How measures of gestural overlap relate to dynamics: Evidence from German and English word-initial stop-lateral clusters

Shihao Du, Stephan Kuberski, Adamantios I. Gafos

SFB 1287, University of Potsdam

Introduction

Background

- Studies on inter-segmental coordination have amassed substantial evidence for the cross-linguistic patterning of consonant clusters ([1]-[23], [25]-[27]);
- The approach in the literature hitherto: document patterns of overlap between segments and study the dependence of various overlap measures on the segmental composition of the cluster;
- Little to no consensus on what overlap measures to use;
- When different measures are used, why some show dependence on the conditioning factors and others do not.

Current work

- Use EMA data from German and English stop-lateral clusters to study the dependence of 4 overlap measures on the stiffness of C1 opening and C2 closing movement (two relevant movements in the C1-to-C2 transition);
- The role of the latter has been studied by Roon et al. [23] and Du & Gafos [10] but that of the first remains unexplored so far. Yet, it is intuitively clear that this parameter should play some role in modulating overlap in C1C2 clusters: C1 opening stiffness controls temporal properties of the C1 opening movement which is co-extensive with the transition between C1 and C2, and thus any measure concerning their overlap.

Data & Measurements

Data

- Electromagnetic articulography (EMA) data from 3 adult German native speakers and 3 adult American English native speakers were analyzed;
- The data were collected using the Carstens AG501 at the authors' institution;
- Sensors were attached to tongue dorsum, tongue blade, tongue tip and the two lips;
- The corpus was comprised of German and English word-initial stop-lateral clusters in which C1 was /p, k/ and C2 was /l/:
  - German: *Plage, Klage*
  - English: *plight, played, pledge, plead, climb, clip, clean*
- German (/English) participants produced ten (/eight) repetitions of each stimulus in a carrier phrase;

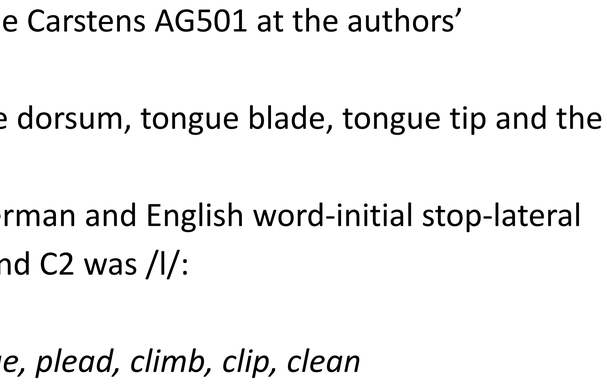
Measurements

- /p/ measured with the lip sensors, /k/ with the tongue dorsum sensor, /l/ with the tongue tip sensor;
- Gestural landmarks in the C1C2 clusters were identified using the Matlab-based software Mview developed at Haskins Laboratories by Mark Tiede;
- C1 opening and C2 closing stiffness:

$$stiffness = \frac{Peak\ velocity}{Amplitude}$$

- Overlap measures:

	Interval
1	C1 release to C2 onset
2	C1 release to C2 target (IPI)
3	C1 offset to C2 onset
4	C1 offset to C2 target

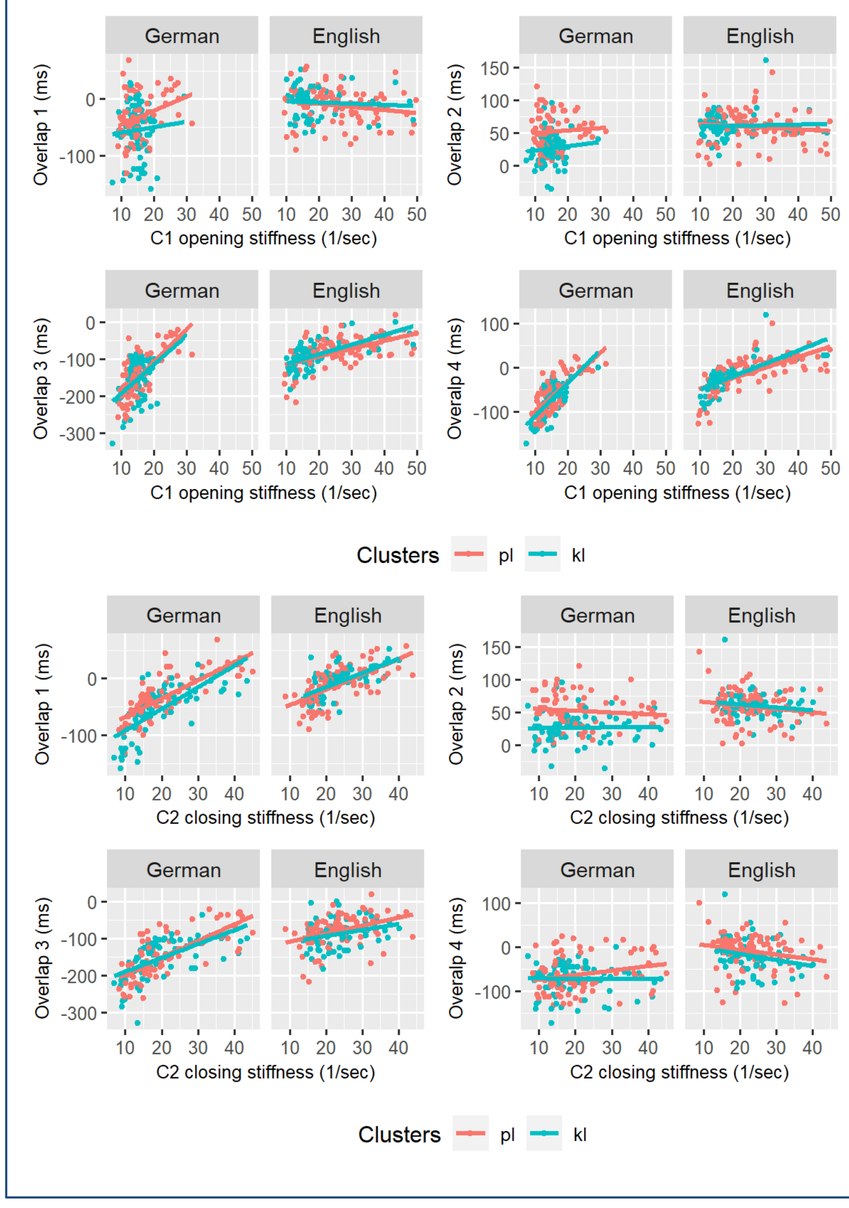


Statistical Models

```
Overlap = C1 opening stiffness × C2 closing stiffness × cluster × language
```

Results

Relations between C1 opening stiffness / C2 closing stiffness and the overlap measures

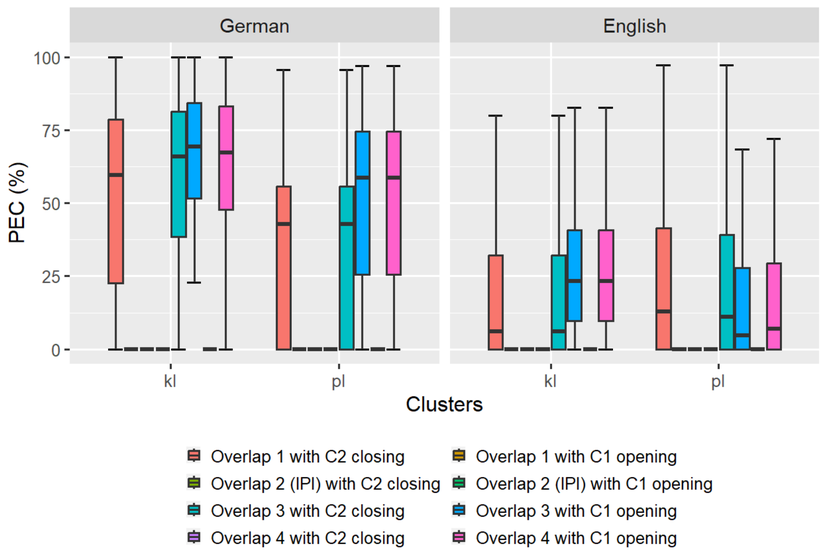


- The main effect of C1 opening stiffness was significant on overlap 3 ($p < 0.001$, F-value = 39.12) and overlap 4 ($p < 0.001$, F-value = 53.42), but not on overlap 1 ($p = 0.81$, F-value = 0.06) and overlap 2 ($p = 0.36$, F-value = 0.84);
- The main effect of C2 closing stiffness was significant on overlap 1 ($p < 0.0001$, F-value = 39.35) and overlap 3 ($p < 0.001$, F-value = 38.12), but not on overlap 2 ($p = 0.44$, F-value = 0.61) and overlap 4 ($p = 0.12$, F-value = 2.42);
- Overall, overlap 1 and 4 are modulated by C2 closing and C1 opening stiffness respectively, overlap 3 is modulated by both stiffnesses, and overlap 2 (IPI) is not modulated by either C1 opening or C2 closing stiffness.

Discussion

Explanation 1

- Stiffness controls the durational properties of a movement (reciprocal of time);
- The more coextensive (co-temporaneous) the movement controlled by the stiffness parameter with the overlap measure in question, the stronger the relation between the two;
- Different overlap measures are coextensive to different degrees with the two relevant movements, thus leading to different relations between them.



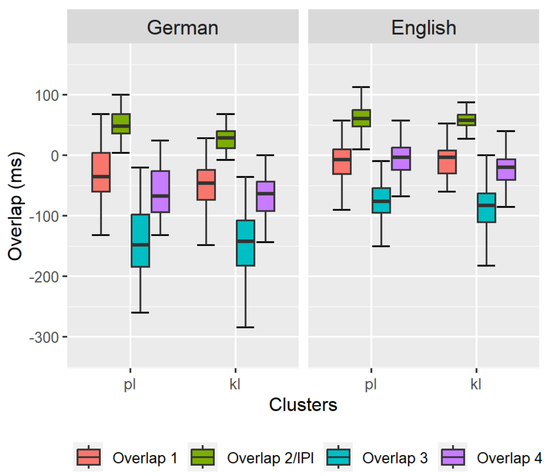
Percentage of exclusive coextensiveness (PEC)

- a property of a pair of an overlap measure (overlap 1, 2, 3, 4) and a movement (C1 opening, C2 closing);
- the proportion of that movement that coextends the interval delineated by the overlap measure.

Explanation 2

- IPI is a relatively short interval; its variability is limited to such an extent that assessing the relation of its duration and the value of any of the two stiffness parameters becomes infeasible.

Overlap measure	SD (across languages)	SD (German)	SD (English)
1	41.211	44.616	29.353
2 (IPI)	**27.096**	**27.463**	**22.586**
3	59.471	57.900	39.657
4	47.283	39.808	38.643



References

[1] Bombien, L., & Hoole, P. 2013. Articulatory overlap as a function of voicing in French and German consonant clusters. The Journal of the Acoustical Society of America, 134(1), 539–550. doi: 10.1121/1.4807510
[2] Brunner, J., Geng, C., Sotiropoulou, S., & Gafos, A. 2014. Timing of German onset and word boundary clusters. Laboratory Phonology, 5(4). doi: 10.1515/lp-2014-0014
[3] Byrd, D. 1994. Articulatory timing in English consonant sequences [PhD dissertation]. UCLA.
[4] Byrd, D. 1996. Influences on articulatory timing in consonant sequences. Journal of Phonetics 24: 209–244. doi: 10.1006/jpho.1996.0012
[5] Byrd, D., & Saltzman, E.L. 1998. Intragestural dynamics of multiple prosodic boundaries. Journal of Phonetics 26, 173–199. doi:10.1006/jpho.1998.0071.
[6] Byrd, D., & Choi, S. 2010. At the juncture of prosody, phonology, and phonetics – the interaction of phrasal and syllable structure in shaping the timing of consonant gestures. In C. Fougeron, B. Kühnert, M. D'Imperio, & N. Vallée (Eds.), Phonology and Phonetics [PP]. De Gruyter Mouton. doi: 10.1515/9783110224917.1.31
[7] Chitoran, I., Goldstein, L., & Byrd, D. 2002. Gestural overlap and recoverability: Articulatory evidence from Georgian. In C. Gussenhoven, T. Rietveld, & N. Warner (Eds.), Laboratory Phonology VII (pp. 419–447). Mouton de Gruyter.
[8] Cho, T., Lee, Y., & Kim, S. 2014. Prosodic strengthening on the /s/-stop cluster and the phonetic implementation of an allophonic rule in English. Journal of Phonetics, 46, 128–146. doi: 10.1016/j.wocn.2014.06.003
[9] Cho, T. 2016. Prosodic boundary strengthening in the phonetics-prosody interface: Prosodic boundary strengthening. Language and Linguistics Compass, 10(3), 120–141. doi: 10.1111/lnc3.12178
[10] Du, S., & Gafos, A. I. 2023. Articulatory overlap as a function of stiffness in German, English and Spanish word-initial stop-lateral clusters. Laboratory Phonology.
[11] Gafos, A. I., Hoole, P., Roon, K., & Zeroual, C. 2010. Variation in overlap and phonological grammar in Moroccan Arabic clusters. In C. Fougeron, B. Kühnert, M. D'Imperio, & Nathalie Vallée (Eds.), Laboratory Phonology 10 (pp. 657–698). De Gruyter Mouton. doi: 10.1515/9783110224917.5.657
[12] Gibson, M., Sotiropoulou, S., Tobin, S., & Gafos, A. I. 2019. Temporal aspects of word initial single consonants and consonants in clusters in Spanish. Phonetica, 76(6), 448–478. doi: 10.1159/000501508
[13] Hardcastle, W. 1985. Some phonetic and syntactic constraints on lingual coarticulation during /kl/ sequences. Speech Communication 4: 247–263.
[14] Hermes, A., Mücke, D., & Auris, B. 2017. The variability of syllable patterns in Tashlhiyt Berber and Polish. Journal of Phonetics, 64, 127–144. doi: 10.1016/j.wocn.2017.05.004
[15] Hoole, P., Bombien, L., Kühnert, B., & Mooshammer, C. 2009. Intrinsic and prosodic effects on articulatory coordination in initial consonant clusters. In G. Fant, H. Fujisaki, & J. Shen (Eds.), Frontiers in phonetics and speech science (pp. 275–286). The Commercial Press.
[16] Lialiou, M., Sotiropoulou, S., & Gafos, A. I. 2021. Spatiotemporal coordination in word-medial stop-lateral and s-stop clusters of American English. Phonetica, 78(5-6), 385-433. doi: 10.1515/phon-2021-2010
[17] Marin, S., & Pouplier, M. 2010. Temporal organization of complex onsets and codas in American English: Testing the predictions of a gestural coupling model. Motor Control, 14(3), 380–407. doi: 10.1123/mcj.14.3.380
[18] Marin, S. 2013. The temporal organization of complex onsets and codas in Romanian: A gestural approach. Journal of Phonetics, 41(3–4), 211–227. doi: 10.1016/j.wocn.2013.02.001
[19] Mücke, D., Hermes, A., & Tilsen, S. 2020. Incongruencies between phonological theory and phonetic measurement. Phonology, 37(1), 133–170. doi: 10.1017/S095267572000068
[20] Pastätter, M., & Pouplier, M. 2013. Temporal coordination of sibilants in Polish onset clusters. The Journal of the Acoustical Society of America, 134(5), 4201–4201. doi: 10.1121/1.4831417
[21] Pouplier, M. 2020. Articulatory phonology. In M. Pouplier, Oxford Research Encyclopedia of Linguistics. Oxford University Press. doi: 10.1093/acrefore/9780199384655.013.745
[22] Pouplier, M., Pastätter, M., Hoole, P., Marin, S., Chitoran, I., Lentz, T. O., & Kochetov, A. 2022. Language and cluster-specific effects in the timing of onset consonant sequences in seven languages. Journal of Phonetics, 93, 101153. doi: 10.1016/j.wocn.2022.101153
[23] Roon, K. D., Hoole, P., Zeroual, C., Du, S., & Gafos, A. I. 2021. Stiffness and articulatory overlap in Moroccan Arabic consonant clusters. Laboratory Phonology, 12(1), 8. doi: 10.5334/labphon.272
[24] Bates, D. et al. (2022). lme4: Linear Mixed-Effects Models using 'Eigen' and S4. R package version 1.1-31. url: https://CRAN.R-project.org/package=lme4.
[25] Shaw, J., Gafos, A. I., Hoole, P., & Zeroual, C. 2009. Syllabification in Moroccan Arabic: Evidence from patterns of temporal stability in articulation. Phonology, 26(1), 187–215. doi: 10.1017/S0952675709001754
[26] Sotiropoulou, S., Gibson, M., & Gafos, A. 2020. Global organization in Spanish onsets. Journal of Phonetics, 82, 100995. doi: 10.1016/j.wocn.2020.100995
[27] Yanagawa, M. 2006. Articulatory Timing in first and second language: A cross-linguistic study. [PhD Dissertation]. Yale University.