How often is maximum speed of articulation approached in speech?

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Economy of Effort
(Lindblom, 1990)

“Unconstrained, a motor system tends to default to a low-cost form of behavior.” (p.413)

“If the speech system operates so as to minimize ‘articulatory effort’ (peak velocities), we should expect it to undershoot phonetic targets quite often, but not necessarily in every single instance. The key point is: Speakers have a choice.” (p.415)
Predictions of Economy of Effort

1. Hypo-articulation (undershoot) occurs when articulatory effort is low
2. Hyper-articulation occurs when articulatory effort is high
3. Kinematic limits of articulation, such as maximum speeds of movement, are generally avoided, except in cases of high information load

The near-ceiling performance hypothesis (NCP)

- Due to its vital importance for the survival and wellbeing of human individuals, speech is maintained near an overall performance ceiling
- Such near-ceiling performance is a major source of variability in speech
- Definition of performance ceiling: The ultimate level of performance allowed by the current neural and muscular capacity
Predictions of NCP

1. Undershoot mainly occurs when articulatory effort is high, i.e., near kinematic limits
2. Full articulation mainly occurs when articulatory effort is low, i.e., far away from kinematic limits
3. Kinematic limits of articulation are frequently approached

An experimental investigation

(Xu, Ying Wai Wong, Dinoj Surendran & Karen Liu)

- To assess limits of articulatory effort by measuring peak velocity of formant movements and its relation to movement amplitude
- To examine whether and when those limits are approached in speech utterances

★ Peak velocity as indicator of articulatory effort:
Pseudo-speech condition:
Imitation of Human produced 5-syllable sequences, sped up
to 9 syllables/s through PSOLA resynthesis

1. bababababa
2. dadadadada
3. gagagagaga
4. mamamamama
5. nanananana
6. lalalalala
7. wawawawawa
8. yayayayaya
9. rarararara
10. wiwiwiwi
11. yoyoyoyo

Procedure:
1. Imitate each sequence 5 times as fast as possible without slurring (fast)
2. Imitate each sequence 5 times as emphatically as possible without slowing down (emphatic)

Subjects:
15 native speakers of American English, 7 males, 8 females, all undergraduate students

Speech condition:
Sentences containing symmetrical CVC syllables

1. So Babali Street will overlay Wawecka Place.
2. They say Wawecka Place is close to Babali Street.
3. I like the way Babali Street is laid out.
4. I have to say Wawecka Place is better.
5. I think I saw Mama Jackson in the parking lot.
6. Today I saw memento boxes at the auction.
7. I heard about the anonymous letter to the company.
8. They called the anonymity expert about the letter.
9. I found a bobby pin on the floor.
10. She gave a Dada painting to the museum.
11. I like to grow dadelphia flowers in my garden.
12. I can buy a goggle strap for you.
13. I work at the Gagalla Company every summer.
14. I went to the Wawa Company for the results.
15. My brother saw “Ya-Ya Sisterhood” on Friday.
16. I just saw Yayona Parker at the movie.
17. You can see the aurora lights in the North.
18. People say Raretta King is getting famous.
19. People say Wee-Wee brand is the best.
20. This is the day Weaweala Company opens.
21. I saw a yo-yo string in the park.
22. I got a yoyology book at the library.

Procedure:
1. Say each sentence 5 times at normal speed (normal)
2. Say each sentence 5 times as fast as possible without omitting sounds (fast)

Subjects:
ibid.
Tracked formants, their velocity profiles, and measurement points

Slow

Formant in st

Fast

Unershoot

Velocity in st/s

Linear relation of peak velocity to movement amplitude

(Sequence; fast, rigorous; female)
Different linear relations at different articulation rates
(Sequence; female; all speeds)

Linear relation of peak velocity to movement amplitude in sentences
(fast, rigorous; female)
Peak velocity at fixed movement amplitudes, as evidence of differing articulatory efforts

Discussion

1. Kinematic limits of articulation, such as max speed of movement, are often approached in speech

2. But this happens in unstressed syllables rather than in stressed syllables; and it happens during hypo- rather than hyper-articulation

3. Articulatory effort, as measured by peak velocity, is higher in unstressed syllables than in stressed syllables

4. Full (or hyper-) articulation occurs in stressed syllables, where articulatory effort is relatively low
**Conclusion**

1. Conventional notion of economy of effort is not precise enough to explain the present data.

2. These data are better predicted by the near-ceiling performance (NCP) hypothesis: *Speech is maintained near an overall performance ceiling.*

3. There could be other performance bottlenecks that may help shape other aspects of speech.

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**Peak velocity over movement amplitude in different scales**

*Sequence*, fast, rigorous; male subject 1

- **Semitone**
  
  - $\text{meanF1}_\text{max\ velocity} = 2.753 + 21.029 \times \text{meanF1}_\text{amplitude}; R^2 = .984$

- **Bark**
  
  - $\text{meanF2}_\text{max\ velocity} = 134.342 + 19.474 \times \text{meanF2}_\text{amplitude}; R^2 = .992$

- **Hz**
  
  - $\text{meanF1}_\text{max\ velocity} = .027 + 20.999 \times \text{meanF1}_\text{amplitude}; R^2 = .983$

- $\text{meanF2}_\text{max\ velocity} = .654 + 19.395 \times \text{meanF2}_\text{amplitude}; R^2 = .992$