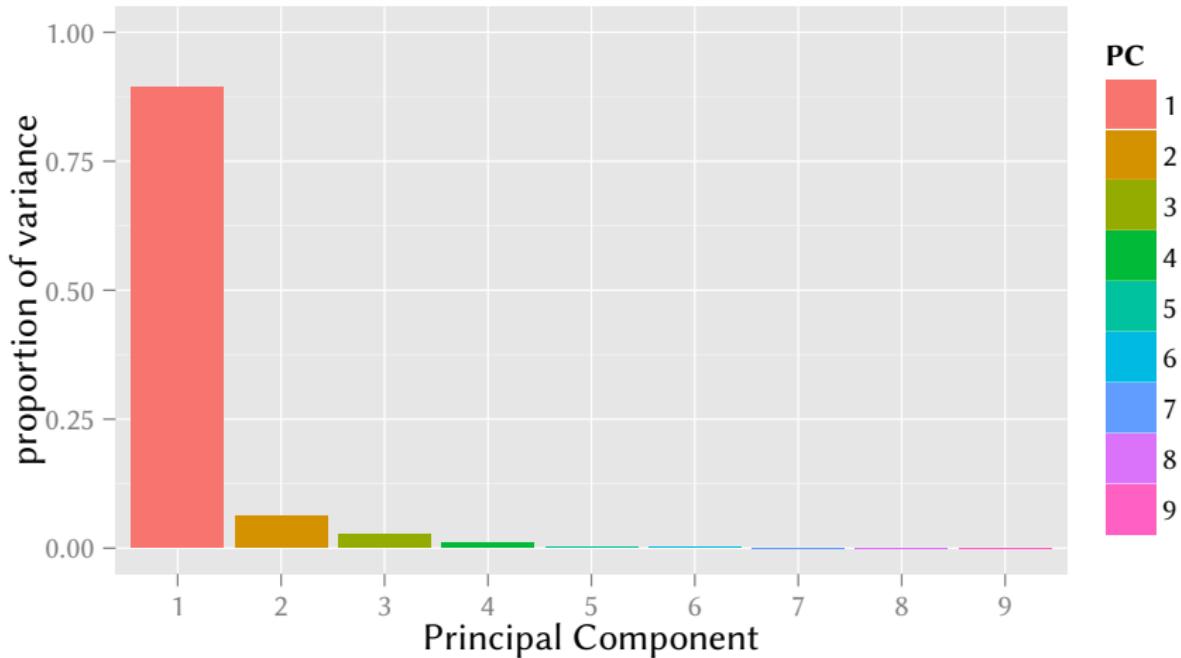
Example from London



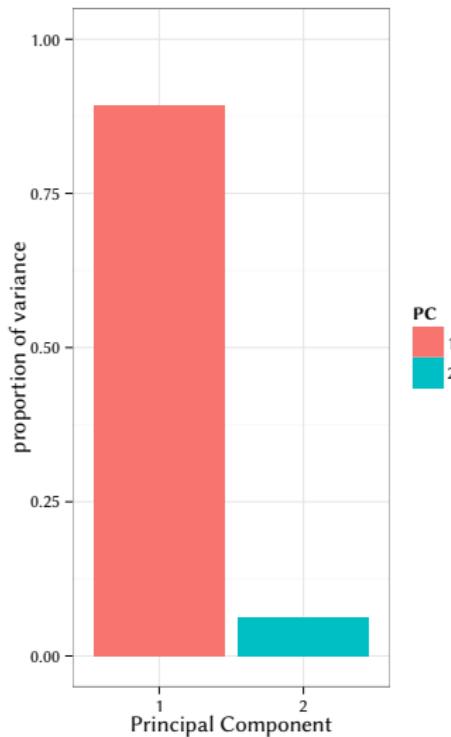
Principal Components Analysis (PCA)

- A multivariate technique that allows summary of systematic patterns of variation in data.
- Reduces the number of observed variables to a smaller number of principal components which account for most of the variance of the observed variables
- Uses correlations of raw data and gives abstract components of correlated variation.
- Identifies patterns in data, highlighting similarities and differences.
- PCA can be used to derive the principal modes of variation in tongue shape (Johnson, 2011; Slud et al. 2005).

Importance of components in current dataset

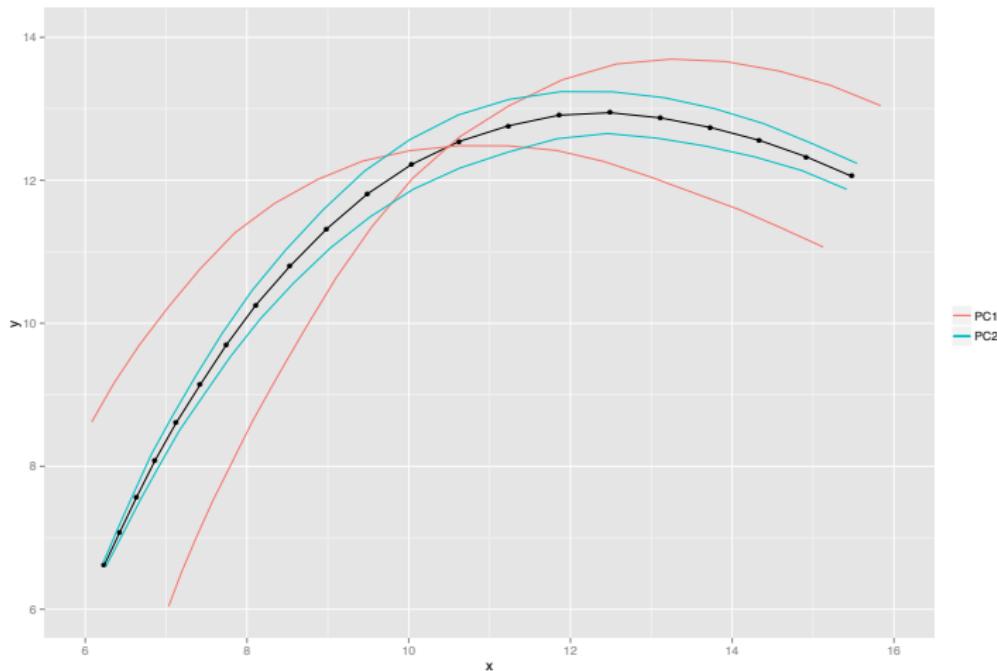


Importance of components



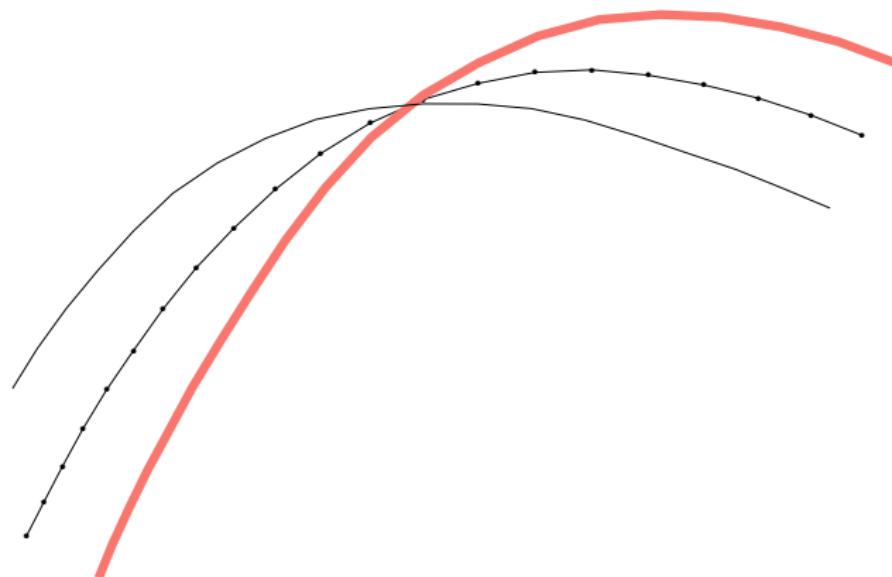
- PC1 forms the articulatory correlate of darkness for this analysis.
- Generally (at least for this dataset), the higher PC1 is, the lighter the /l/.
- PC2 accounts for only a small amount of the variation.

Principal Components Analysis (PCA): Loadings



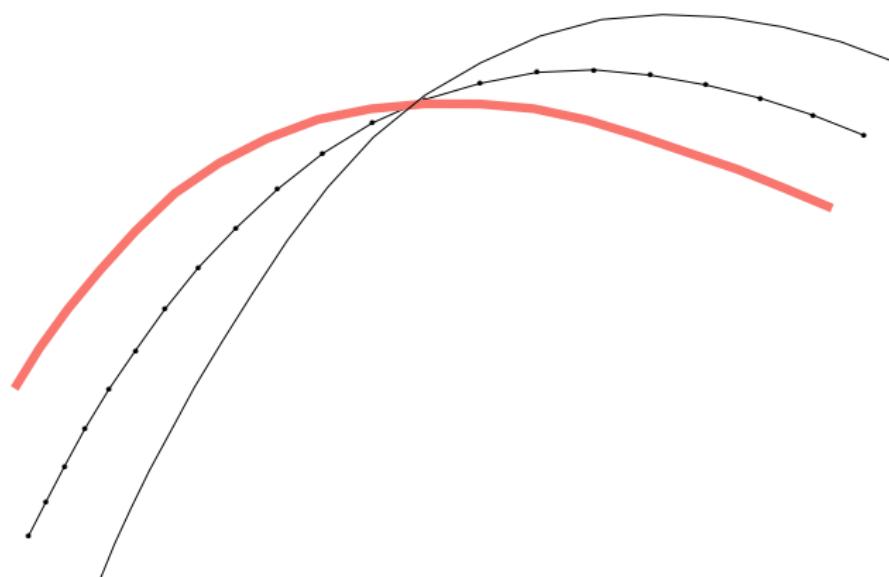
Principal Components Analysis (PCA): Loadings

■ High PC1



Principal Components Analysis (PCA): Loadings

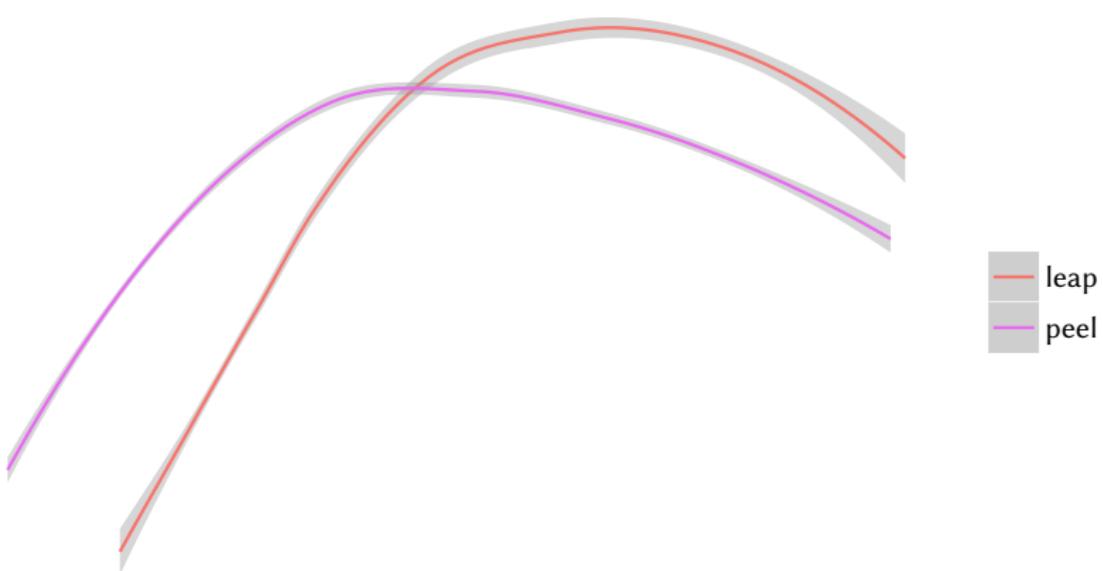
■ Low PC1



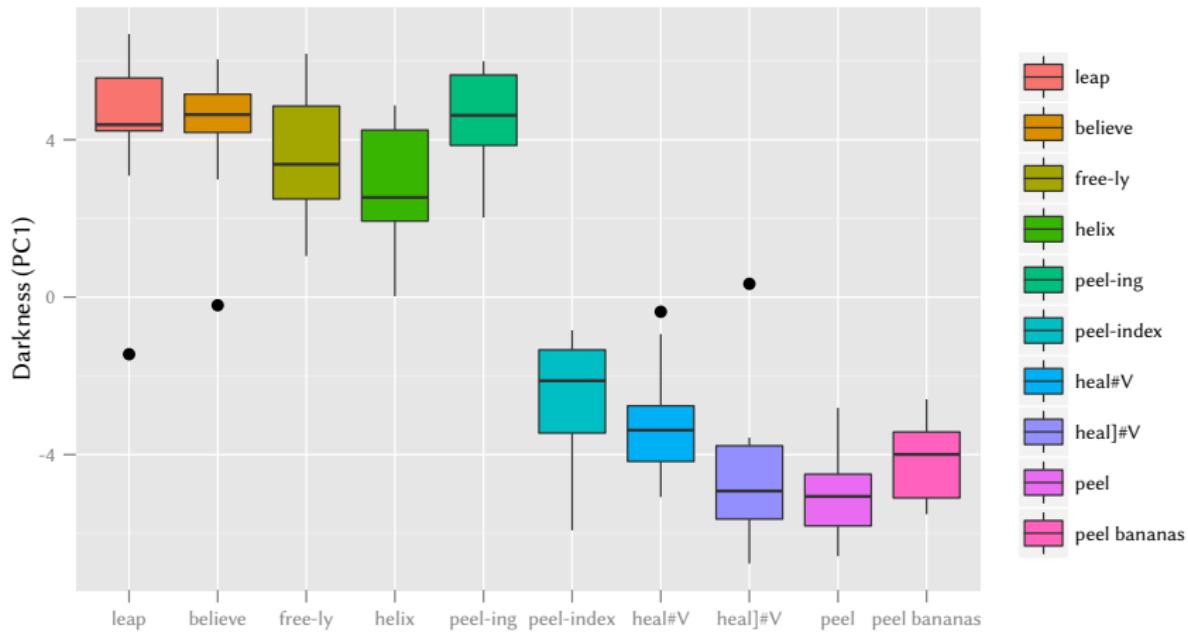
RP



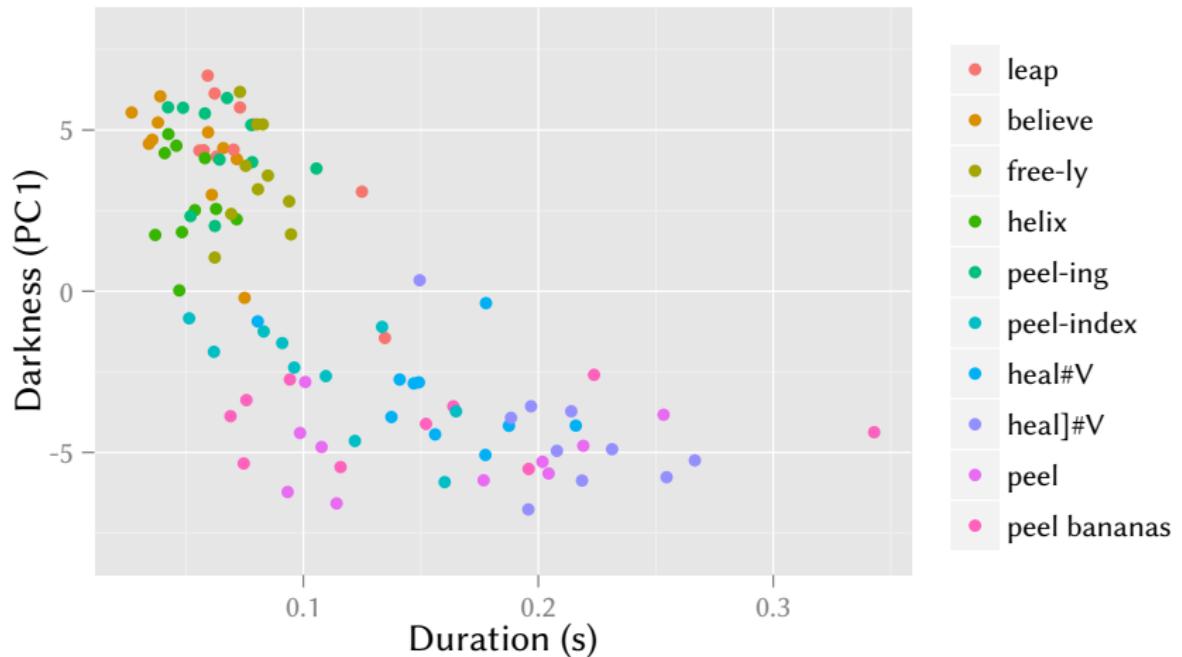
RP



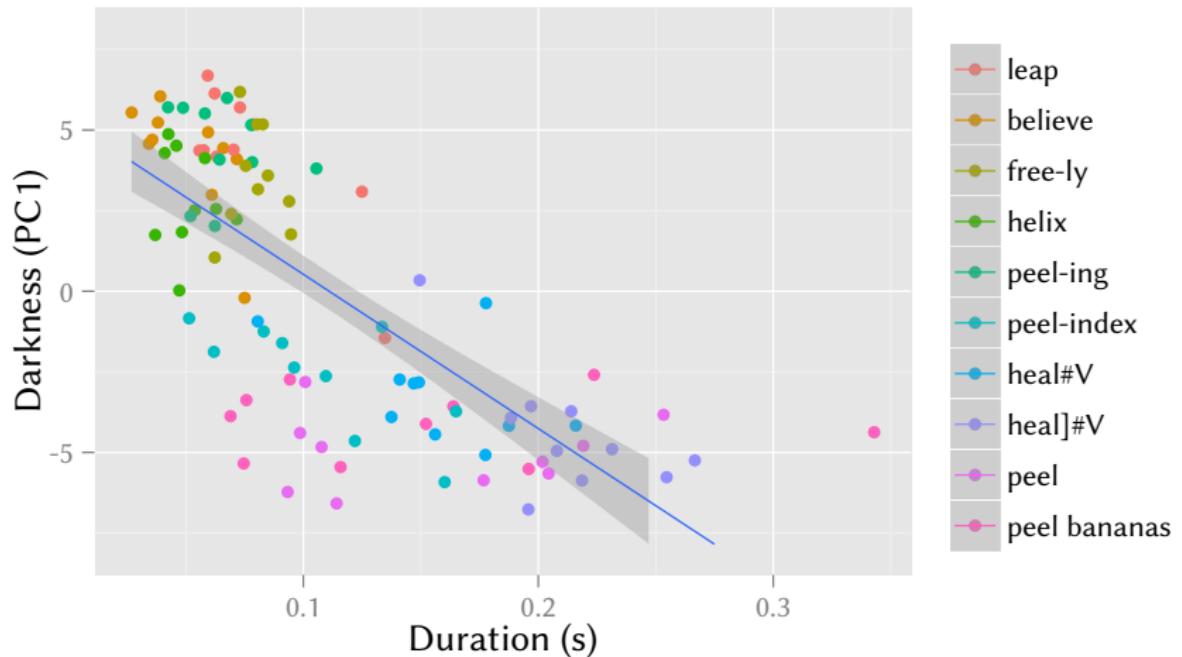
RP: Darkness as PC1



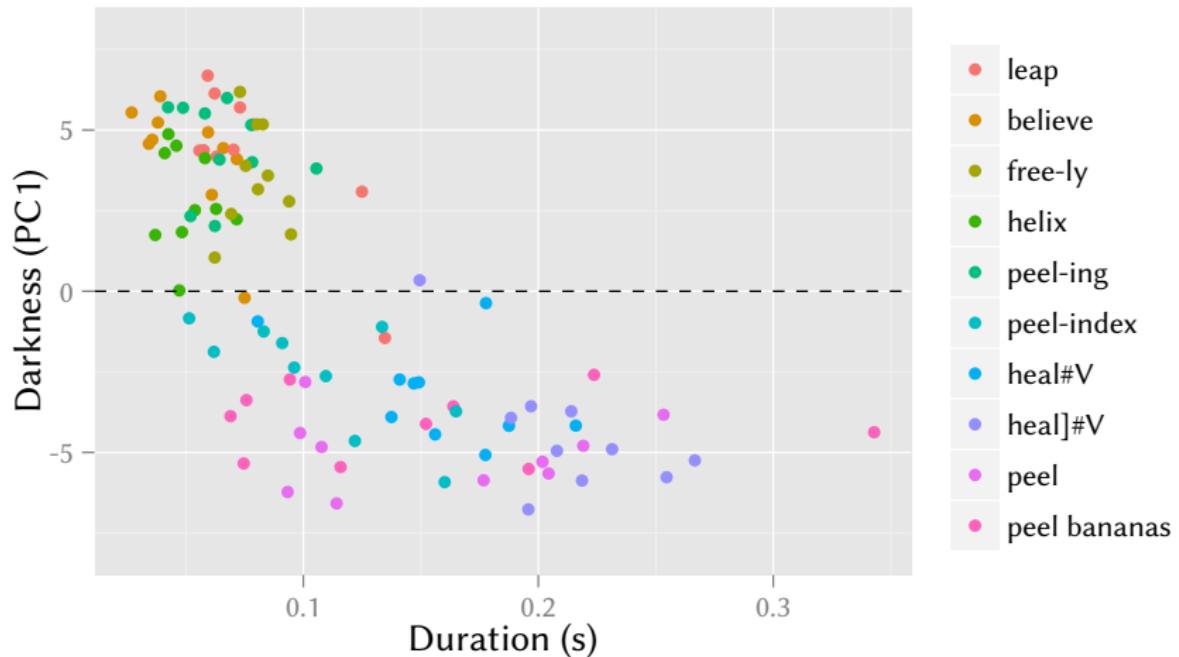
RP: Darkness vs. Duration



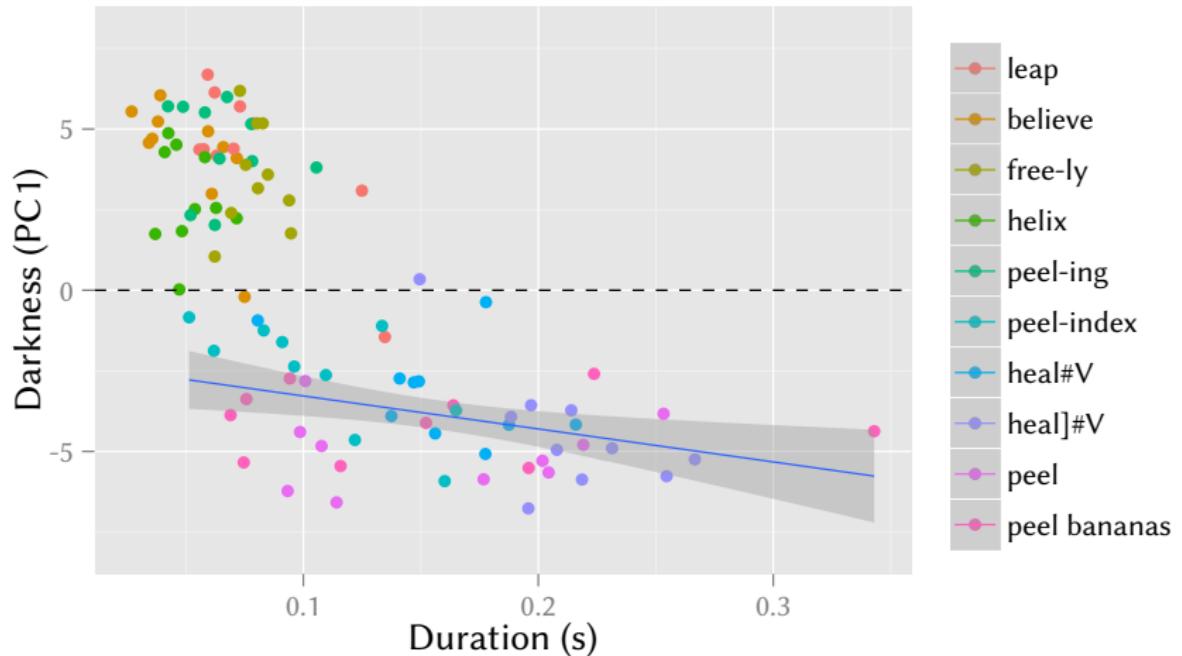
RP: Darkness vs. Duration



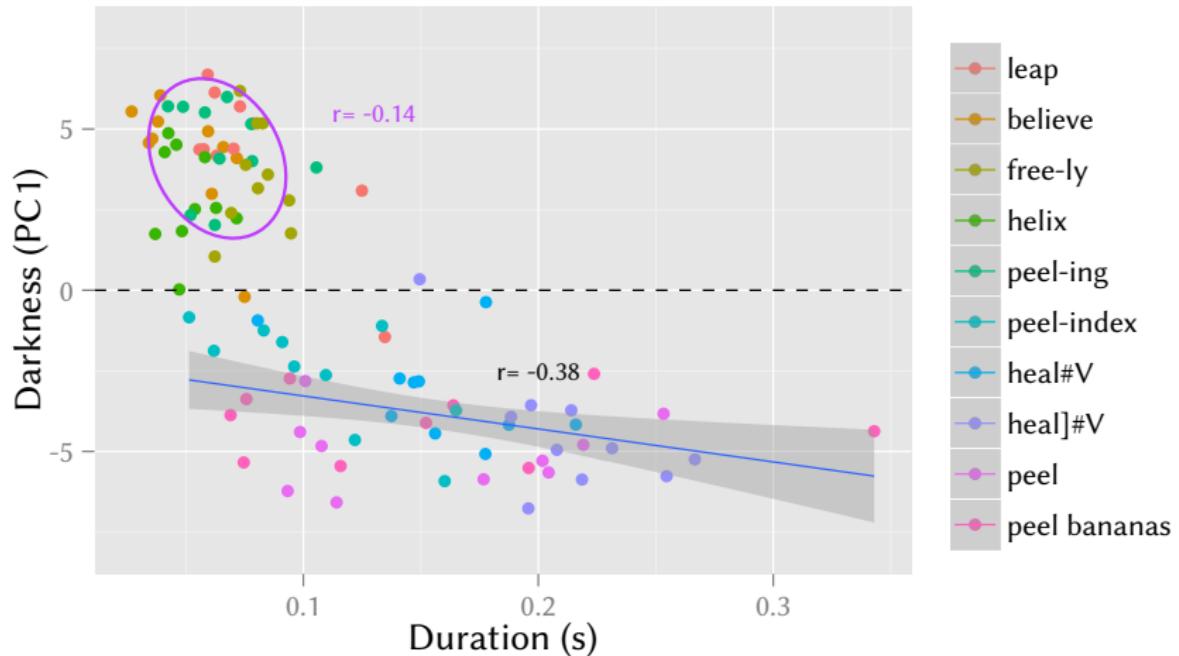
RP: Darkness vs. Duration



RP: Darkness vs. Duration



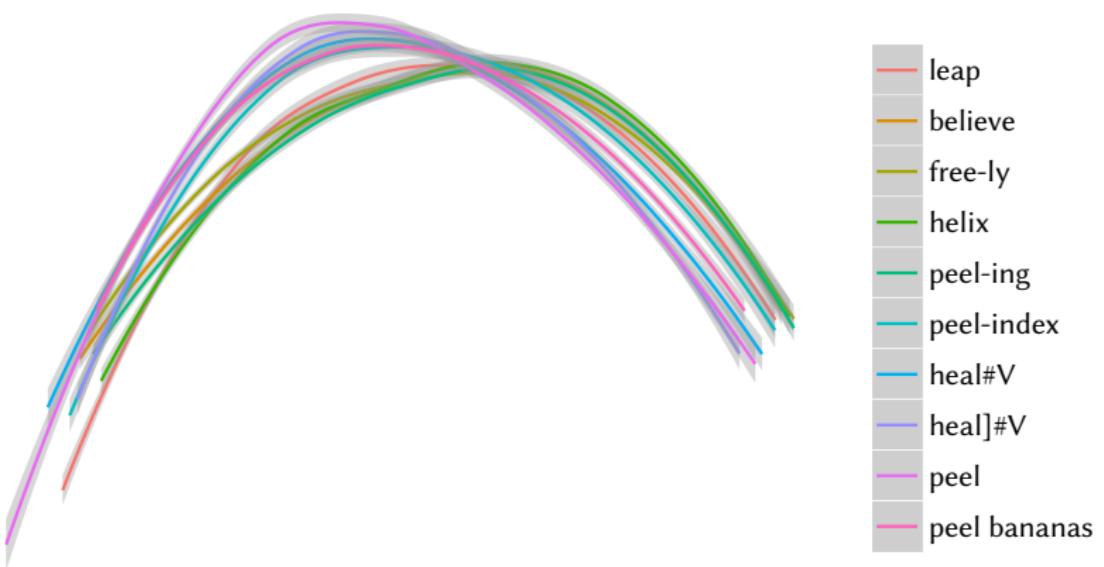
RP: Darkness vs. Duration



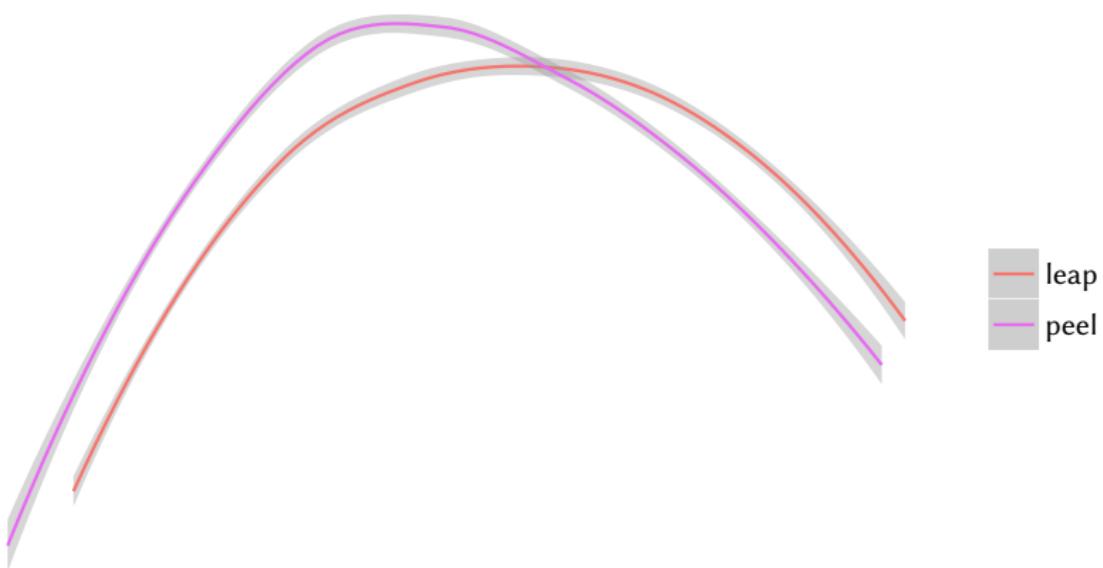
RP summary

- The distinction between light [l]s and dark [ɫ]s confirmed by non-overlapping loess confidence intervals is further validated by the PCA.
 - Typical onset /l/s in phonological contexts 1-5 (e.g. word-initial, suffixal) are lighter in this variety.
 - The backed tongue body, reduced tongue-tip gesture, and retracted tongue root typical of [ɫ] is found in phonological contexts 6-10.
- There seems to be a moderate correlation between darkness and duration for the dark [ɫ]s: $r = -0.3751$.
- Correlation of light [l]s: $r = -0.1378$.

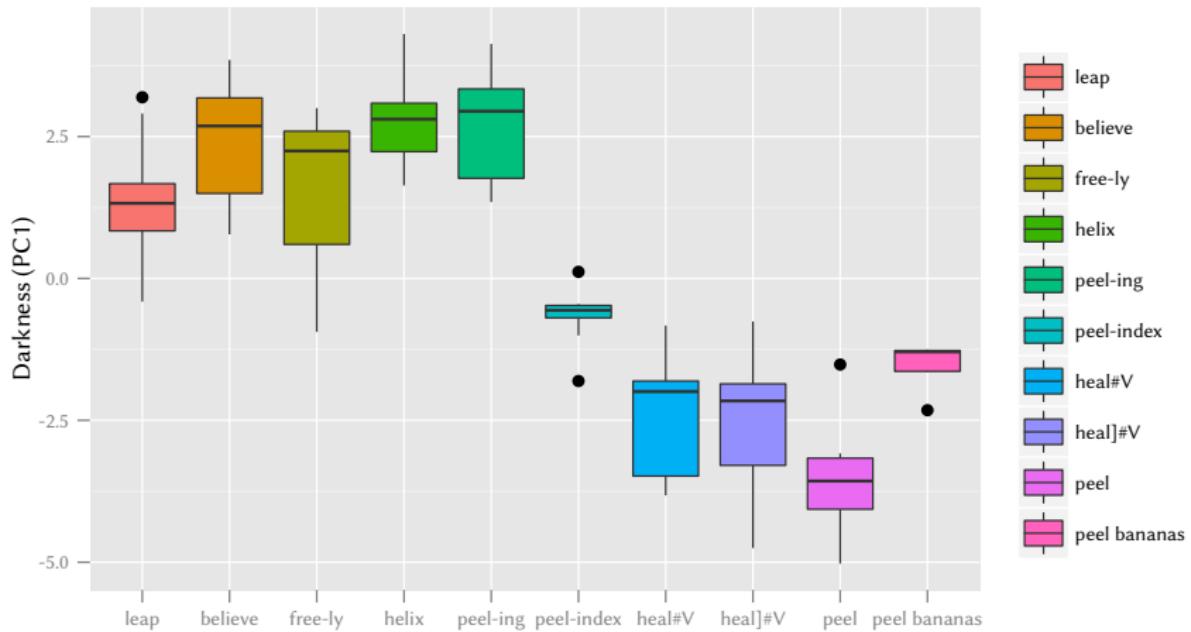
London



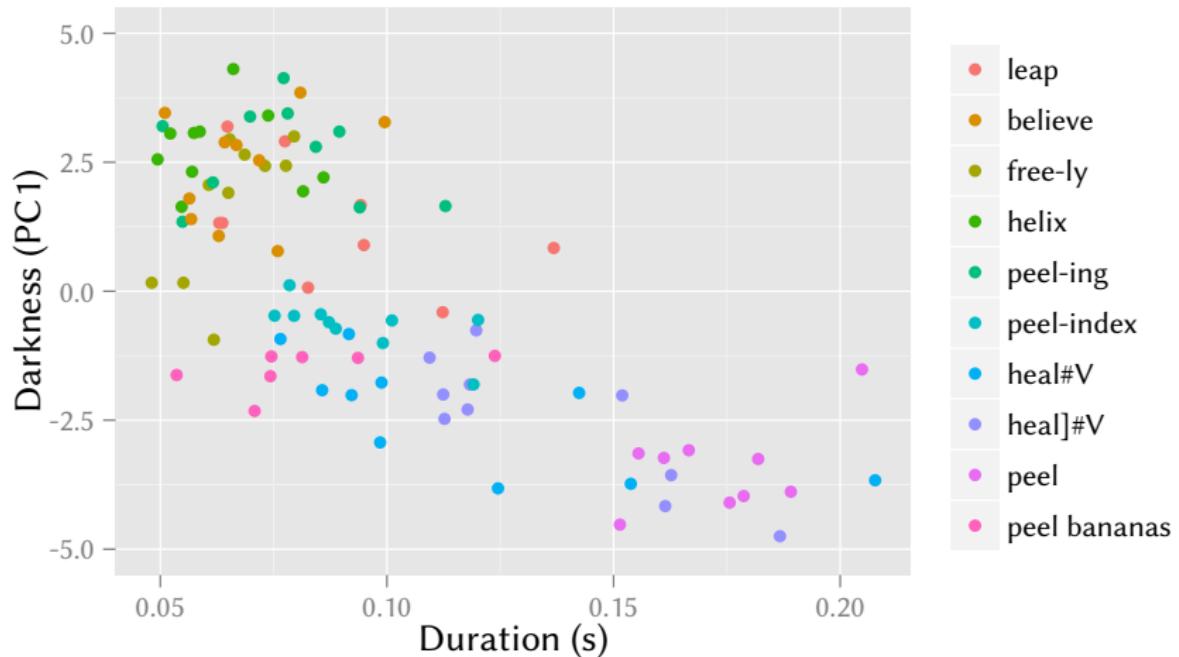
London



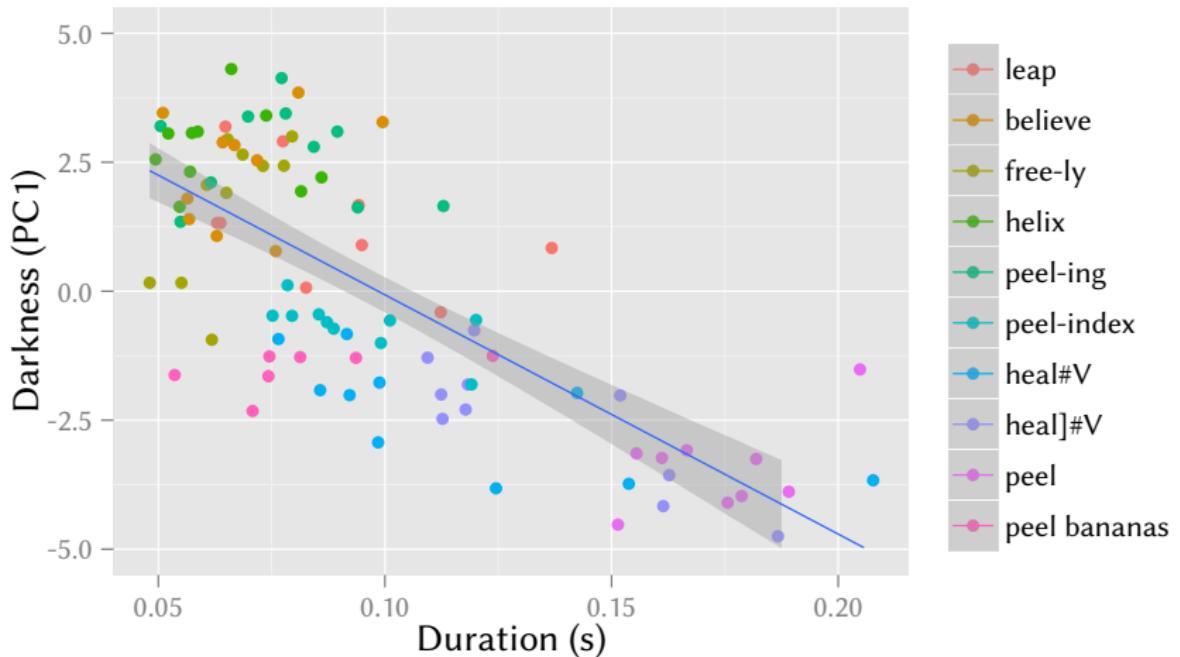
London: Darkness as PC1



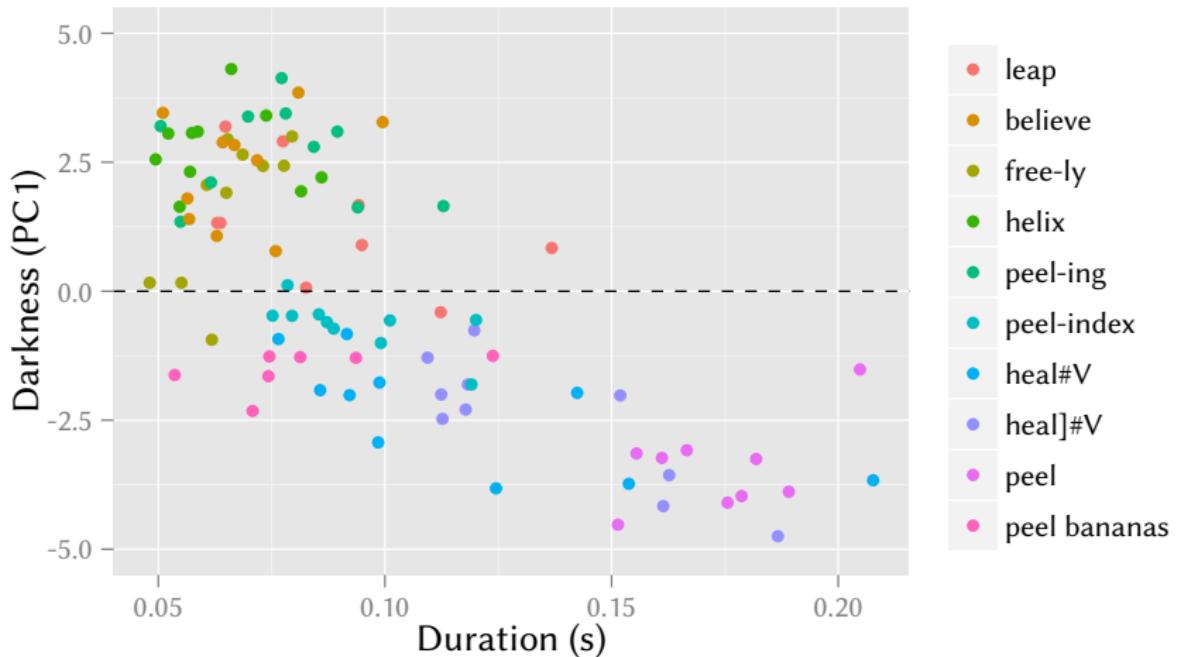
London: Darkness vs. Duration



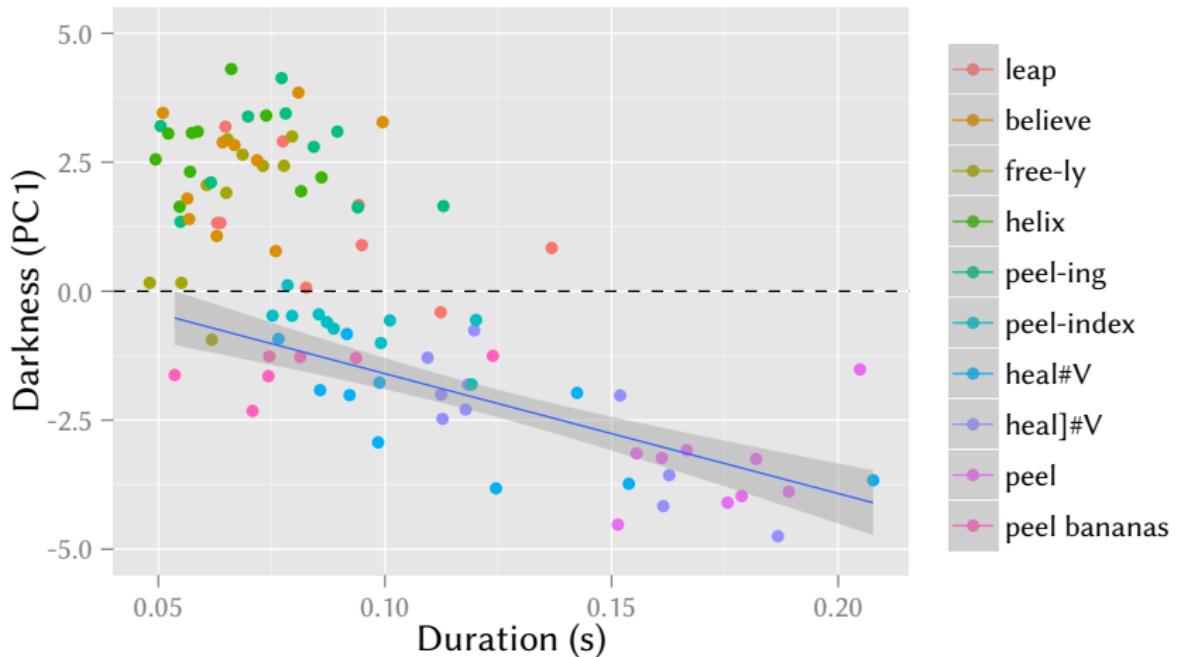
London: Darkness vs. Duration



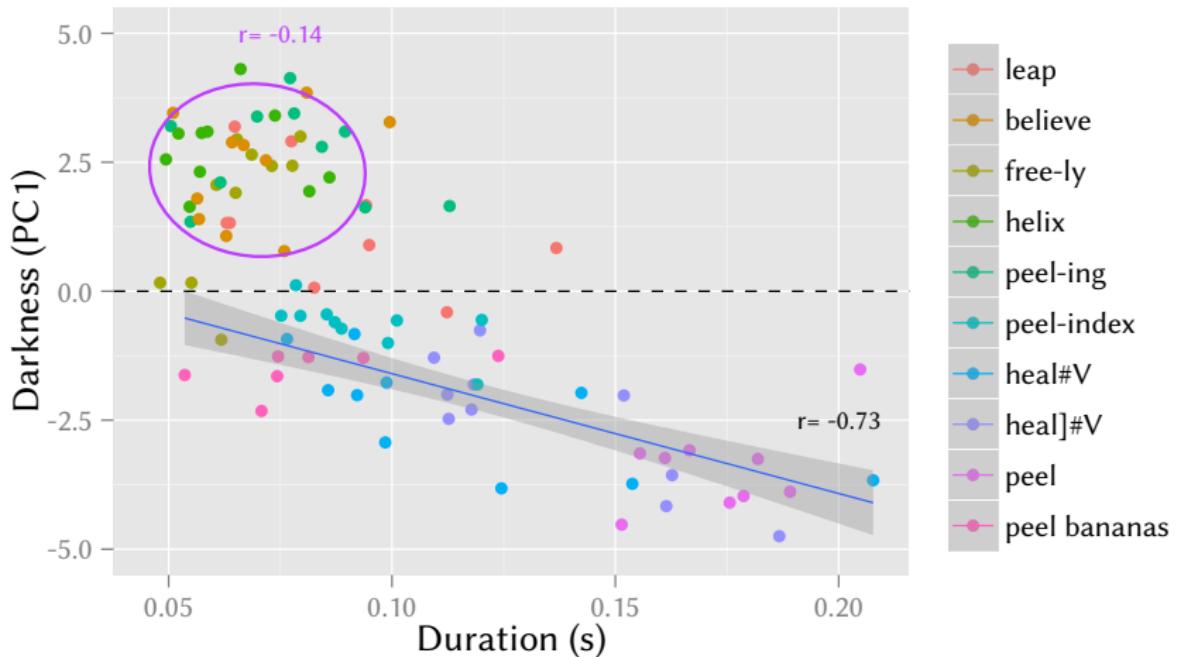
London: Darkness vs. Duration



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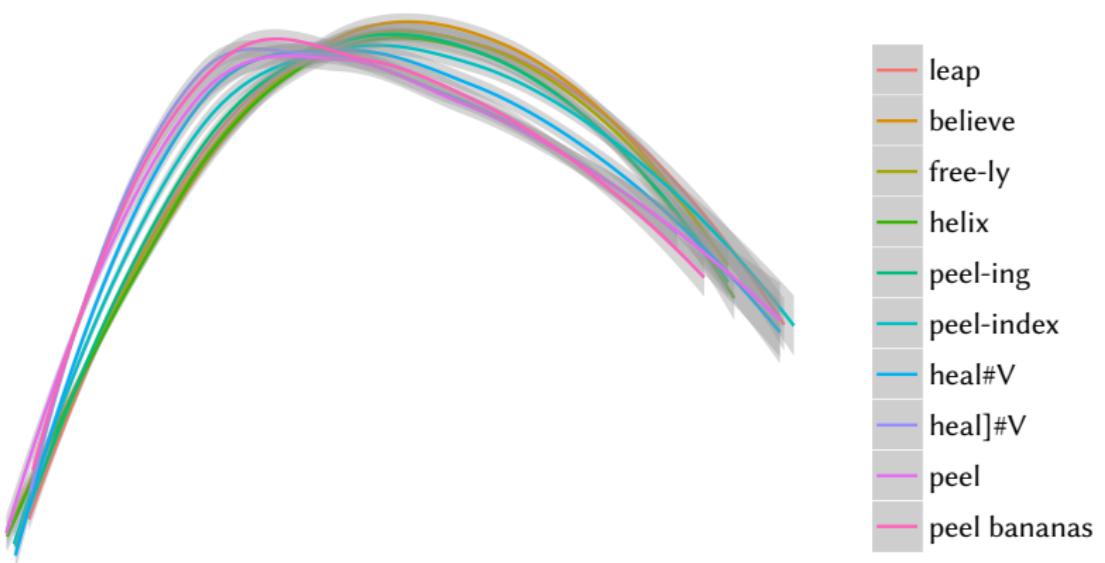
London: Darkness vs. Duration



London summary

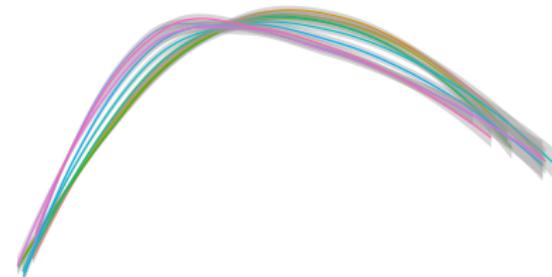
- London shows the same phonological distinction between light and dark /l/ as RP, but the difference is less sharp phonetically.
- This is interesting, given that the so-called ‘darker’ /l/s are actually vocalised.
- This is a drawback of ultrasound - we can’t see exactly what the tongue-tip is doing, although we can hear the vocalisation.
- Typical onset /l/s in phonological contexts 1-5 (e.g. word-initial, suffixal) are lighter in this variety.
- This seemingly categorical distinction is shown in the PCA too
- There seems to be a stronger correlation between dark/vocalised /l/ and duration($r = -0.7283$).
- There is no convincing correlation for the light [l]s, however ($r = -0.1445$).

Newcastle



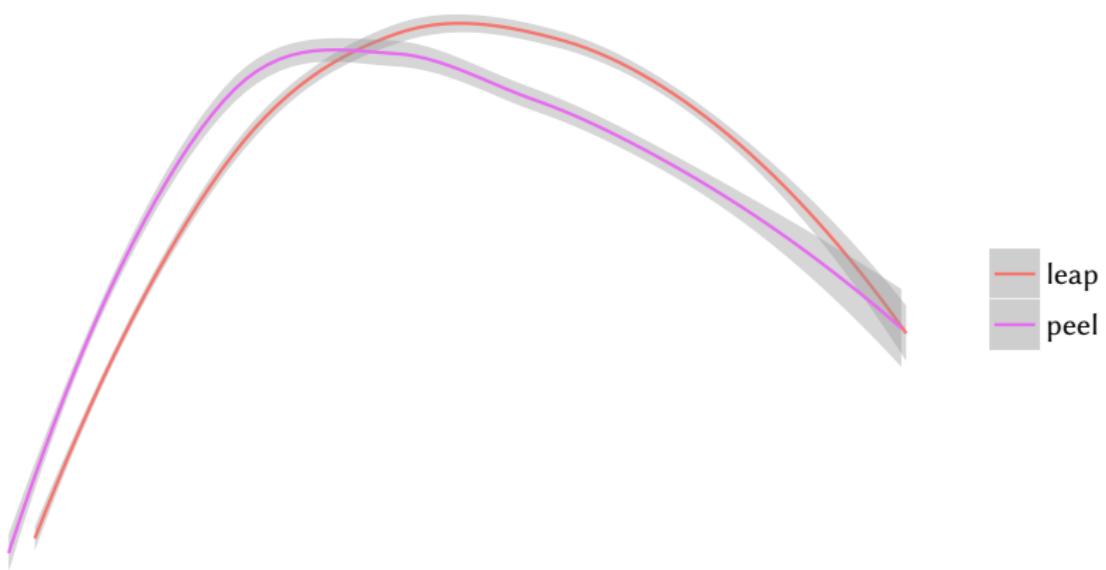
Newcastle

Newcastle is of interest, as the descriptive claims are the inverse of those found for Manchester

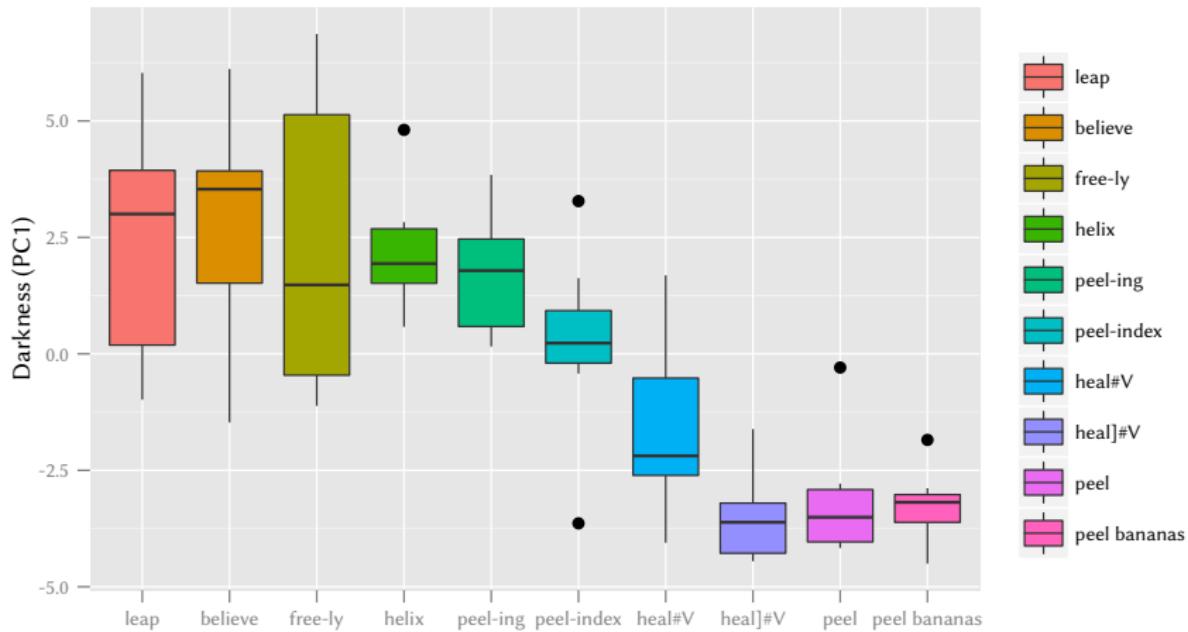


It is claimed that Newcastle /l/ is light in all contexts (Wells, 1982) although see Watt and Allen (2003:268) and Carter and Local (2007).

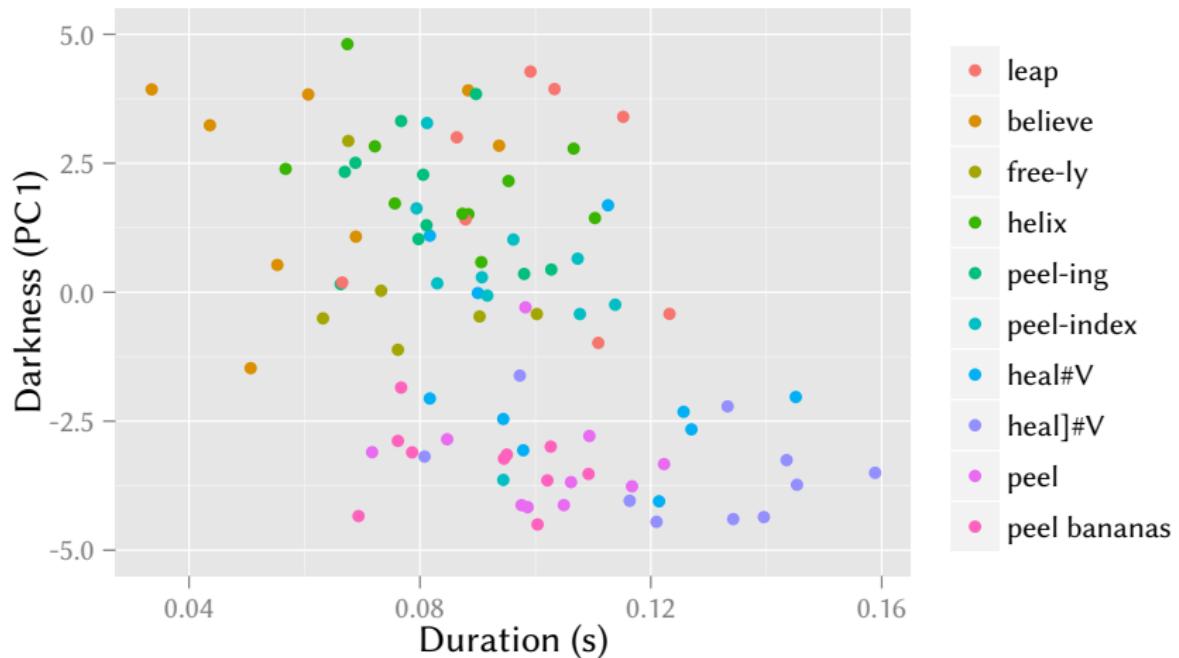
Newcastle



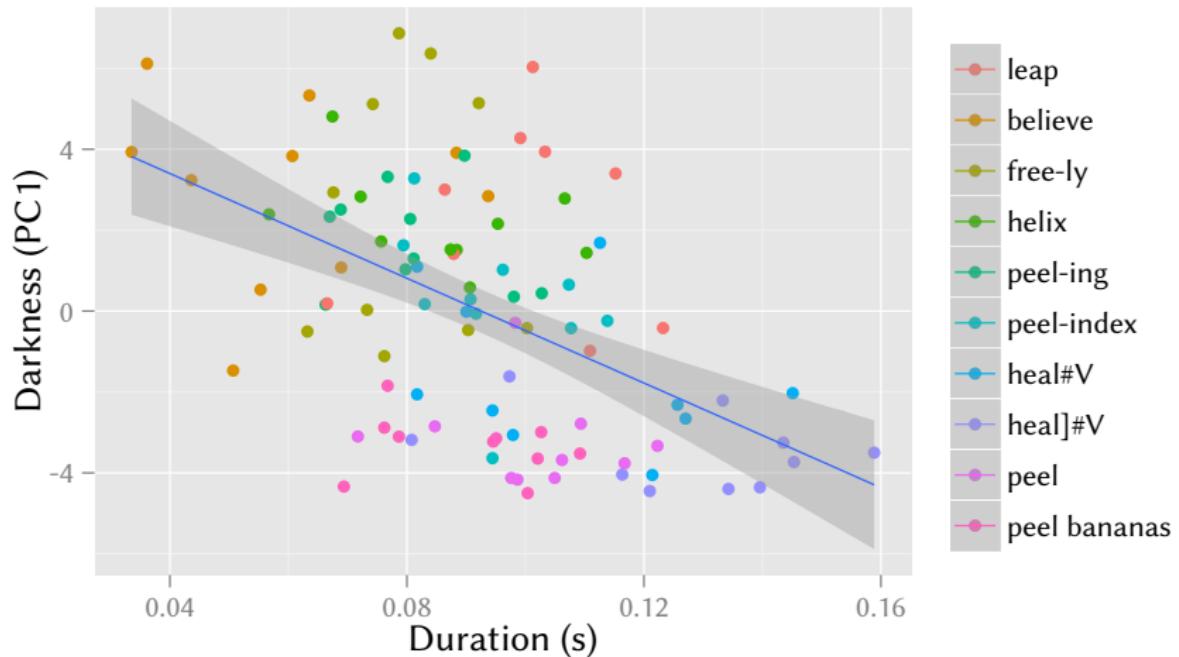
Newcastle: Darkness as PC1



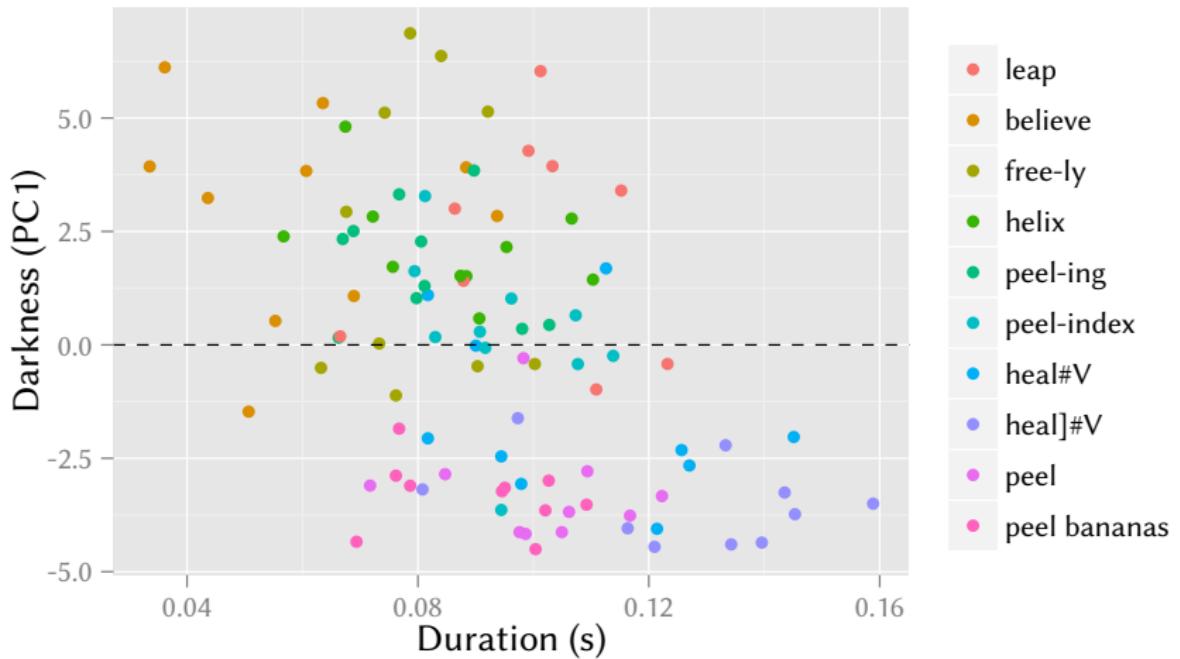
Newcastle: Darkness vs. Duration



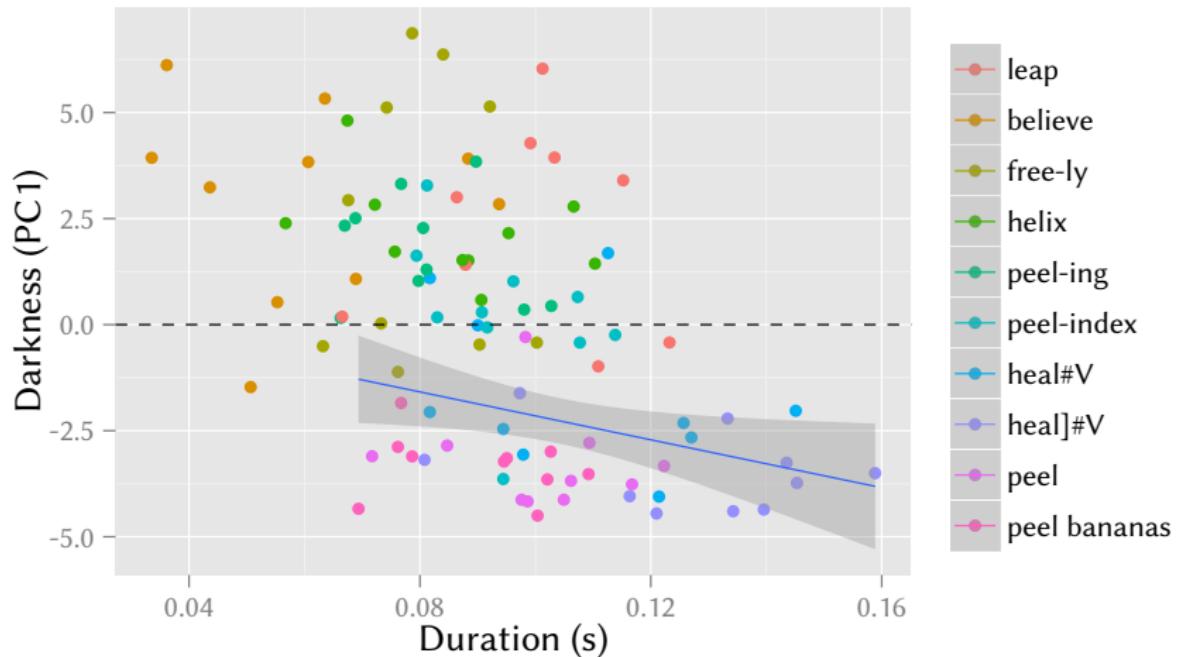
Newcastle: Darkness vs. Duration



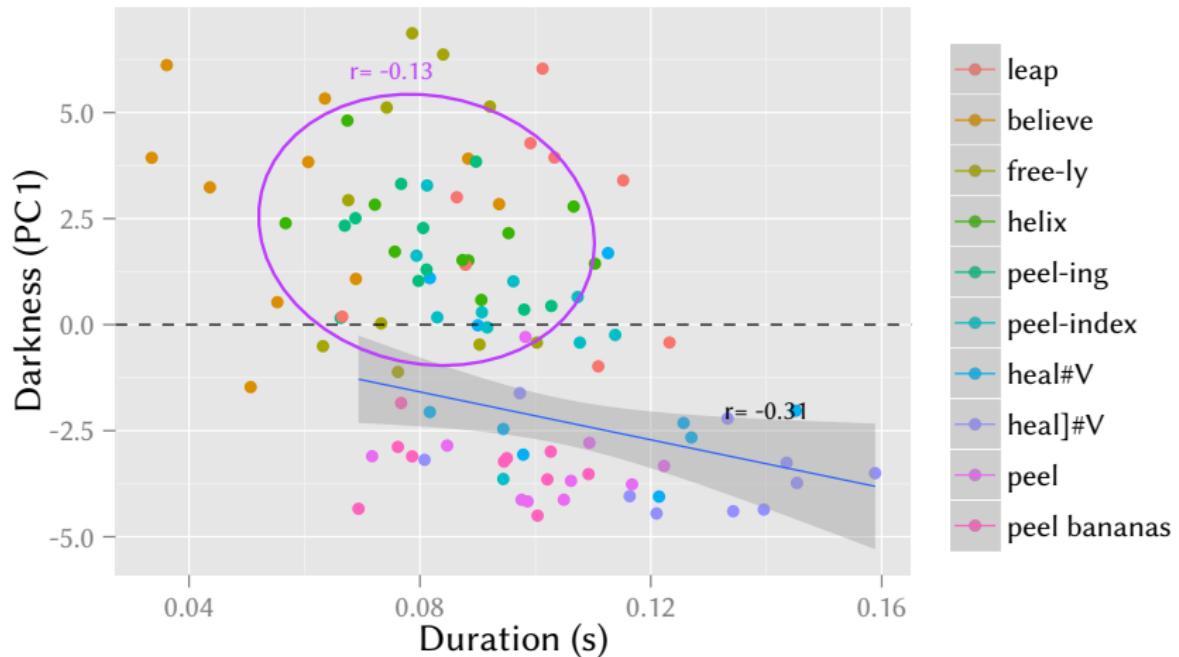
Newcastle: Darkness vs. Duration



Newcastle: Darkness vs. Duration



Newcastle: Darkness vs. Duration



Newcastle summary

- Although initial and final tokens show non-overlapping confidence intervals, the seemingly categorical light/dark distinction is less convincing in Newcastle.
- Are there two categories in this dialect?
- Could it be the case that all Newcastle /l/s are light and the darker /l/s are backer due to a correlation with duration?
 - Perhaps, but there is only a moderate correlation: ($r = -0.3086$)
 - Light /l/ correlation: ($r = -0.1346$)

Best fit

Model	RP	London	Newcastle
1. $\text{Darkness} \sim \log(\text{Duration})$	0.5973	0.5546	0.2298
2. $\text{Darkness} \sim \text{Category}$	0.8323	0.7463	0.5552
3. $\text{Darkness} \sim \text{Category} * \log(\text{Duration})$	0.849	0.8154	0.5699

Table 1 : Comparison of adjusted r-squared values from three linear models. Grey cells indicate significantly better fit by ANOVA comparison ($p < 0.05$)

- Darkness is PC1.
- Phonological contexts 1-5 are categorised as ‘light’ and 6-10 as ‘dark’.
- Newcastle adding interaction is a significant improvement on duration, but only just improves on category alone ($p < 0.07$).

RP model

$$\text{Darkness} \sim \text{Category} * \log(\text{Duration})$$

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	-0.457	2.010	-0.227	0.821
catdark	-6.460	2.288	-2.823	0.006
log(Duration)	-1.550	0.717	-2.164	0.033
catdark:log(Duration)	-0.027	0.904	-0.030	0.976

- Although both category and duration are significant factors in the RP model of darkness, the interaction between the two is not.
- Considering duration's small contribution to the overall fit of the model, it may be the case that with RP, durational effects are very low-level.
- This is not necessarily surprising given the stark difference between the two patterns. In RP, it seems category is the most important factor alone.

London model

$$\text{Darkness} \sim \text{Category} * \log(\text{Duration})$$

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	0.871	1.785	0.488	0.627
catdark	-9.220	2.063	-4.469	0.000
log(Duration)	-0.493	0.670	-0.737	0.463
catdark:log(Duration)	-2.377	0.821	-2.897	0.005

- In London, category is significant, but duration only so when interacting with category.
- This dialect is evidence of both categorical and gradient effects being important.
- cf. Yuan and Liberman (2009, 2011) who also found an interaction between duration and darkness.

Newcastle model

$$\text{Darkness} \sim \text{Category} * \log(\text{Duration})$$

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	-0.567	2.694	-0.210	0.834
catdark	-8.357	4.241	-1.970	0.052
log(Duration)	-1.129	1.049	-1.076	0.285
catdark:log(Duration)	-1.788	1.774	-1.008	0.316

- Although category approaches significance, it seems that none of the factors have a convincing effect on the Newcastle /l/s.

Summary I

- All speakers suggest the same phonological pattern, albeit to varying extremes in the phonetics.
 - RP has a clear articulatory distinction, London also but to a lesser extent.
 - Newcastle does seem to have a difference between initial and final /l/s, contrary to claims in the descriptive/sociolinguistic literature. However, the evidence that this is two clear categories is less convincing than in other varieties.
- The models show an interesting array of possibilities for /l/-darkening:
 - The RP pattern may be indicative of a very conservative dialect. Low-level durational effects operate across the board, but are not phonologised. This may explain why RP has remained at the first stage of the life-cycle.

Summary II

- London shows a mixture of both categorical and gradient effects. Category has the strongest effect, but dark [ɫ]s also show a significant interaction with duration. This is not surprising. Given that London has wide spread /l/-vocalisation, we could speculate that duration-driven darkening is the main force behind the successive rise of lenition trajectories in this variety.
- Newcastle shows little influence of categorical or gradient effects. Perhaps this dialect indeed has one category, but other gradient effects may be at play, missing from the current model.

Conclusion

- Articulatory data is important for diagnosing between categoricity and gradience.
- A one-size-fits-all conclusion simplifies the facts.
- Different dialects display different combinations of categorical and gradient effects.
- Visualisation methods and statistical techniques such as PCA give more power for diagnosing between such effects reliably.

Thanks for listening!!



The University of Manchester



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