Factors Affecting Lexical Reduction

- **Smooth Signal Redundancy hypothesis**
  - Two opposing constraints affect duration:
    - producing robust communication
    - efficiently expending articulatory effort
  - This opposition leads to an inverse relationship between language redundancy and duration
  - Smooth signal redundancy is the “most efficient way of ensuring robust information transmission in a noisy environment”
  - Speakers use prosodic prominence to regulate smooth signal redundancy
Probabilistic Reduction Hypothesis: Word forms are reduced when they have a higher probability (Jurafsky et. al., 2001)

- Reduction includes:
  - vowel reduction
  - final /t/, /d/ deletion
  - duration

- Probability determined by:
  - neighboring words
  - syntactic and lexical structure
  - semantic factors
  - discourse factors
  - frequency
Second Mention Reduction

• One discourse factor affecting reduction is whether the word is old or new in the discourse

• **Second Mention Reduction (SMR):** When English speakers repeat words, the second mention is reduced (shorter and less intelligible) relative to the first mention (Fowler and Housum, 1987)

• Effect not articulatory priming (Fowler, 1988)
  - No second mention shortening in lists
  - Second mention shortening in paragraphs and conversation
  - No shortening for homophonous primes in paragraphs
Factors Reducing SMR

- SMR does not appear when the second use of the word refers to a new item of the same sort (Bard, Lowe, & Altmann, 1989)

- Repeated mention shortening occurred within a description of a scene, but not between scenes (marked by metanarrative statements like “in the next scene”) (Fowler, Levy and Brown, 1997)
Frequency

- Frequency has a significant effect on duration of words (Jurafsky et al., 2001, Aylett and Turk, 2004)
- Syllables in high frequency words have significantly shorter durations than those in low frequency words, even after controlling number of phonemes (Aylett and Turk, 2004)
Clear Speech

- Clear speech is a listener-directed style of speech (Bradlow, 2002)
  - Used in adverse listening conditions like when listener is hard-of-hearing or a non-native (Uchanski, 2005)
  - Speakers hyper-articulate to be easily understood
  - Hyperarticulation is the opposite of reduction
  - Clear speech can involve significantly longer speech sound durations than conversational speech (Picheny, Durlach, and Braid, 1986)
Project Goals

• Look at two factors affecting probability:  
  – SMR  
  – Frequency

• Examine the interaction of these two factors with each other and with clear speech

• Use these results to evaluate theories of reduction
Clear Speech Hypotheses

1) Clear speech is maximally hyperarticulated
   → No SMR or frequency effects in clear speech

2) Clear speech is just one of many factors affecting articulation level
   → Both SMR and frequency effects maintained, scaled up, in clear speech

3) The goal of clear speech is communicating maximum information, not hyperarticulation
   → SMR maintained in clear speech, it communicates discourse structure, a meaningful contrast
   → Frequency effect lost, no useful information in contrast between high and low frequency words
First SMR/Frequency Hypothesis

- SMR and frequency have additive effects
  - Main effect for each factor, no interactions
    - Significant SMR
    - Significant correlation between frequency and 1st mention duration
    - Significantly longer durations in clear speech
Second SMR/Frequency Hypothesis

- The probabilistic factors have interactive effects with each other and speech style
  - E.g. Significant correlation between SMR ratio and frequency
  - Interactions could happen in clear or conversational or both
The Experiment I

- Five paragraphs containing 59 repeated mentions in equivalent phonetic and prosodic contexts
- Six paid students read the paragraphs in clear and conversational styles
- Clear instructions: “Please read the paragraphs very clearly, as if you are talking to a listener with a hearing loss, or to a non-native speaker learning your language.”
- Conversational instructions: “Please read the paragraphs as if you are talking to someone familiar with your voice and speech patterns, like a friend.”
If you want to go to Gina’s Pizza Shop, I can tell you the best way to get there. Go straight down this street and follow the signs for the Johnson Expressway. However, don’t actually go onto the Johnson Expressway. When you get to the on-ramp, take a left onto Cleveland Street, the main street in town. You’ll go past a big school called Cleveland High School, right between a church with a yellow door and a church with a blue steeple. There is a small alley just past the church with the blue steeple. Take this alley for several blocks, and turn left on the third road you come to. Eventually, the road will split in two. Take Fillmore Boulevard, which is the one on the right. A block and a half later you’ll see the sign for Gina’s Pizza Shop, also known as the best pizza place in town.
The Experiment II

- Durations measured for repeated words' first and second mentions in both styles
- To examine amount of SMR, compared first mention divided by second mention instead of raw durations
  - These ratios let me compare reduction in clear and conversational speech, which is because of the longer durations associated with clear speech
- Recordings containing major disfluencies or disfluencies on or around target words were not included because of the known effects of disfluencies on duration (Bell et.al., 2003)
Results: Second Mention Reduction

- Wilcoxon signed-rank tests averaging over speakers
- Significantly longer durations in clear speech
  - 1\textsuperscript{st} mentions (p<.0001)
  - 2\textsuperscript{nd} mentions (p<.0001)
- Significant SMR
  - conversational (p<.0005)
  - clear (p<.0005)
- Replicates Fowler and Housum (1987) and extends to clear speech
Results: Comparing Amounts of Reduction

- No significant difference between the reduction ratios in clear and conversational speech overall or for any of the speakers
Accounting for Prosodic Variation

- Some of the SMR effect in clear speech might be due to its larger number of prosodic breaks.
- To test this, I reanalyzed after removing words that appeared in different prosodic contexts:
  - Each speaker produced four mentions of each word: 1\textsuperscript{st} conversational, 2\textsuperscript{nd} conversational, 1\textsuperscript{st} clear, 2\textsuperscript{nd} clear.
  - Each word was coded as preceded and/or followed by a break or not next to a break.
  - The revised dataset included only words in which all four mentions were in the same prosodic context.
Results of Reanalysis

- Removed 60 of the 370 items (16.2%)
- Found similar results to the original analysis
- Still significant SMR (Wilcoxon) averaging over speakers
  - conversational (p<.0005)
  - clear (p<.001)
Results of Reanalysis

- Still found no significant difference between clear and conversational ratios
Frequency and Duration

- Partial correlation between log frequency and 1\textsuperscript{st} mention duration (controlling for length in phonemes):
  - Conversational: \(-0.461 (p < .001), r^2 = 0.213\)
  - Clear: \(-0.554 (p < .0001), r^2 = 0.307\)
Spearman correlation between log frequency and SMR ratio:
- Conversational: 0.296, significant (p < 0.05)
- Clear: -0.009, not significant (p = 0.950)
Summary and Implications

- Durations in clear speech were significantly longer than in conversational
  - Clear speech involves hyperarticulation
- Both SMR and frequency effects are found in clear speech
  - Clear speech does not involve maximal hyperarticulation, it is one of many factors affecting word pronunciation
  - The two probability factors are behaving similarly, supporting both theories of reduction
Interaction Implications

- High frequency words have more SMR than low frequency words in conversational speech, but not in clear speech
  - Maximum reduction when all forces support reduction in conversational speech
  - The lack of interaction in clear speech could be because clear speech imposes a limit on reduction (a floor effect)
  - The PRH has no explanation because it merely describes reduction and offers no opposing force
  - The SSRH can explain clear speech floor effect if clear speech requires a higher level of redundancy
Future Work

- Reanalyze with all possible words
- Examine these effects in another language (French)
- Analyze reduction with vowel measurements:
  - Peak amplitude of lexically stressed vowel
  - F1 and F2 of lexically stressed point vowels to examine vowel spaces
- Redo experiment controlling frequency better
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References:


Unexpected Results

- There does not appear to be a difference between the range of ratios when the entity or event is the same or different across mentions.
More Implications

- Second mention reduction appears to be very robust, appearing in:
  - conversational and clear speech,
  - face-to-face and video-mediated speech (Anderson and Howarth, 2002),
  - speech to adults and infants (Fisher and Tokura, 1995)
- It does not appear to be affected by:
  - whether the mentions reference to the same and different entities
  - distance between mentions (within limits of medium-length paragraphs)
  - lexical features such as, neighborhood density, familiarity, length, or syntactic category
• (Monte Carlo, p<.0083) SMR for 3/6 speakers in conversational and 3/6 speakers in clear

• The remaining speakers trended towards reduction
Speaker Comparisons

1st Mention Durations in Conversational Speech
'Soup' Paragraph

2nd Mention Durations in Conversational Speech
'Soup' Paragraph
Speaker Comparisons

1st Mention Durations in Clear Speech
’Soup’ Paragraph

2nd Mention Durations in Clear Speech
’Soup’ Paragraph
Ratio x Log Frequency Scatterplots