On the speed-accuracy trade-off and speed-curvature power law of tongue movements in repetitive speech

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What are the implications for models of speech?

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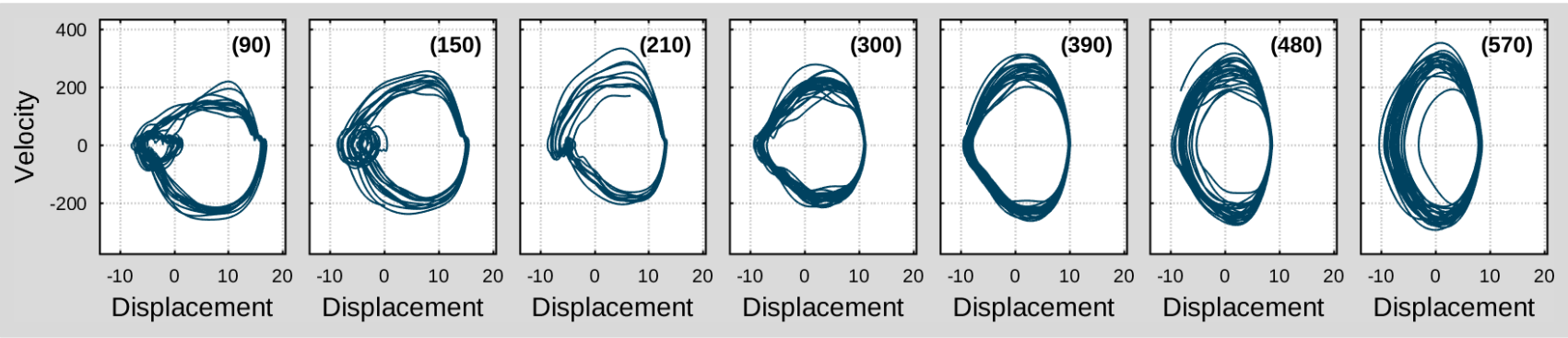
- about 4000 syllables of [ta] and [ka] each
- six native speakers of **German and English**

Experimental paradigm

- **phase portraits** of tongue back state variables (displacement x, velocity $\dot{x}$) in sequences of **[taka...]**
- **speech**:



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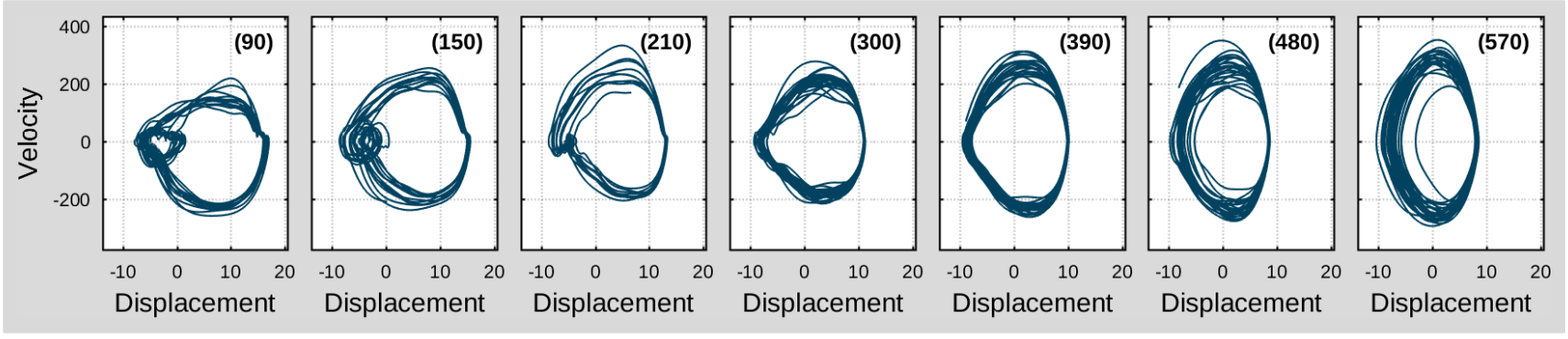
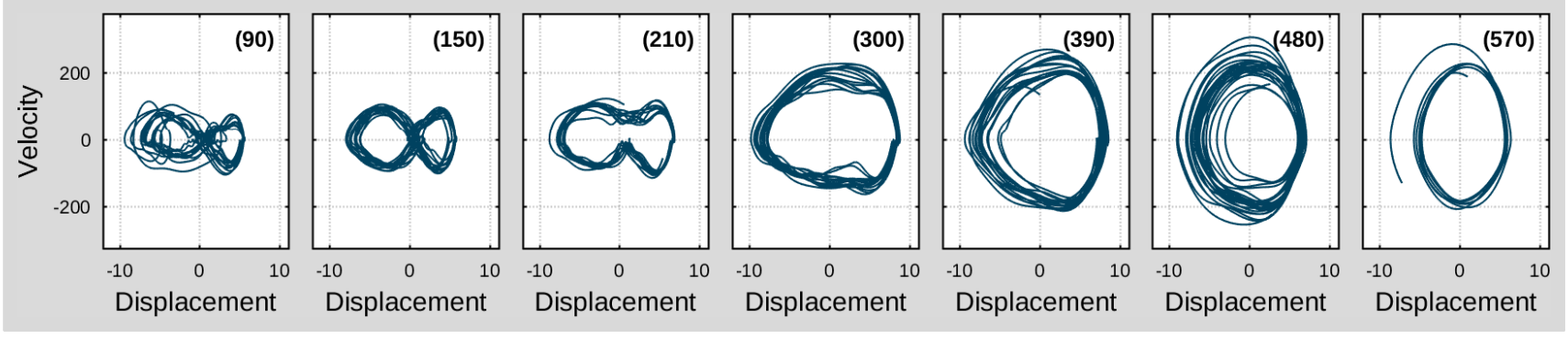


- **non-speech** (trumpet double tonguing):



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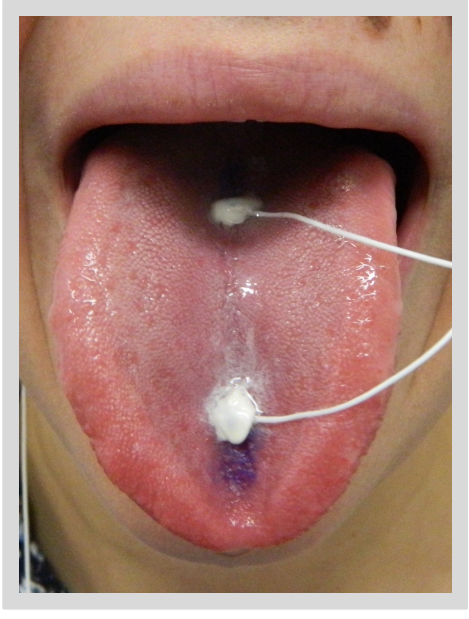

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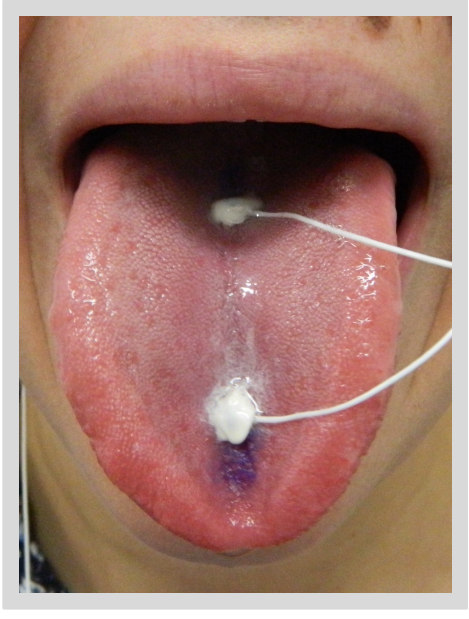

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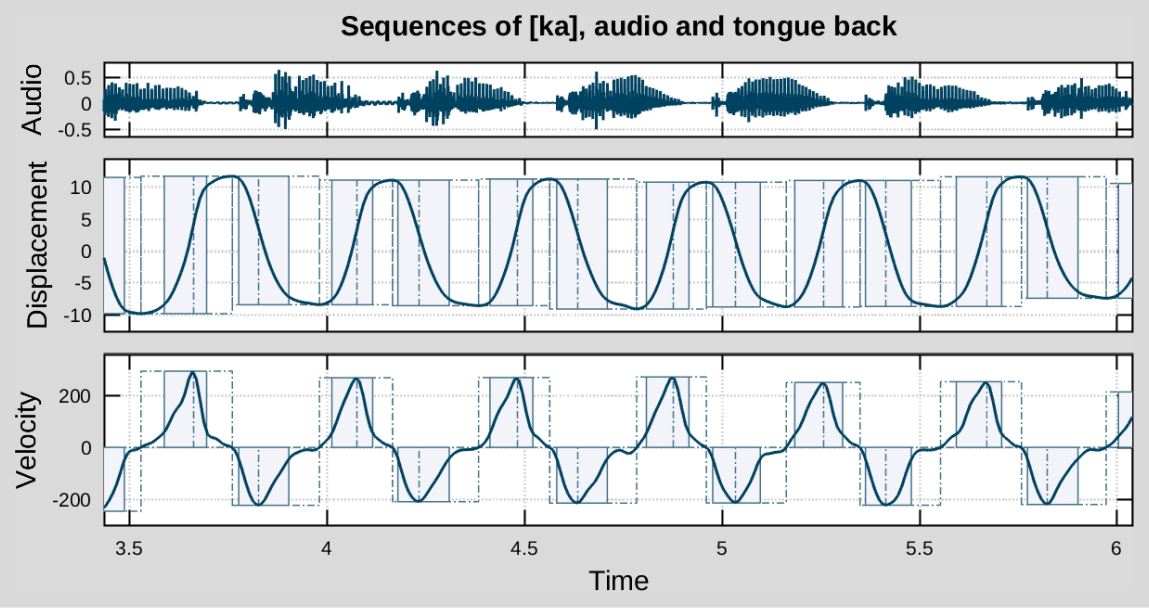

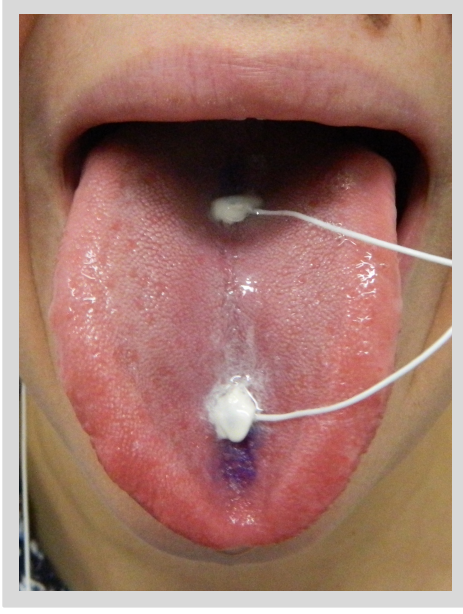

Kinematic relations

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- **standard model of speech gestures** (linear oscillator with critical damping, Fowler et al., 1980; Browman and Goldstein, 1986; Saltzman and Munhall, 1989)

$$\ddot{x} = -kx - b\dot{x}, \quad b = 2\zeta\sqrt{k}, \quad \zeta = 1 \tag{1}$$

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- **empirical evidence** repeatedly reported, e.g., in Ostry et al. (1983), Munhall et al. (1985), and Vatikiotis-Bateson and Kelso (1990)

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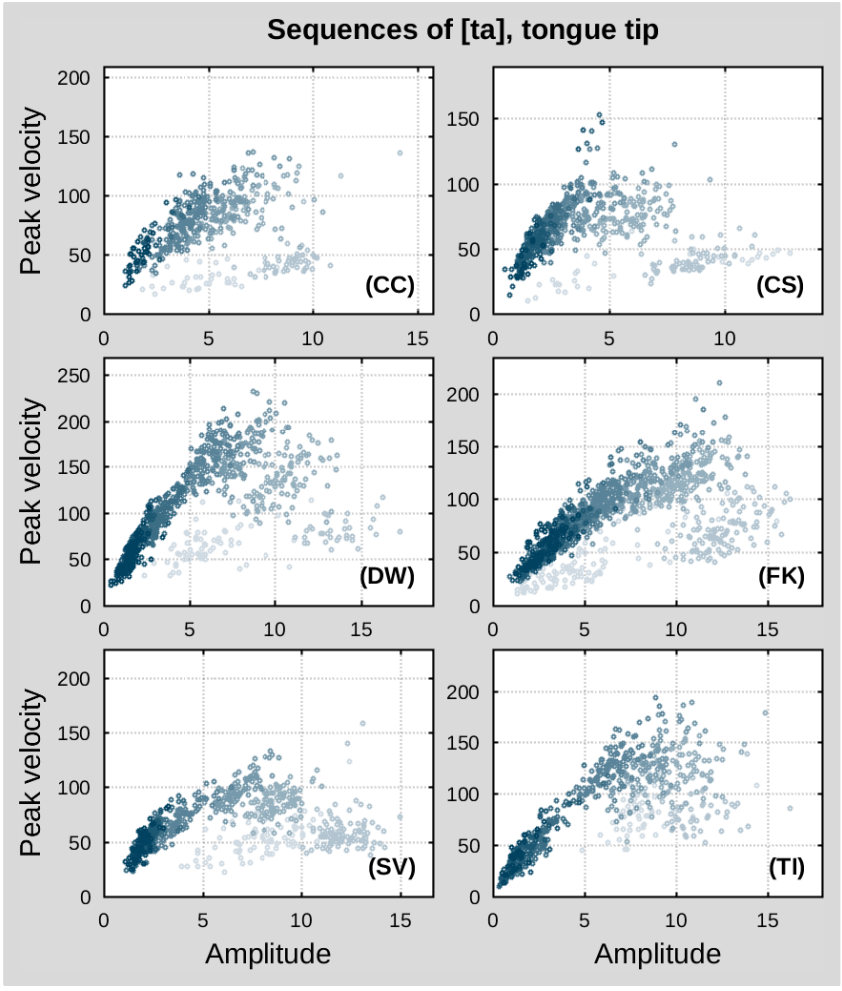

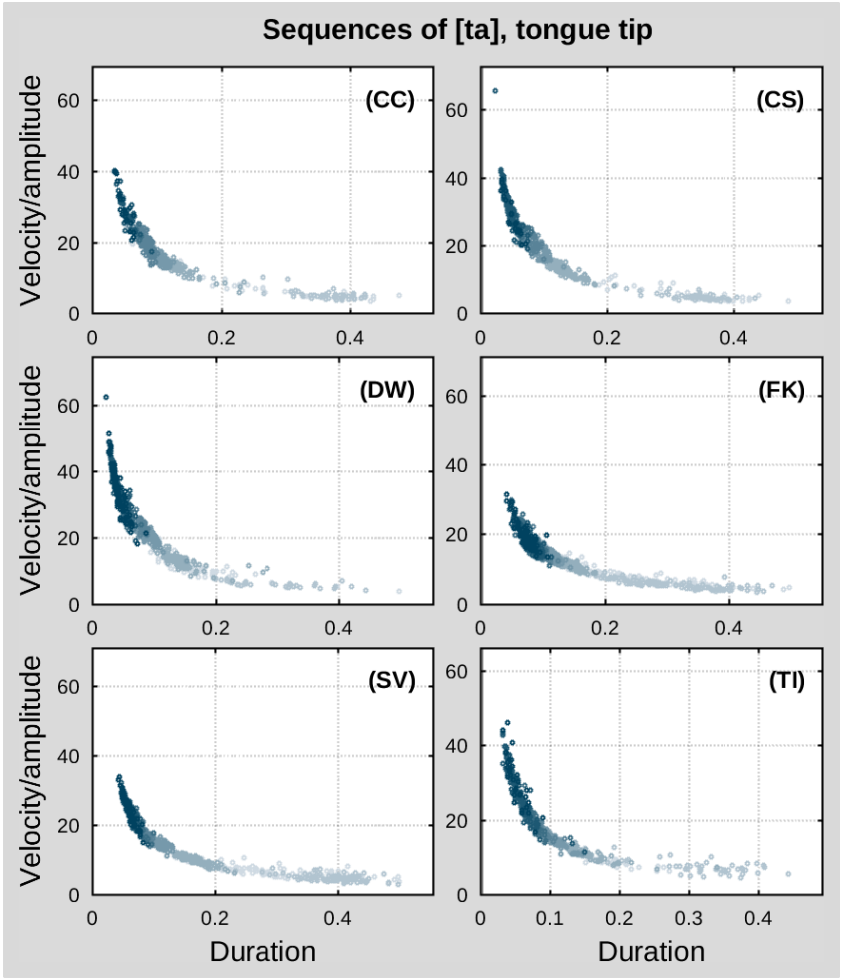

- **broad consistency** with theoretical predictions and empirical reports

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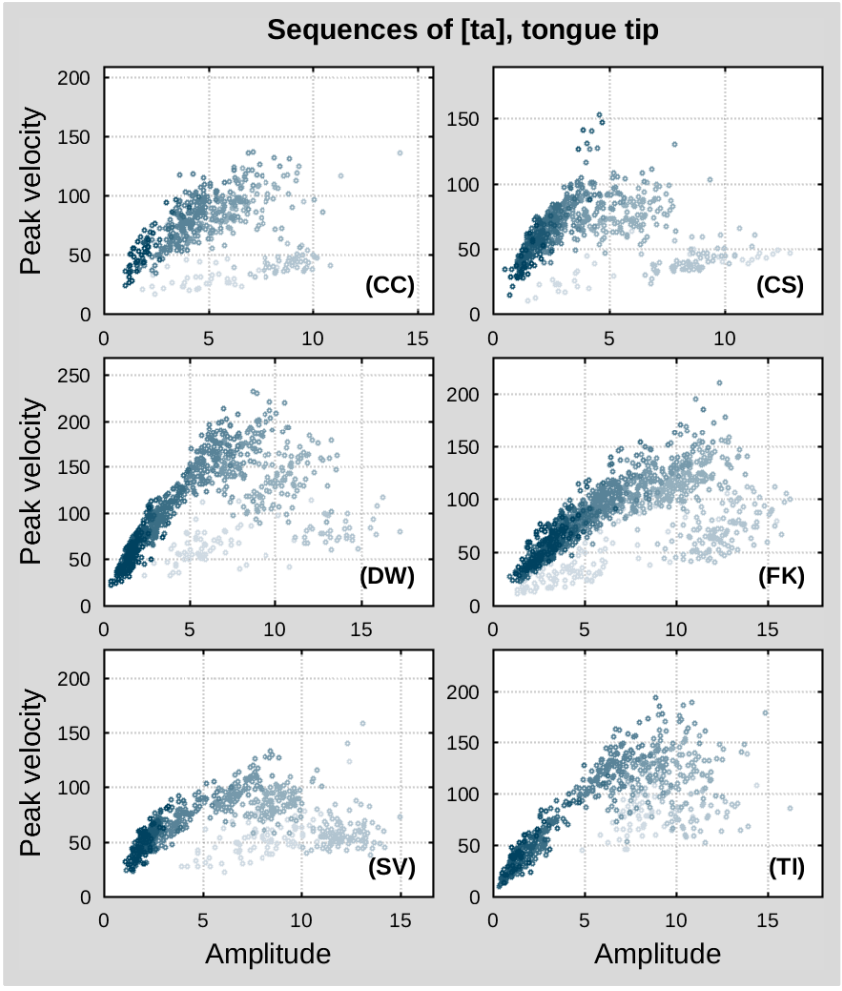

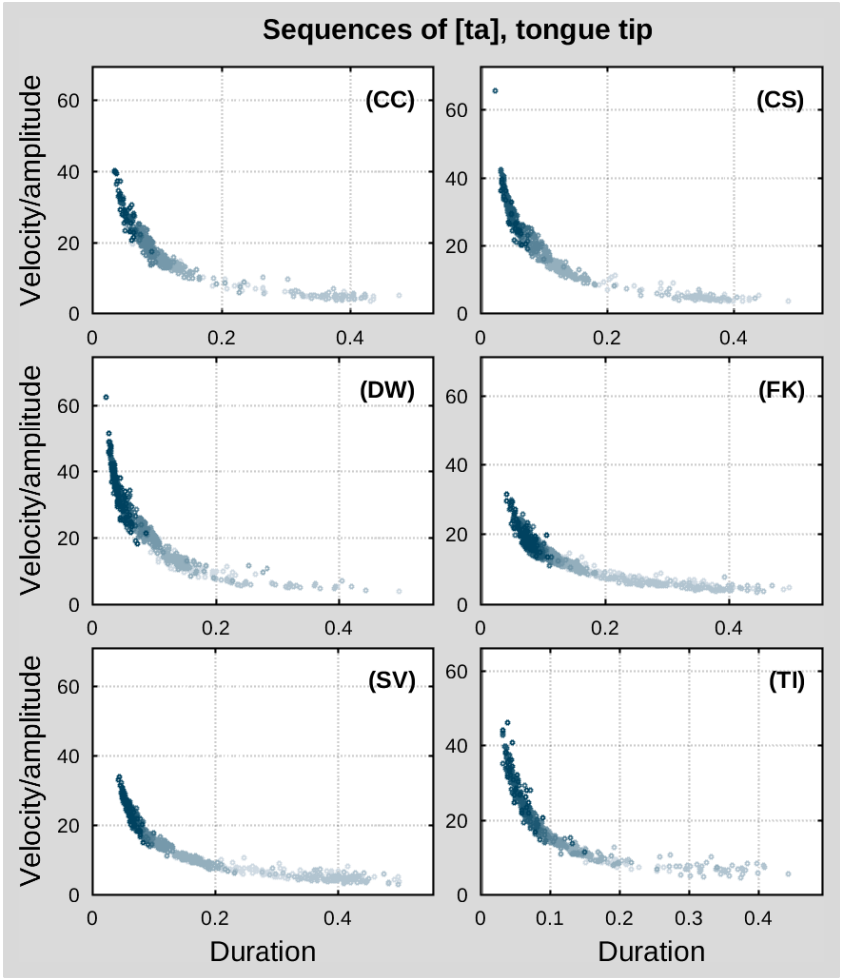

- **broad consistency** with theoretical predictions and empirical reports
- divergence of A-v^* correlation at **larger amplitudes** (slower rates) considered in Sorensen and Gafos (2016)

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- **velocity gain factor** k segregates geometrical subunits
- **exponent** β is consistently found to be close to the value of 1/3

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- consider linear relation in log-log-transformed data

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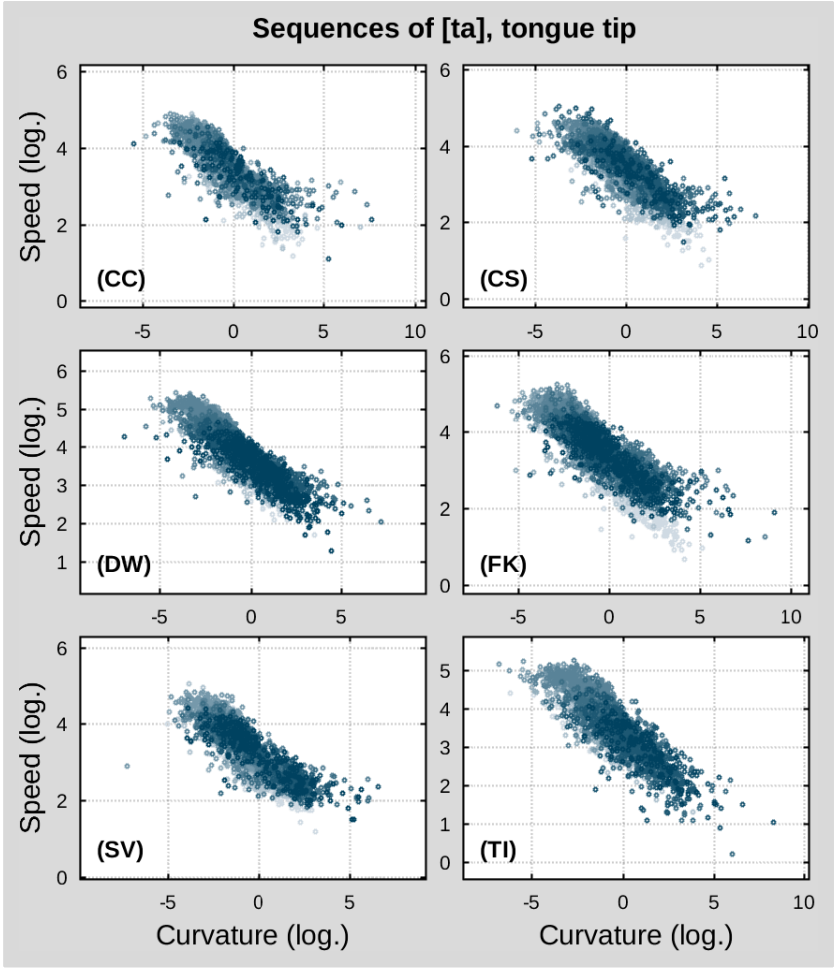

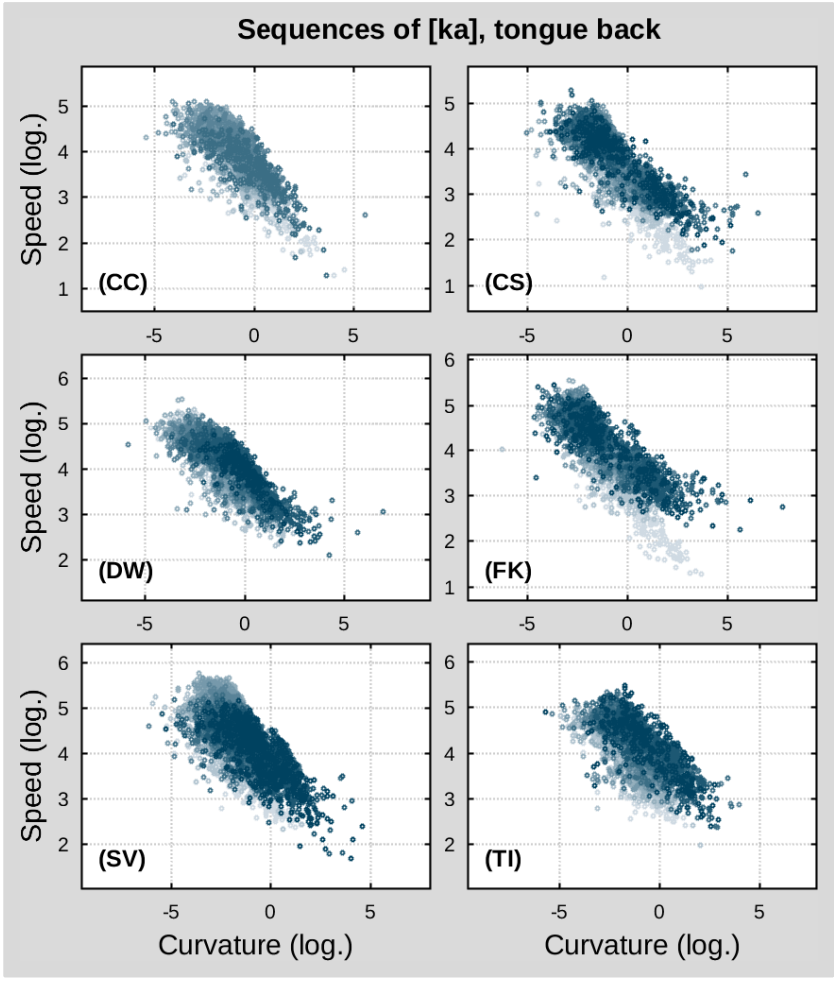

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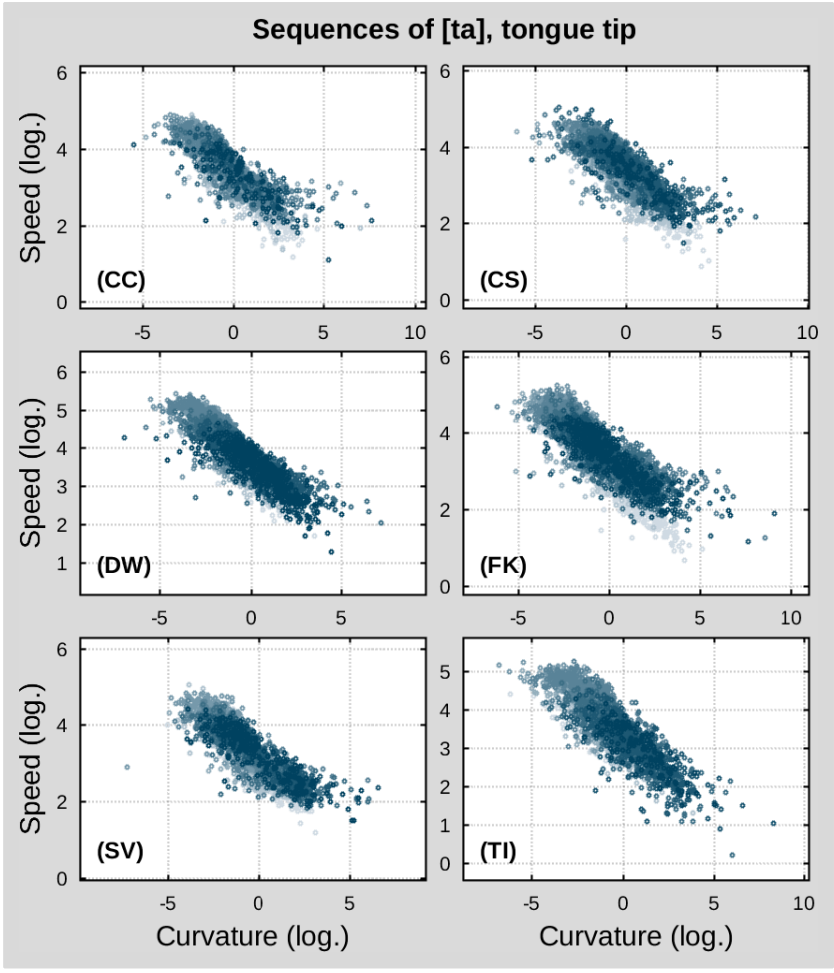

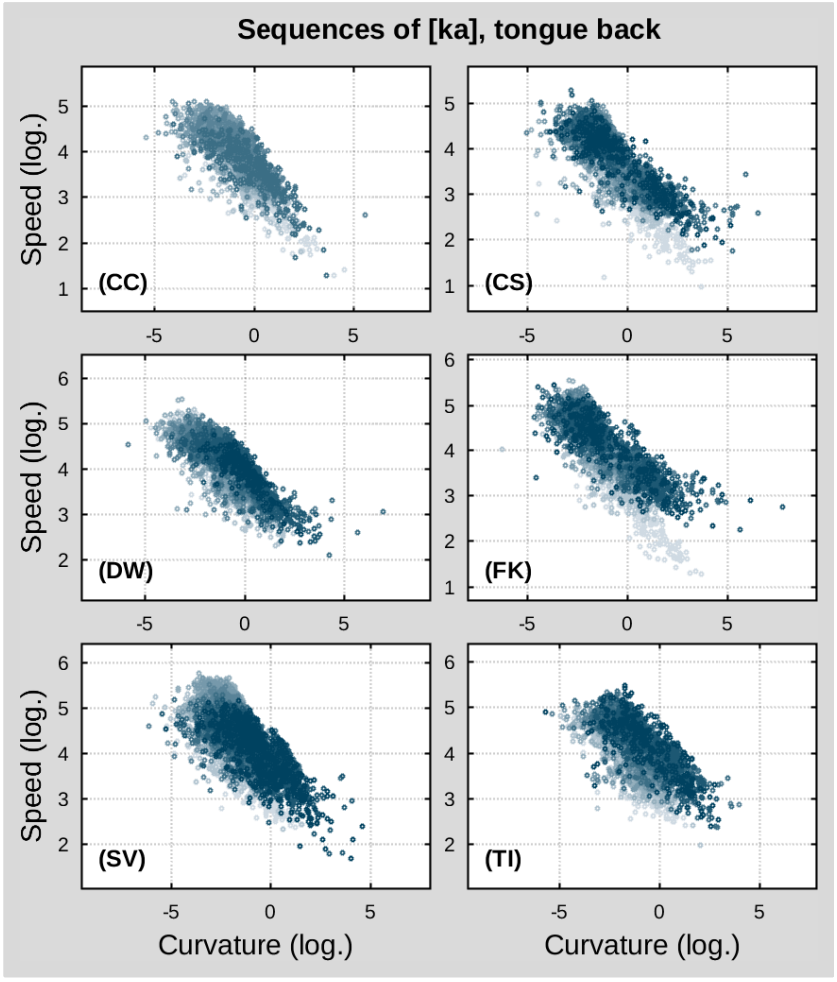

- clear evidence for the **power law in speech**

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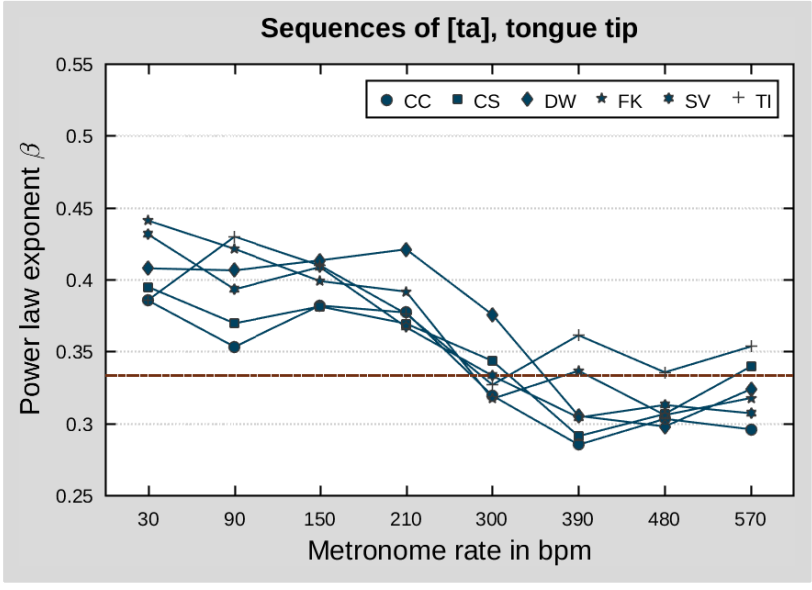
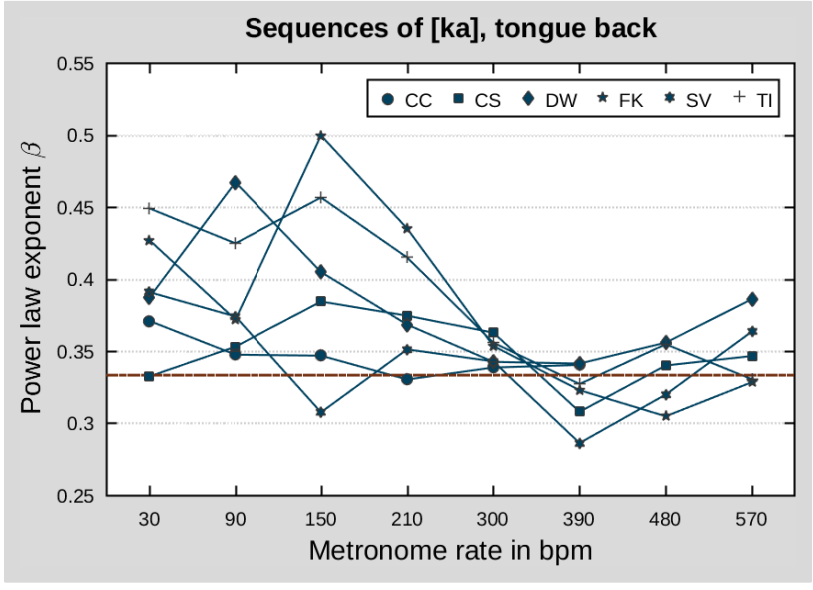
- new: significant **rate dependency** of the power law exponent β





- closest match with commonly found value of 1/3 at metronome rate of 300 bpm (**fast speech rate**)

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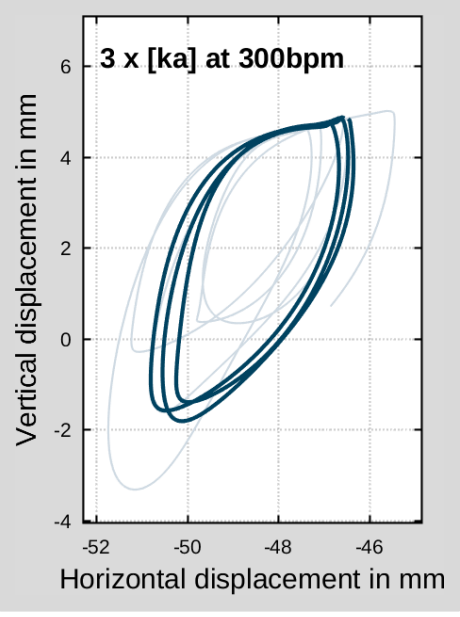

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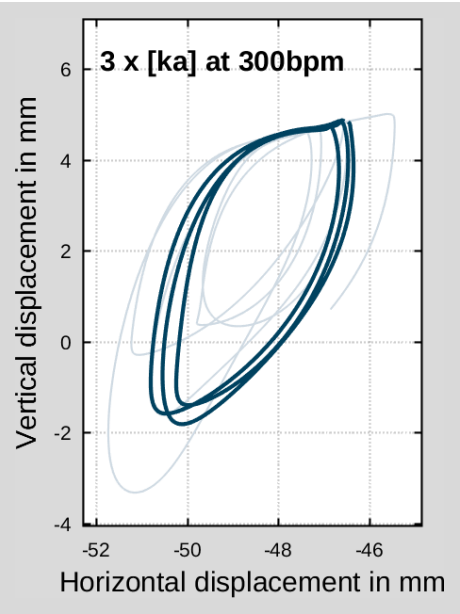

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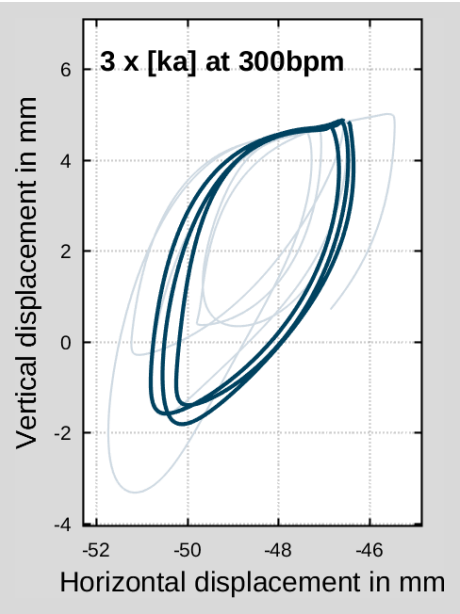

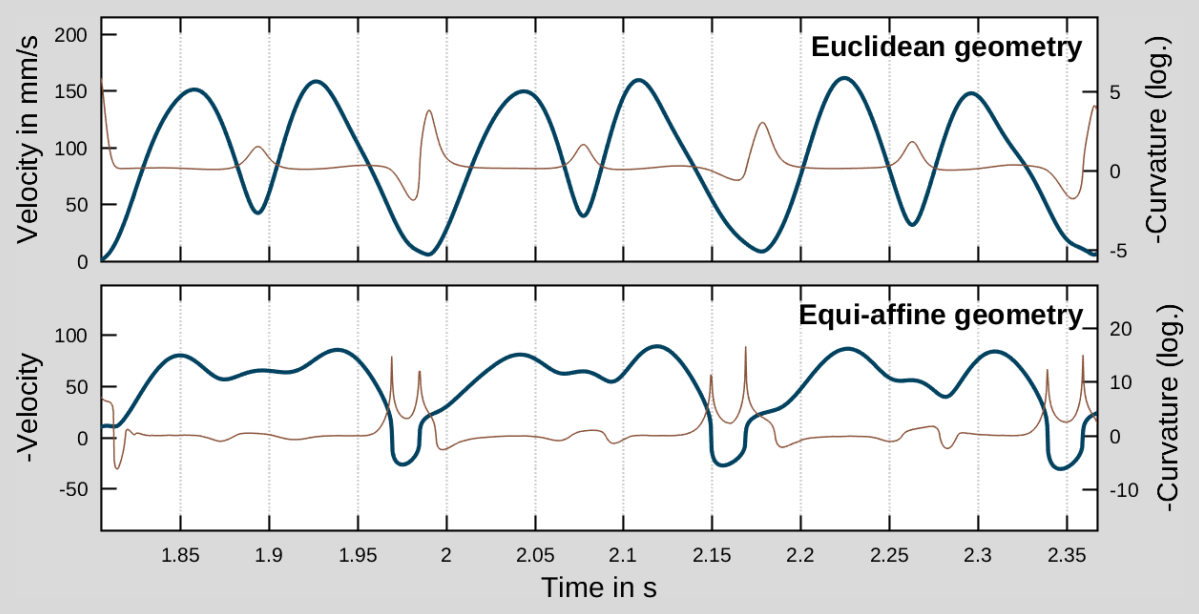

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How to achieve this in speech?

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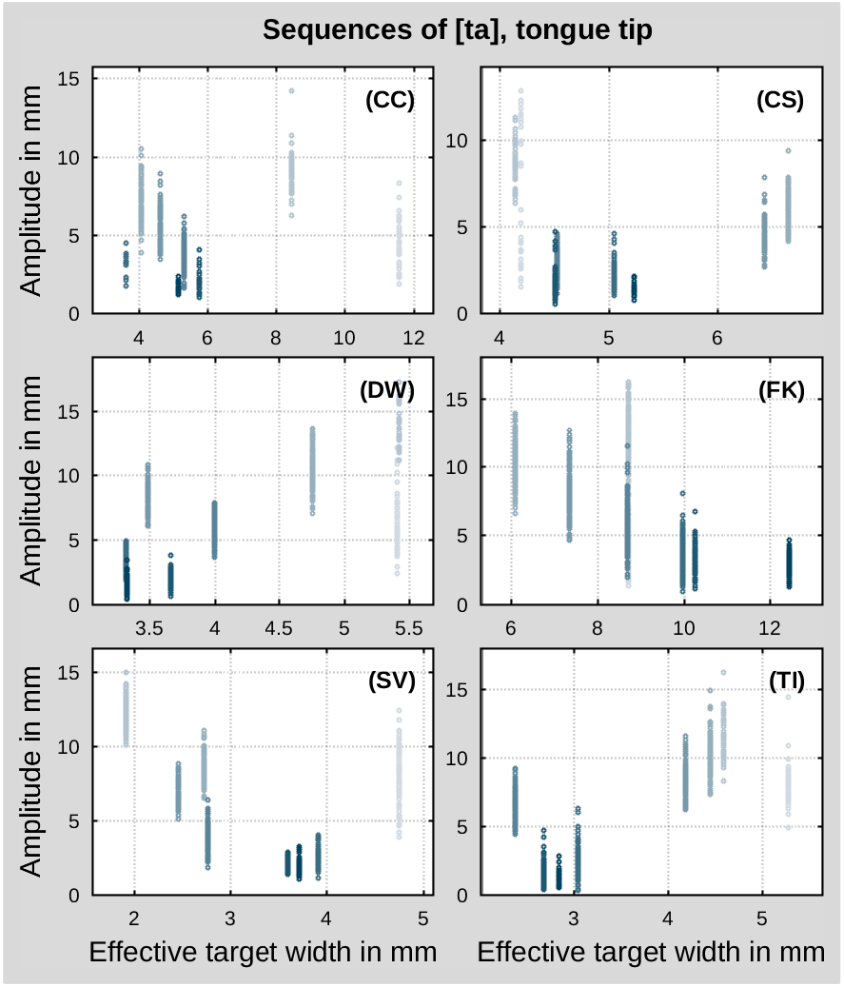

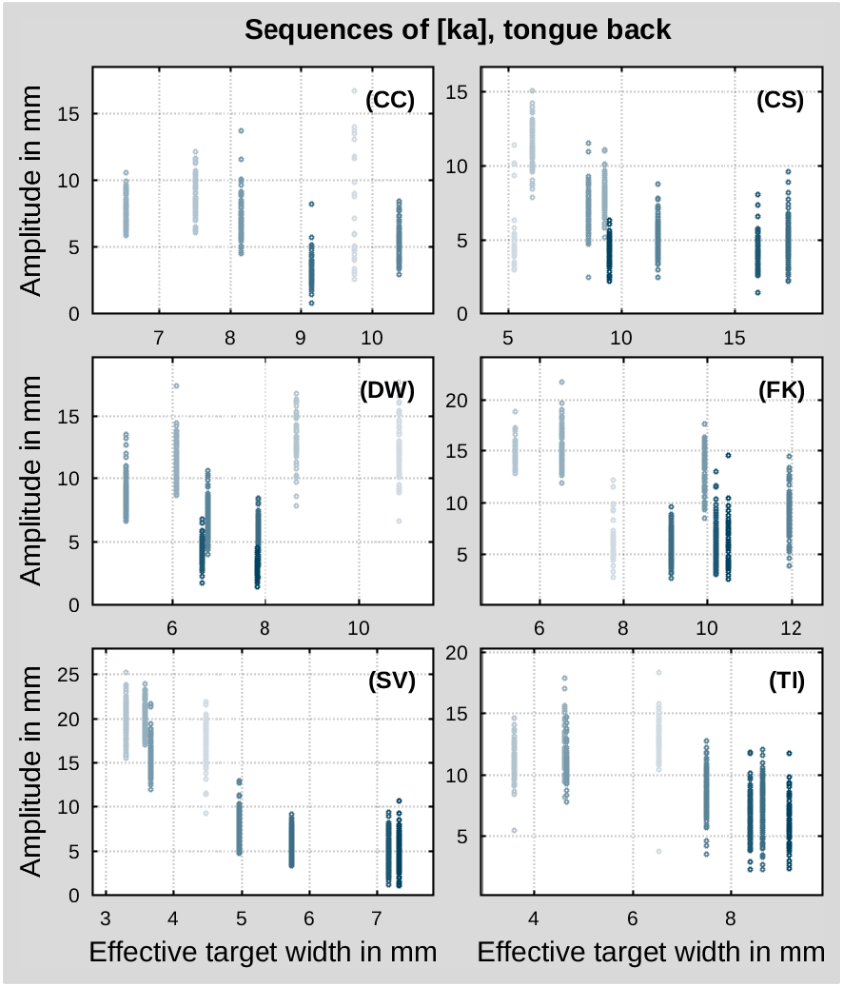

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- endpoint distributions determine an *a posteriori* defined **effective target width** (Wobbrock et al., 2011)

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- observations of **movement duration** T should reveal the **linearity of Fitts' law**

$$T = a + b\,ID \tag{8}$$

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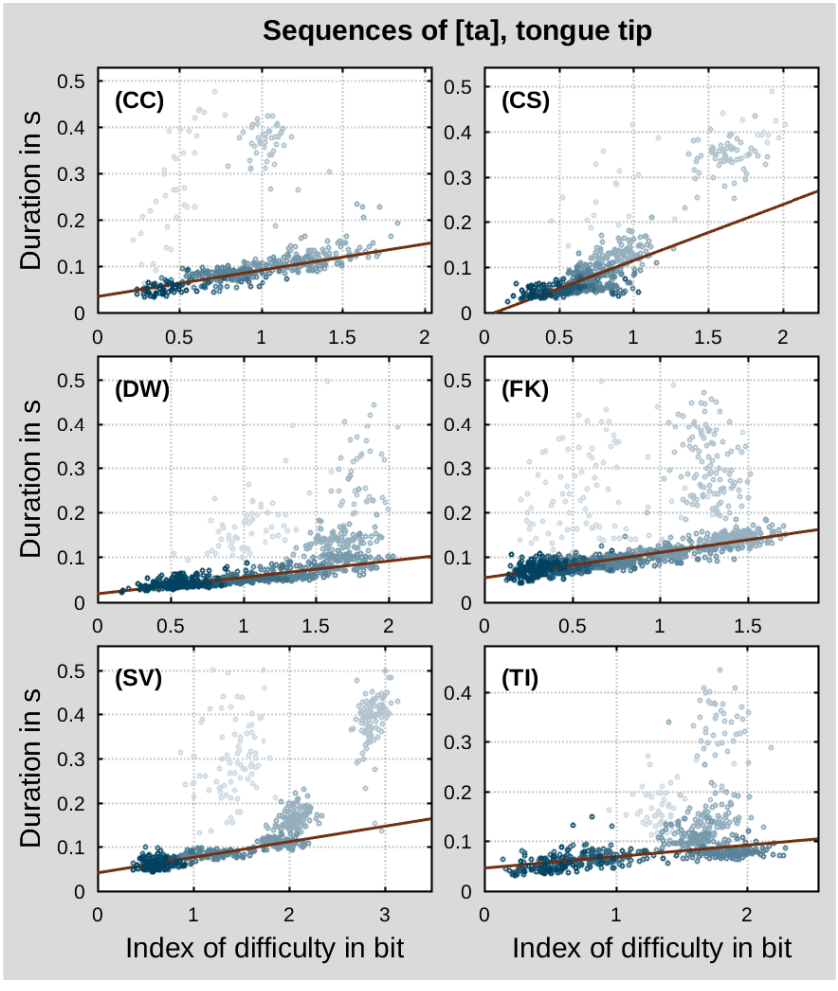
Sequences of [ta], tongue tip
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(DW)
(FK)
(SV)
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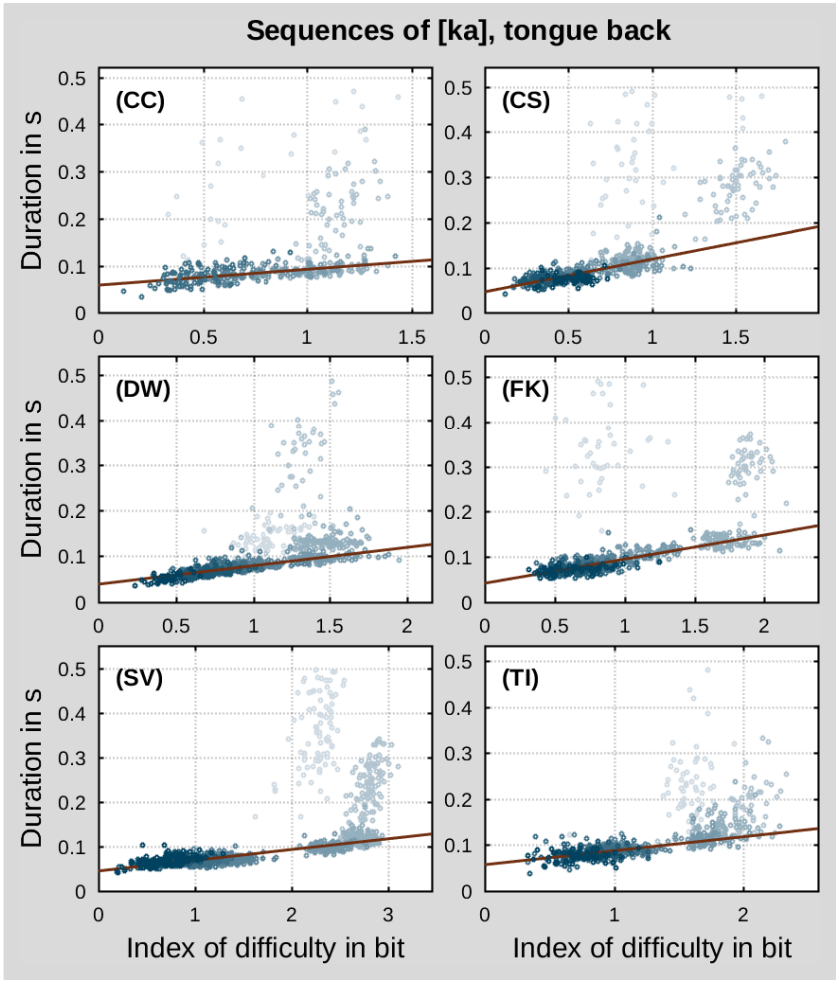
Duration in s
Index of difficulty in bit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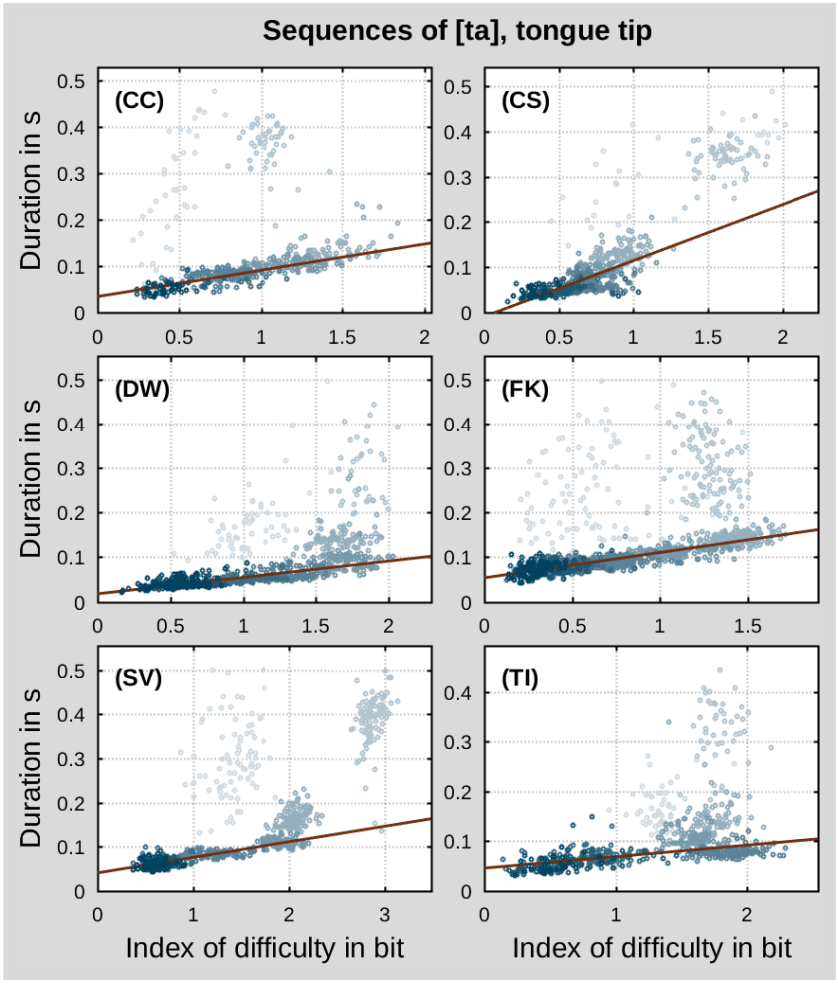
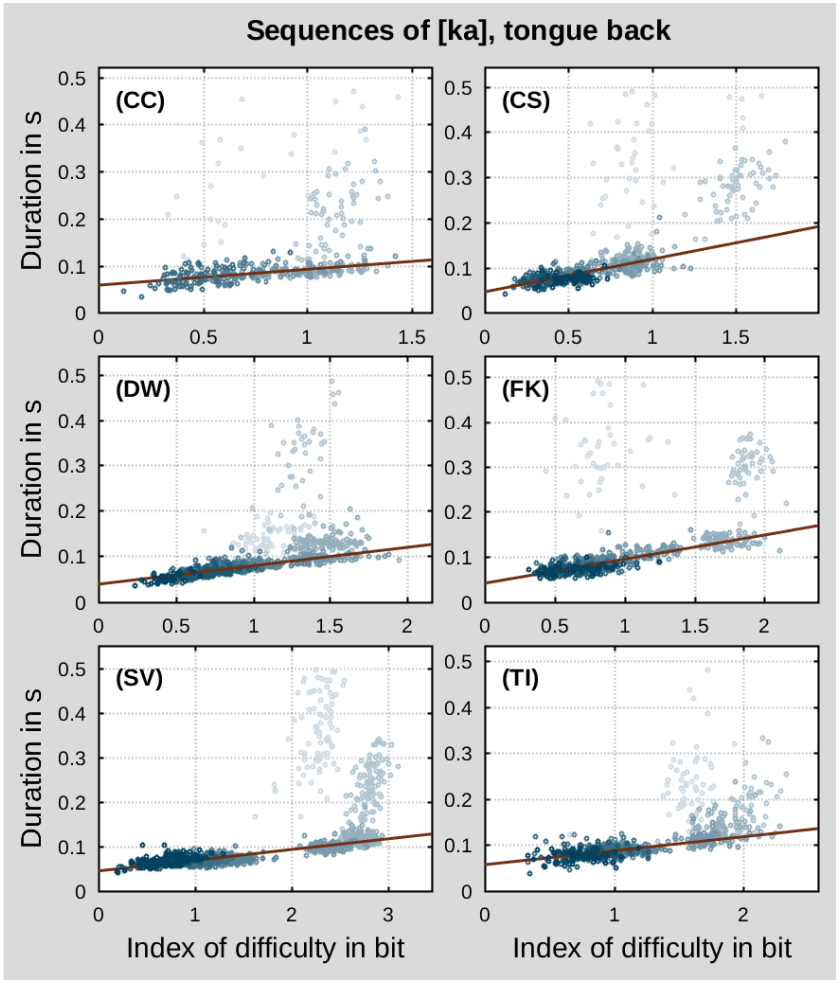
Index of difficulty in bit

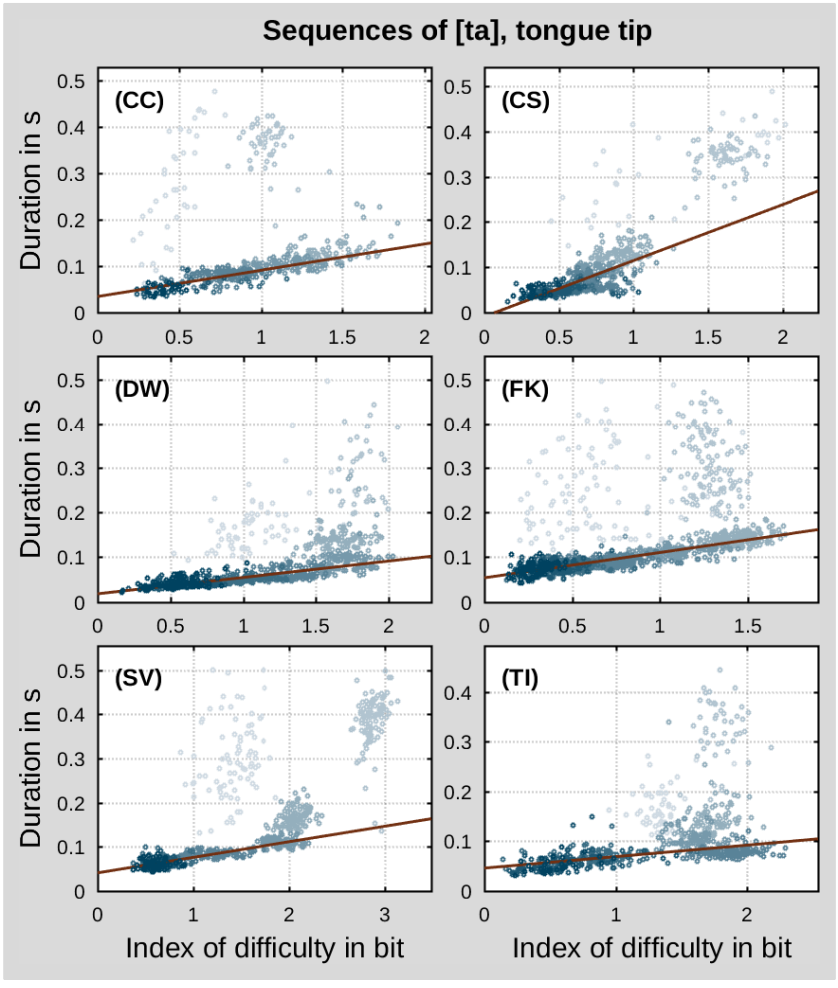
Fitts' law

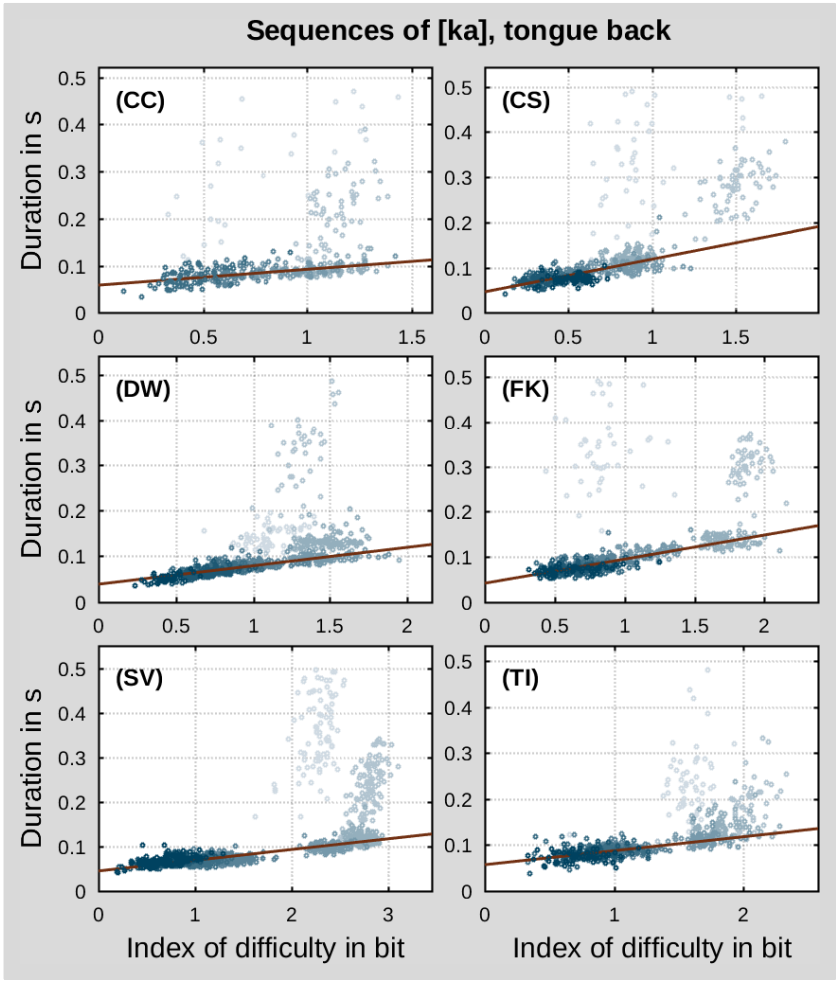




- statistics on **contiguous subsets of rates** yields critical rates

Fitts' law





- statistics on **contiguous subsets of rates** yields critical rates
- **fast rates** (≥150–210 bpm, dark shades) abide to Fitts' law
- **slowest rates** (<150–210 bpm, bright shades) do not

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But, what about the absence of Fitts' law at slower rates?

- the model fails at those rates (<150–210 bpm) where one would expect it to apply
- other models with different dynamics exist but have not been investigated yetKröger et al., 1995; Sorensen and Gafos, 2016)

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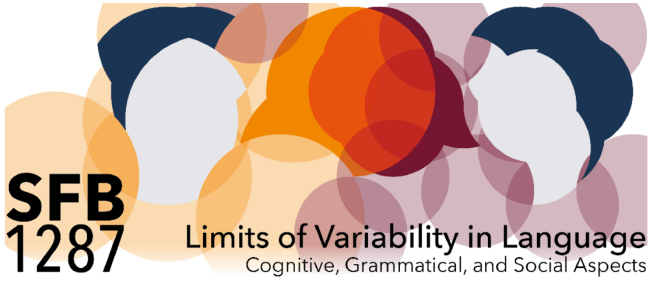
Thank you very much.



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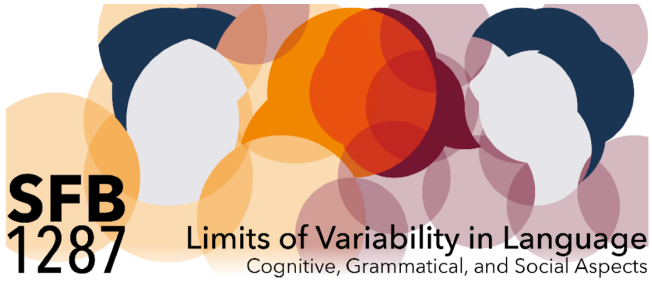

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