DFG Schwerpunktprogramm “Sprachproduktion”

Kompensatorisches Artikulationsverhalten und phonetische Zielrepräsentationen im Prozeß der menschlichen Sprachproduktion (Compensatory articulation and the nature of phonetic goals)

Compensatory articulation has been well-demonstrated under laboratory conditions
e.g tongue compensates for immobilization of jaw by a bite-block

===> motor-equivalent behaviour forms a key design feature of most speech-production models

BUT

Can compensatory abilities be demonstrated under more natural conditions?

At what level (articulatory, auditory ....) must equivalence be defined?

Compensatory Articulation

Approaches

1 Experimentally induced perturbation
e.g static (bite-block) and dynamic perturbation of the jaw.

2a Coarticulation as naturally occurring perturbation

2b Loud speech as a naturally-occurring bite-block condition

Assessment of tongue-jaw trade-offs

Compute:

intrinsic tongue contribution
from
measured tongue position
minus
jaw contribution to tongue position

Then:

Look for negative correlations between jaw and intrinsic tongue contributions

In consonants such as /t/, /s/, /n/, /l/ the tongue's main task is to form a constriction (or closure) near the alveolar ridge.

Two natural sources of perturbation:

1. Coarticulation

Use different flanking vowels to induce different jaw heights in the consonant

e.g

in /ata/ vowels have *low* jaw position

in /iti/ vowels have *high* jaw position

These difference will spread to the intervening consonant

2. Loud vs. normal speech

In loud speech an overall more open jaw posture can be expected to occur

To what extent does the tongue compensate for these "perturbations"?

Possible outcomes and their implications

Complementary covariation .....

1. Simply does not occur.

2. Occurs sporadically (over speakers, sounds ....).

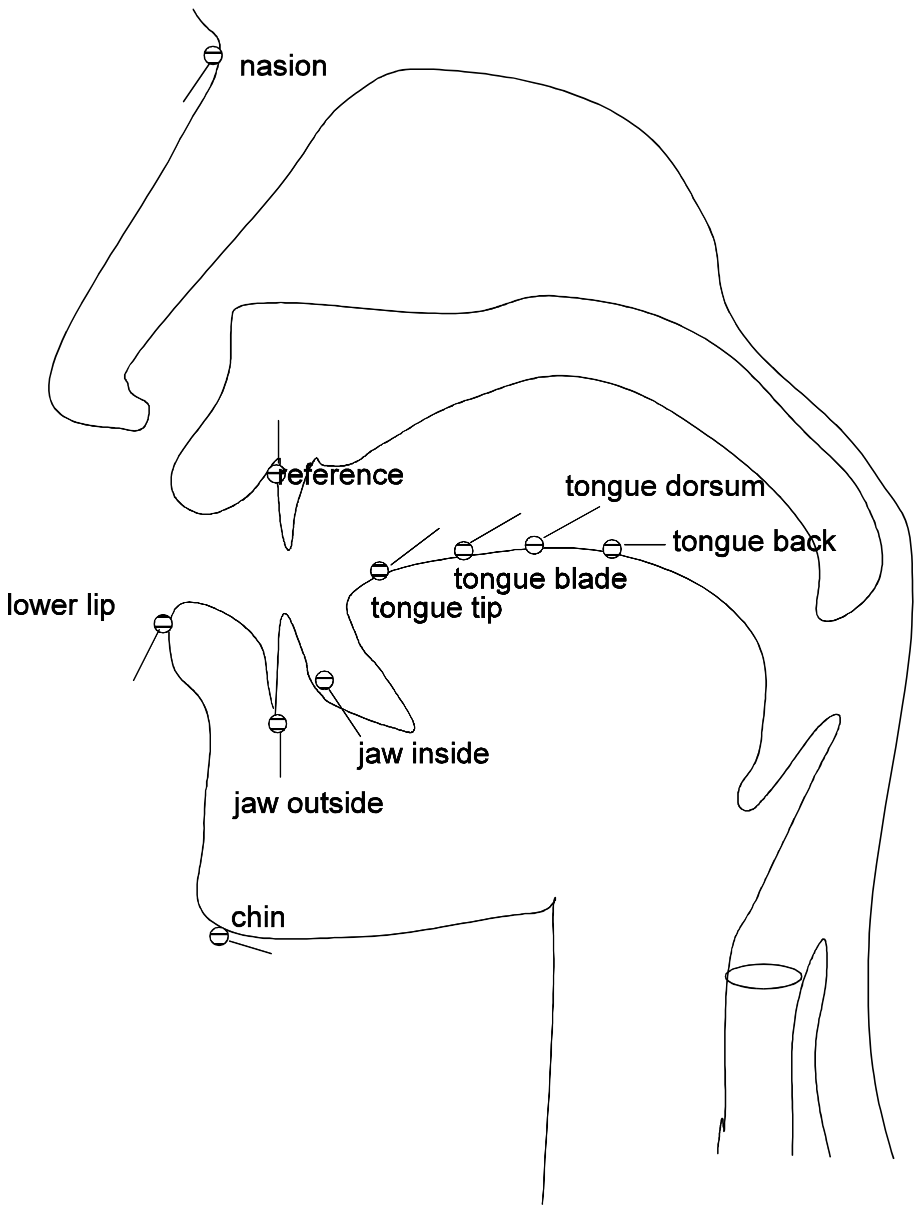
3. Occurs consistently on all consonants.
   ===> a general principle of articulatory organization?

4. Occurs consistently, but with systematic differences between consonants.
   ===> a selectively-used articulatory strategy to ensure the acoustic and perceptual integrity of the target sounds?

Additional question:

Any evidence that amount of complementary covariation is sensitive to the level at which the perturbation is applied?

utterance (loudness perturbation) vs. *segment* (coarticulatory perturbation)



Coil positions

Material

“hab’ das Verb /VCV/ mit dem Verb /VCV/ verwechselt”

(i.e 2 different VCV target sequences in each sentence)

C = /**t, d, n, l, s, ʃ**/

V1 = V2 = /**i, e, a**/

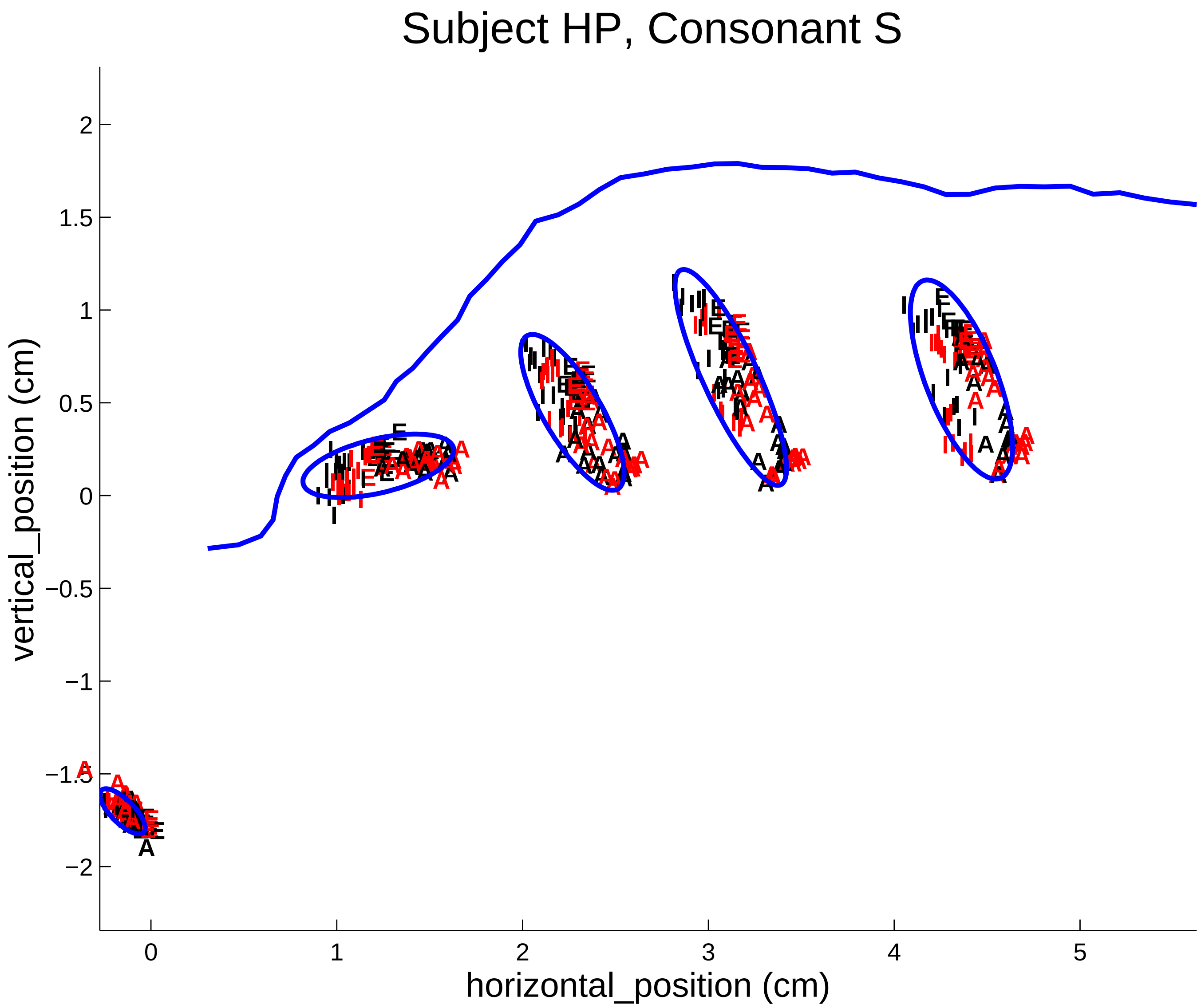
Two volume levels: Normal and Loud

12 repetitions of each combination of C, V and volume

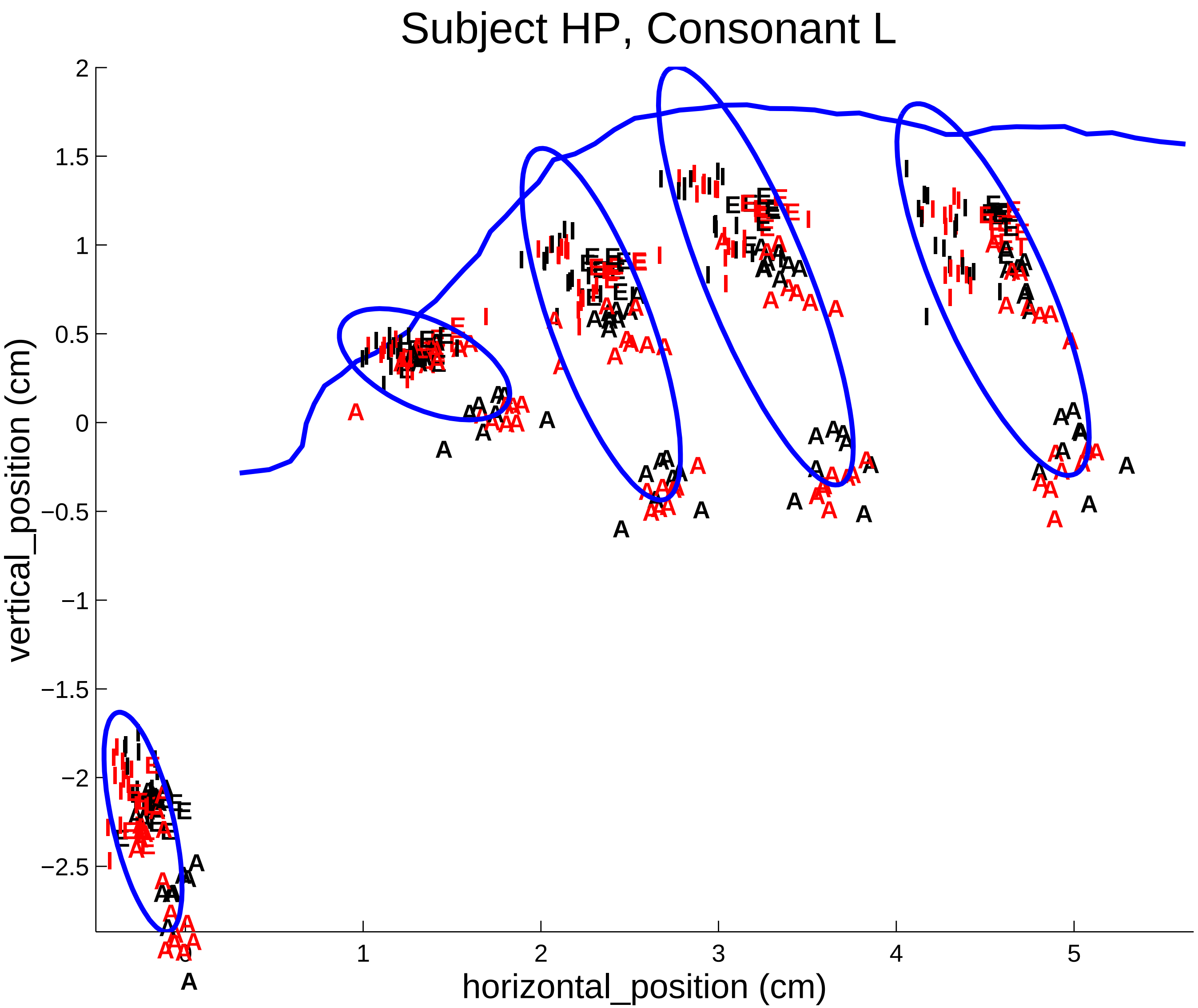
Five subjects

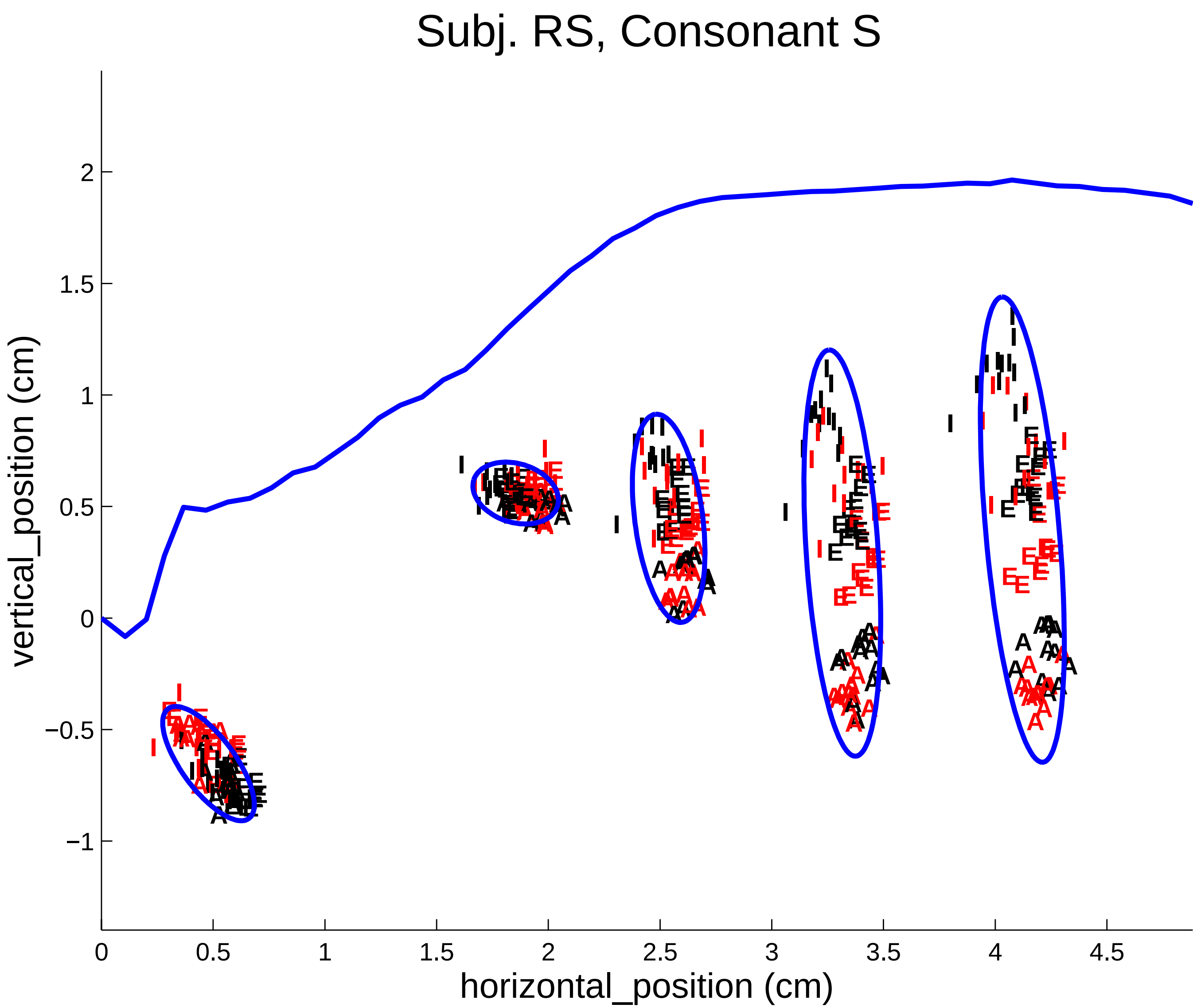
The following four figures show scatter plots of sensor positions for two target consonants of two subjects.

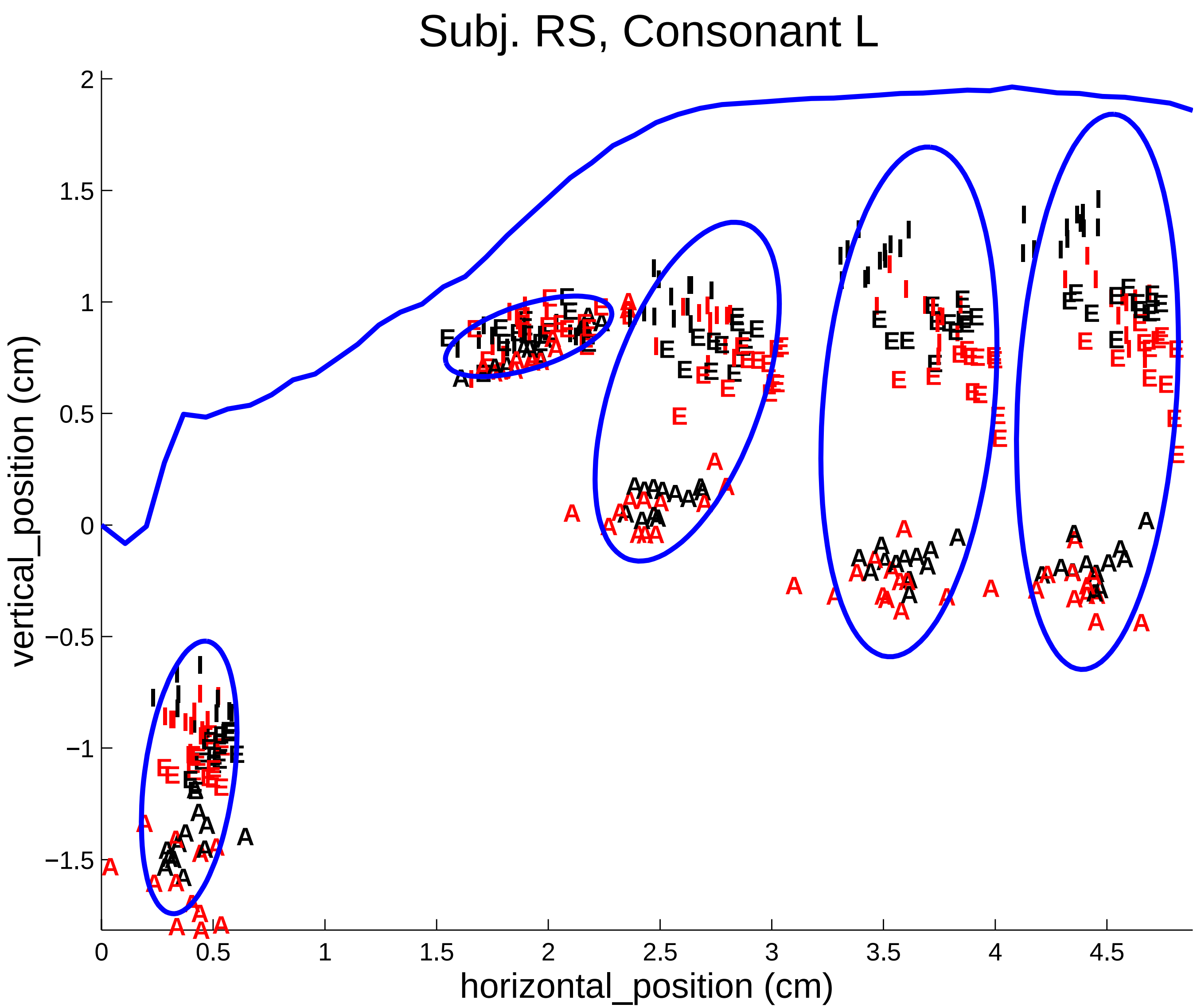
> The upper case letters I, E and A indicate the flanking vowel.
>
> Black letters: Normal volume utterances
> Red letters: Loud volume utterances



Subject HP, Consonant S
vertical_position (cm)
horizontal_position (cm)
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
0
1
2
3
4
5


Subject HP, Consonant L
vertical_position (cm)
horizontal_position (cm)
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−2.5
1
2
3
4
5

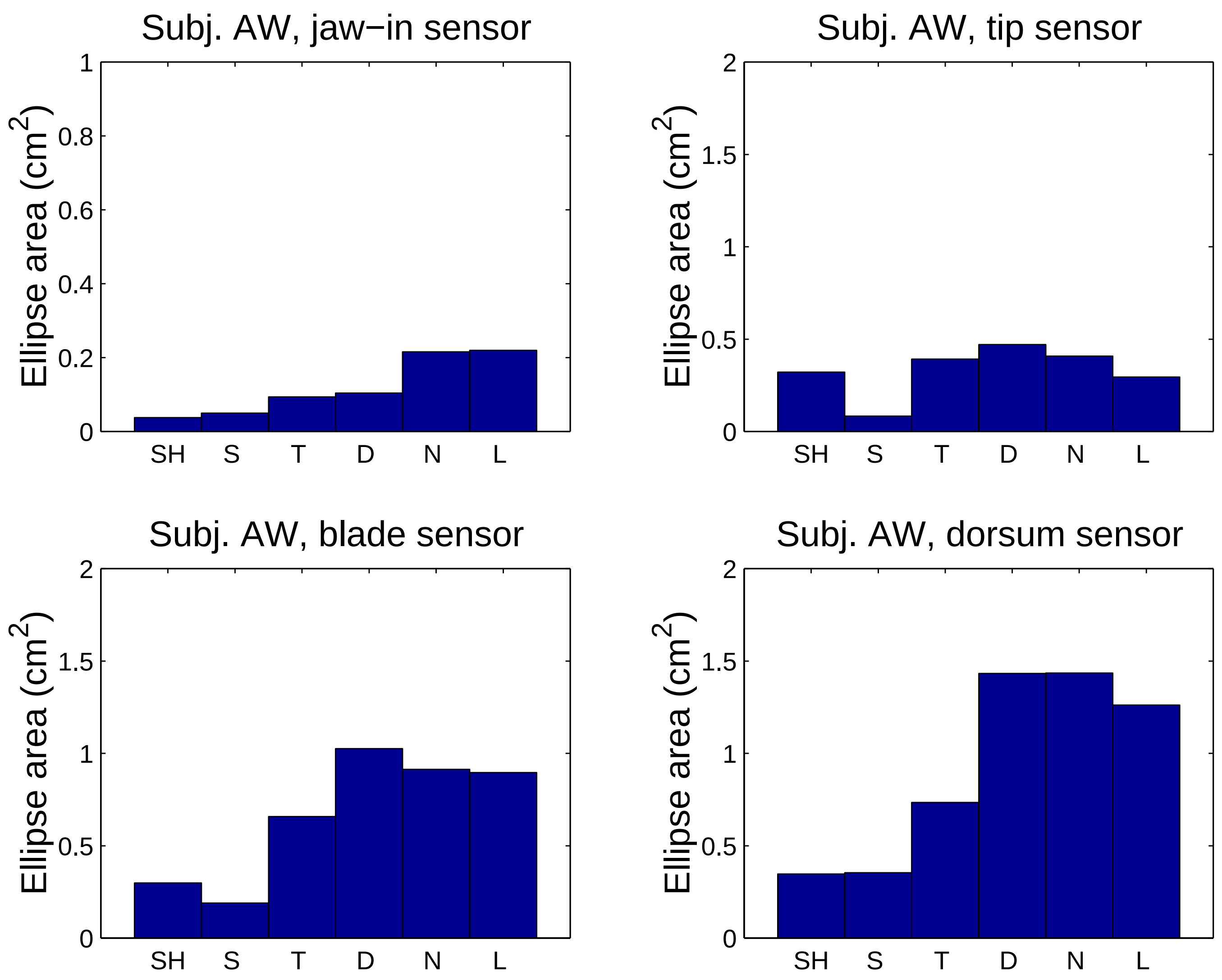

Subj. RS, Consonant S
vertical_position (cm)
horizontal_position (cm)
2
1.5
1
0.5
0
−0.5
−1
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5


Subj. RS, Consonant L
vertical_position (cm)
horizontal_position (cm)
2
1.5
1
0.5
0
−0.5
−1
−1.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5

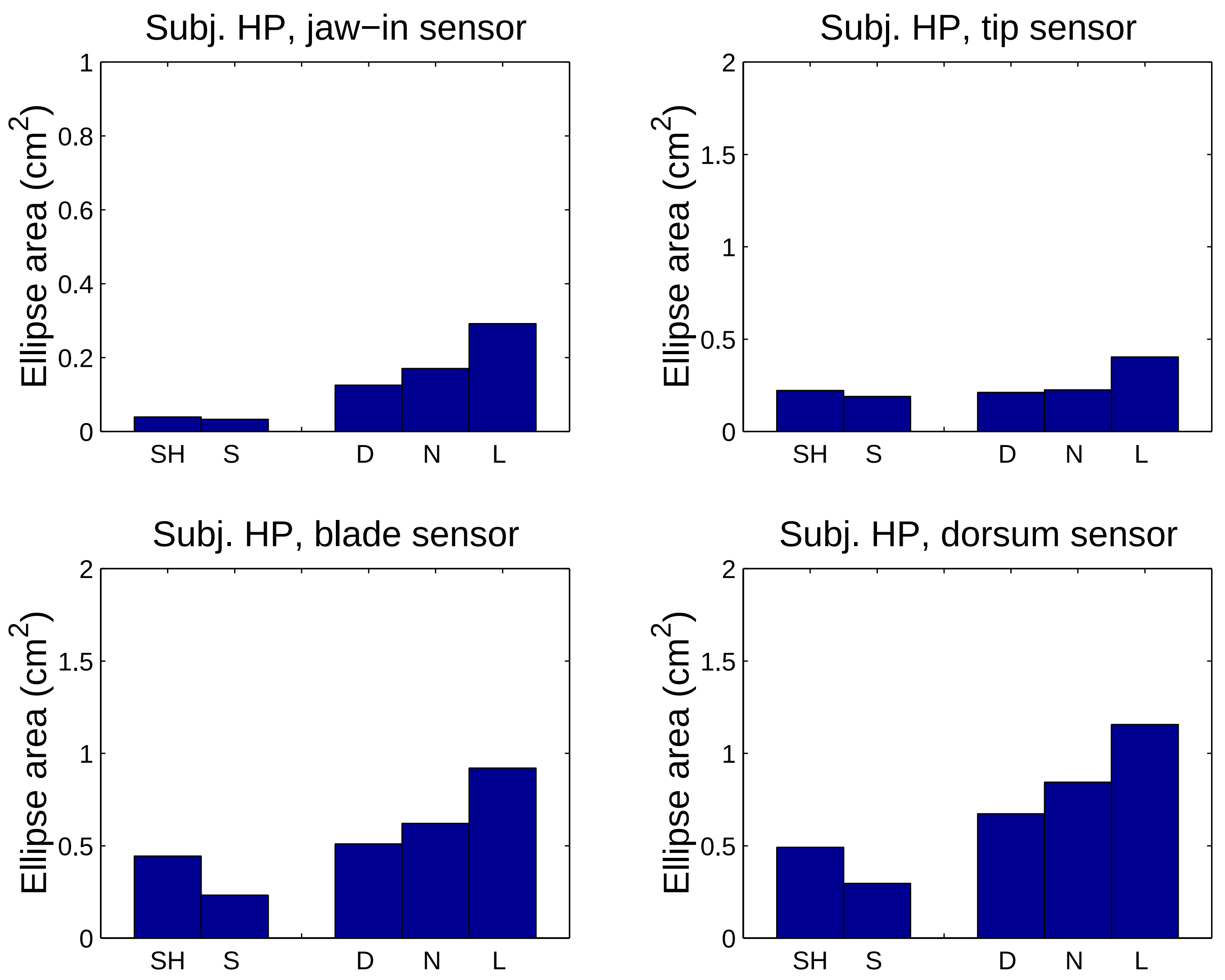
The following five figures summarize for each subject the total variability of the target consonants over the vowel-context and volume conditions, i.e the area of the 2-sigma ellipses shown in the scatterplots above.

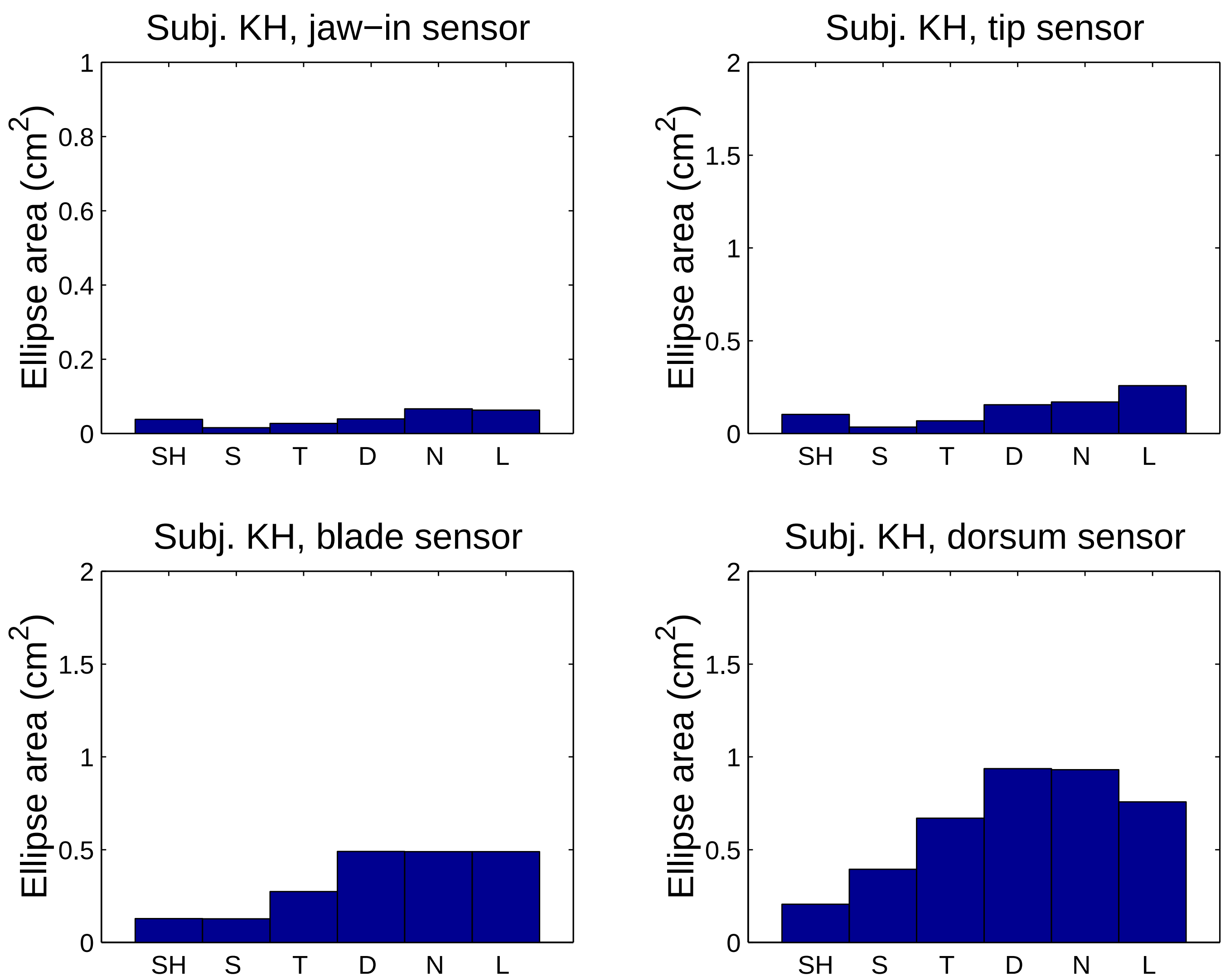
Data are shown for one of the jaw sensors, and three of the tongue sensors.

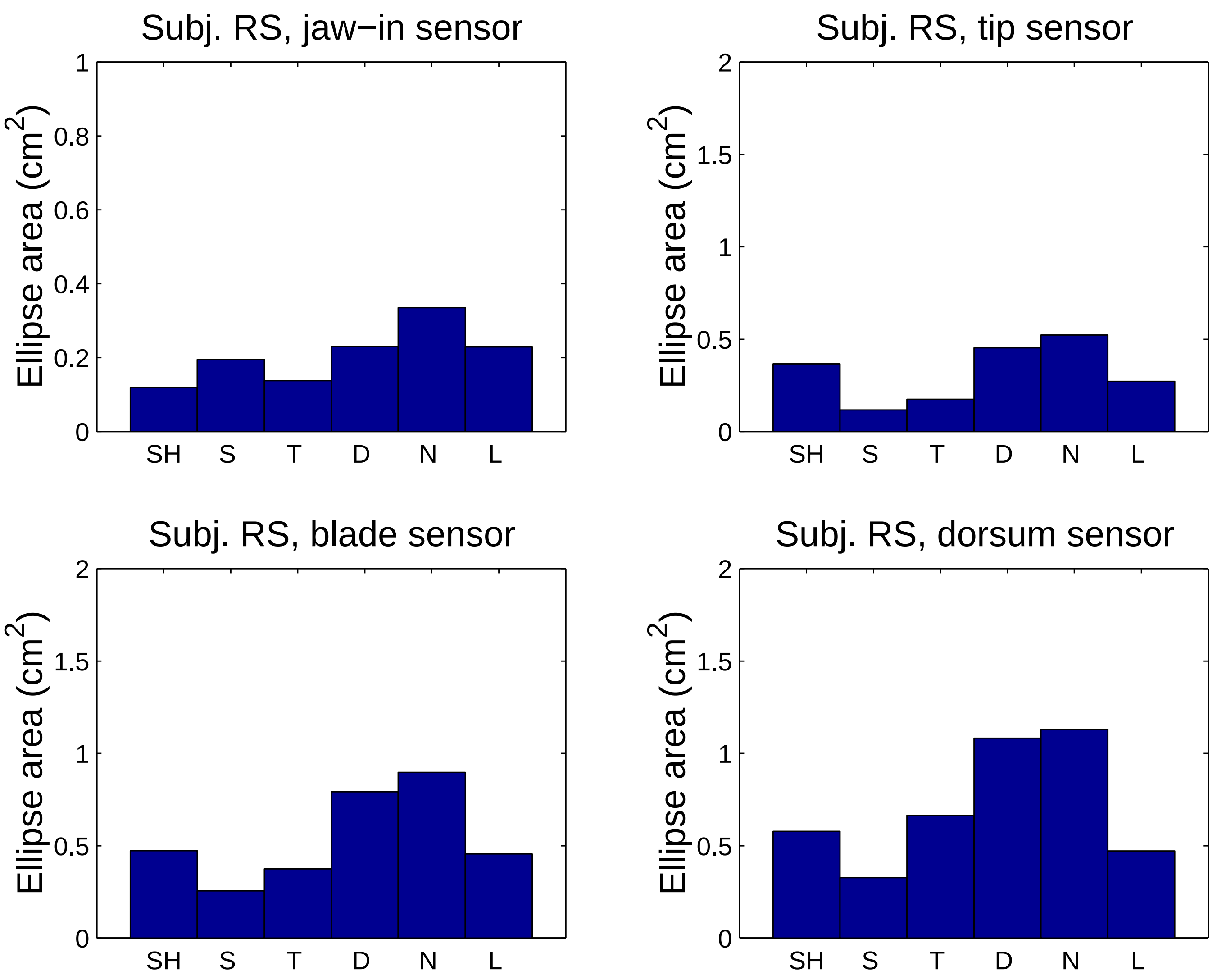
Notes:
Subject HP: corpus did not include the consonant /t/.
Subject SR: tongue-blade sensor failed during the experiment



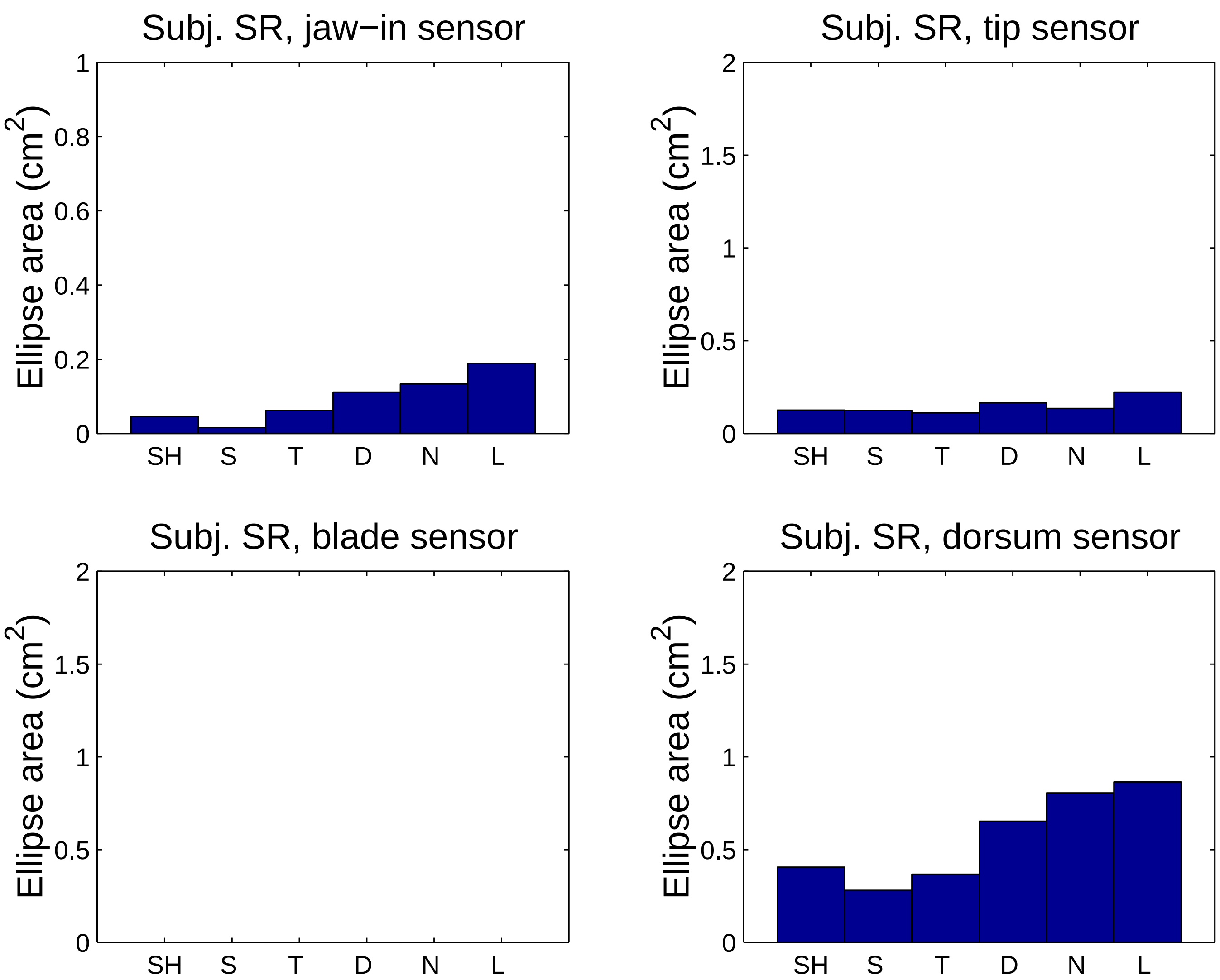
Subj. AW, jaw−in sensor
Subj. AW, tip sensor
Subj. AW, blade sensor
Subj. AW, dorsum sensor
Ellipse area (cm2)
SH
S
T
D
N
L


Subj. HP, jaw−in sensor
Subj. HP, tip sensor
Subj. HP, blade sensor
Subj. HP, dorsum sensor
Ellipse area (cm2)
SH
S
D
N
L
0
0.2
0.4
0.6
0.8
1
0.5
1.5
2


Subj. KH, jaw−in sensor
Subj. KH, tip sensor
Subj. KH, blade sensor
Subj. KH, dorsum sensor
Ellipse area (cm2)
SH S T D N L
0 0.2 0.4 0.6 0.8 1
0 0.5 1 1.5 2



Subj. RS, jaw−in sensor
Subj. RS, tip sensor
Subj. RS, blade sensor
Subj. RS, dorsum sensor
Ellipse area (cm2)
0
0.2
0.4
0.6
0.8
1
0.5
1.5
2
SH
S
T
D
N
L



Subj. SR, jaw−in sensor
Subj. SR, tip sensor
Subj. SR, blade sensor
Subj. SR, dorsum sensor
Ellipse area (cm2)
0
0.2
0.4
0.6
0.8
1
0.5
1.5
2
SH
S
T
D
N
L

The next figure shows for all consonant and all subjects the strength of the correlation between jaw and intrinsic tongue-tip height.

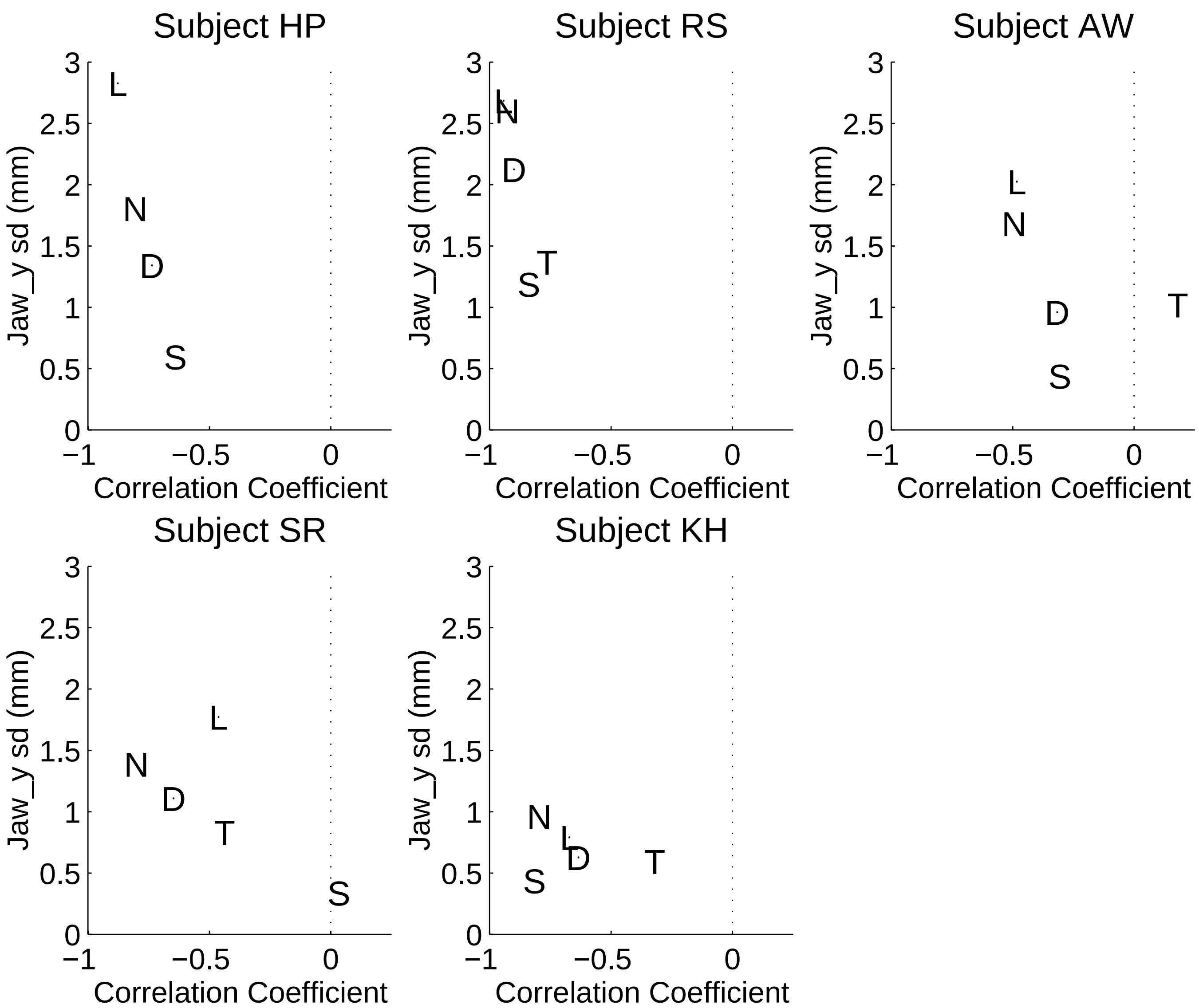
The correlation coefficients are shown on the x-axis.
The standard deviation of jaw height is shown on the y-axis.

There are two reasons for showing the correlations in relation to jaw-height variability:

1. A strongly negative correlation coefficient (i.e complementary covariation) is of little functional relevance if jaw variability is low.

2. If jaw variability is low there is an increased danger of spuriously high correlation coefficients due to noise in the data.

====> The most robust cases of complementary covariation are those where high correlation coefficients co-occur with high jaw variability, i.e the top left region in each panel.


Subject HP
Subject RS
Subject AW
Subject SR
Subject KH
Jaw_y sd (mm)
Correlation Coefficient
L
N
D
S
T
3
2.5
2
1.5
1
0.5
0
−1
−0.5
0

Summary

- Sibilant fricatives (perhaps also /t/) need the teeth obstacle. This constrains the jaw so strongly that little tongue-jaw covariation is possible.

- /l/ and /n/ are overall very variable, but nonetheless use covariation to constrain variation at the tongue-tip.

Outlook

- Does more natural material exhibit more covariation or less covariation

- Do speakers show precisely those patterns of variability that are consistent with maintaining the acoustic and perceptual integrity of the sounds?

- Improve the estimate of the intrinsic tongue contribution by better decomposition of jaw into translational and rotational components