

The Impact of Executive Functions on Auditory-Motor Adaptation of Speech Across Age

Meike J. Meertens¹, Katharina M. Polsterer^{1,2,3}, Stefanie Keulen⁴, Martijn B. Wieling^{1,2,4}, Defne Abur^{1,2}

¹*Center for Language and Cognition, University of Groningen, The Netherlands*

²*Research School of Behavioral and Cognitive Neurosciences, University of Groningen, The Netherlands*

³*Acoustics Research Institute, Austrian Academy of Sciences, Vienna, Austria*

⁴*Brussels Centre for Language Studies, Vrije Universiteit Brussel, Brussels, Belgium*

Speech production changes as we age, with articulation rates becoming slower and articulatory movements becoming more variable [1]. These changes may be due to alterations in the underlying motor control for speech. Because effective speech relies on precise motor commands, disruptions or variability in motor control make it necessary for the system to alter movements in response to sensory feedback, as can be explained by speech motor control models such as Directions Into Velocities of Articulators (DIVA [2]). Auditory-motor adaptation allows the updating of motor commands in response to altered auditory feedback, such as compensating for formant shifts. This process may be influenced by aging as a result of changes in cortical processing of auditory feedback [3]. Because speech adaptation relies on frontal and prefrontal cortical areas that also support executive functions (EF), individual differences in (subdomains of) EF [4] may affect how effectively speech motor commands are updated [5]. Although EF become less differentiated and more domain-general with age [6], it is unclear if and how EF influence speech motor adaptation across age. Therefore, the purpose of this cross-sectional study is to investigate whether auditory-motor adaptation may partially be influenced by EF, and whether this relationship differs between younger and older adults.

In our study, participants completed an auditory-motor adaptation task, and three EF tasks. Our sample included 30 younger adults (YA; 15F/15M; 19–34 years) and, at present, 10 older adults (OA; 7F/3M; 58–80 years). Participants' hearing was screened and no moderate/severe hearing loss at frequencies ≤ 1 kHz or severe hearing loss > 1 kHz was detected. The presented results are preliminary, as data from the OA group are still being collected to match the YA group in number and sex. During the auditory-motor adaptation task, participants read one-syllable Dutch words (onset and coda were single plosives, nucleus: / ϵ /, e.g., /dek/), and were asked to prolong the vowel for about one second. The task consisted of a baseline phase (20 trials with unaltered auditory feedback), a hold phase (40 trials with a +30% shift of the first formant, F_1), and an after-effect phase (40 trials with unaltered feedback). The F_1 change was measured by calculating the F_1 across the hold phase trials relative to the individual's mean F_1 across all trials in the baseline phase (Figure 1). Lower F_1 changes (more negative) indicate greater adaptation, thus compensating for the direction of the altered feedback. Following the Unity and Diversity framework [4], executive functions were assessed using a Flanker task (inhibition), an n-back task (updating), and a Wisconsin Card Sorting Task (shifting). Inhibition was measured using the inverse efficiency score (IES, reaction time relative to accuracy), updating as n-back cost (RT increase from 0-back to 2-back), and shifting as the percentage of perseverative errors (Figure 2).

Through a linear regression analysis with age group and EF tasks as independent variables, and F_1 change per participant as dependent variable, we found a significant interaction ($p = .049$, $\beta = 21.342$) between age group and updating (i.e. n-back) performance on F_1 change. Figure 3 visualizes this interaction and shows that the amount of adaptation depends on updating performance (i.e. less adaptation associated with lower updating performance) for OA, but not for YA. Scores for the other two EF tasks did not predict F_1 adaptation scores*. These results suggest that a poorer updating efficiency (i.e. higher n-back cost) in older adults was related to reduced capacity to adapt speech motor commands in response to altered auditory feedback. Updating may play a greater role in auditory-motor adaptation in older adults, whereas in younger adults, variability in updating efficiency does not appear to limit adaptation.

*: At the conference, a complete analysis using mixed-effects regression and a larger OA sample will be presented.

References

- [1] Fougerson, C., Guitard-Ivent, F., & Delvaux, V. (2021). Multi-dimensional variation in adult speech as a function of age. *Languages*, 6(4), 176. <https://doi.org/10.3390/languages6040176>
- [2] Tourville, J. A., & Guenther, F. H. (2011). The DIVA model: A neural theory of speech acquisition and production. *Language and Cognitive Processes*, 26(7), 952–981. <https://doi-org.proxy-ub.rug.nl/10.1080/01690960903498424>
- [3] Li, J., Hu, H., Chen, N., Jones, J. A., Wu, D., Liu, P., & Liu, H. (2018). Aging and sex influence cortical auditory-motor integration for speech control. *Frontiers in Neuroscience*, 12, 749. <https://doi.org/10.3389/fnins.2018.00749>
- [4] Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: A latent variable analysis. *Cognitive Psychology*, 41(1), 49–100. <https://doi.org/10.1006/cogp.1999.0734>
- [5] Ranasinghe, K. G., Gill, J. S., Kothare, H., Beagle, A. J., Mizuiri, D., Honma, S. M., Gorno-Tempini, M. L., Miller, B. L., Vossel, K. A., Nagarajan, S. S., & Houde, J. F. (2017). Abnormal vocal behavior predicts executive and memory deficits in Alzheimer's disease. *Neurobiology of Aging*, 52, 71–80. <https://doi.org/10.1016/j.neurobiolaging.2016.12.020>
- [6] Glisky, E. L., Alexander, G. E., Hou, M., Kawa, K., Woolverton, C. B., Zigman, E. K., Nguyen, L. A., Haws, K., Figueredo, A. J., & Ryan, L. (2020). Differences between young and older adults in unity and diversity of executive functions. *Neuropsychology, Development, and Cognition. Section B, Aging, Neuropsychology and Cognition*, 27(6), 829–854. <https://doi.org/10.1080/13825585.2020.1830936>

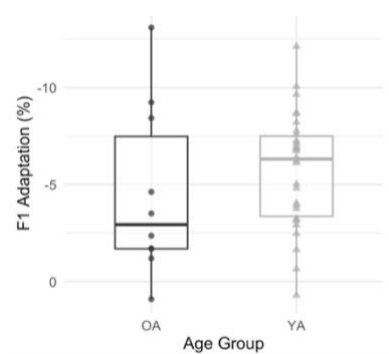


Fig. 1. F_1 change by age group

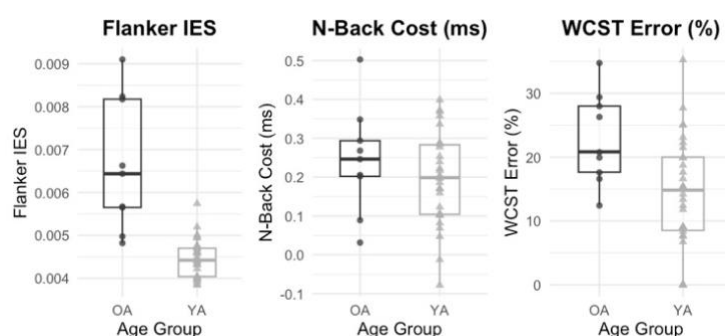


Fig. 2. Scores on executive function tasks by age group

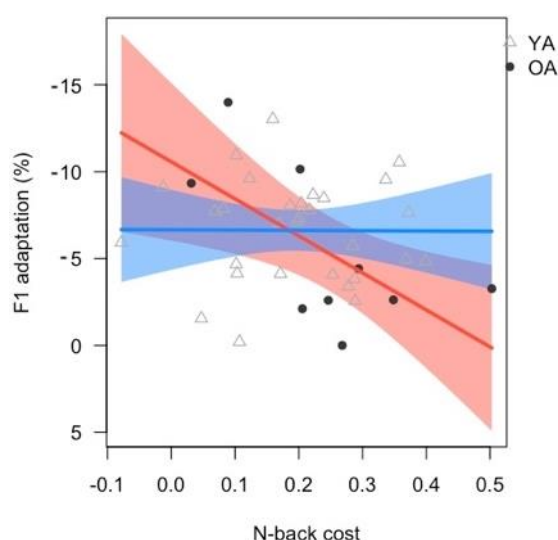


Fig. 3. Model predicting F_1 change by n-back cost and age group