Comparing the Impact of Hearing Aid Algorithms for Neural Auditory Learning

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1. Introduction

Non-linear frequency compression (NLFC) is an alternative sound processing strategy in hearing aids that aims to improve the audibility of high-frequency sounds. NLFC transfers speech-relevant acoustic information from the high frequency spectrum (> 5 kHz), typically lost in individuals with hearing loss, to the lower frequency range [1,2]. So far, little is known about the neural effects of such signal-processing strategies in older adults with hearing loss [3].

In the present study we investigated behavioral and neural differences between normal hearing older adults and older adults using hearing aids with or without activated NLFC during auditory learning. In a longitudinal EEG setting (4x at an interval of two weeks and 1x FU), we set out to examine the dynamic interplay of bottom-up and top-down processes during an auditory oddball paradigm.

2. Methods

Participants:

1) Moderately hearing impaired fitted with hearing aid with activated NLFC, 64-77 years, N=13 → *NLFC*
2) Moderately hearing impaired fitted with hearing aid without NLFC, 61-77 years, N=13 → *no NLFC*
3) Normal hearing old, 60-75 years, N=13 → *NHO*

Design:

At five measurement time points M1 (NLFC off), M2, M3, and M4 at an interval of two weeks and at M5 (follow-up: 6 weeks after M4) an active oddball task was performed by all study participants while EEG was recorded (see **Fig.1**). EEG data was processed with a microstate approach.

Stimulus Material:

The stimuli comprised of logatomes consisting of natural fricatives /sh/ and /s/ embedded between two /a/ sounds as well as two morphed transitions of the logatomes. The logatome /ascha/ was used as the standard, while /asa/ and the transitions were used as deviants, varying in the degree of acoustic deviation (difficulty levels: easy, moderate and difficult) from the standard.

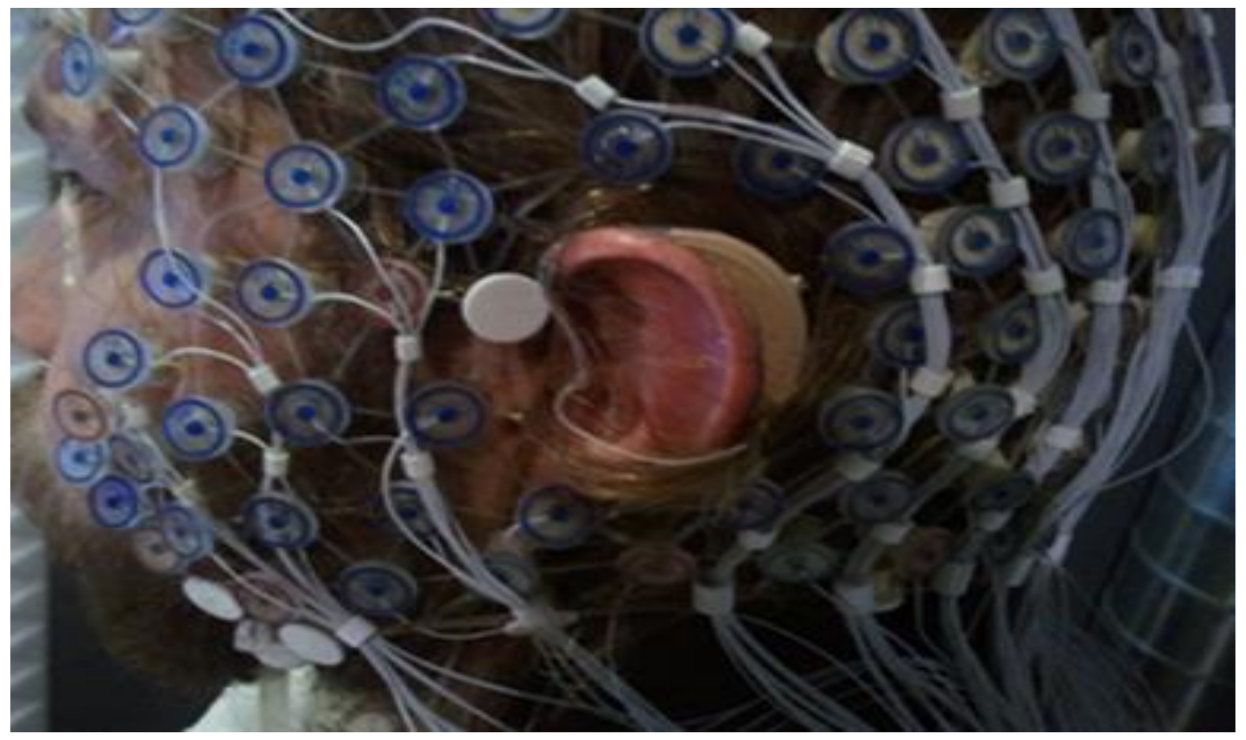

Fig.1: EEG Geodesic system and hearing aid user

3. Results: ERP microstates

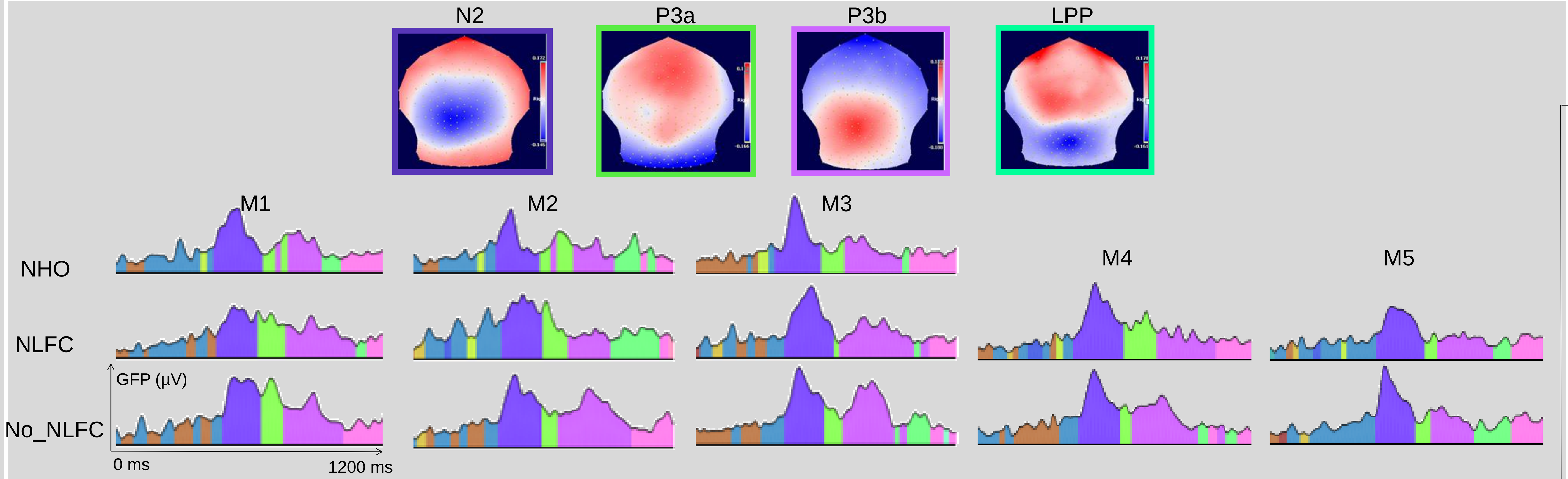

Fig 2: ERP-Microstate maps and respective time course from 0-1200ms after stimulus onset are depicted separately for each group and measurement time point. In each plot, the time course of the difference wave only of the easy deviant minus the standard is plotted. The ERP analysis was computed using the Cartool toolbox [4] by using a microstate approach: The topographical data was clustered on grand-average level and then fitted back to the individual data. There were no significant group differences at baseline M1, for the easy condition during which NLFC was switched off in all groups.

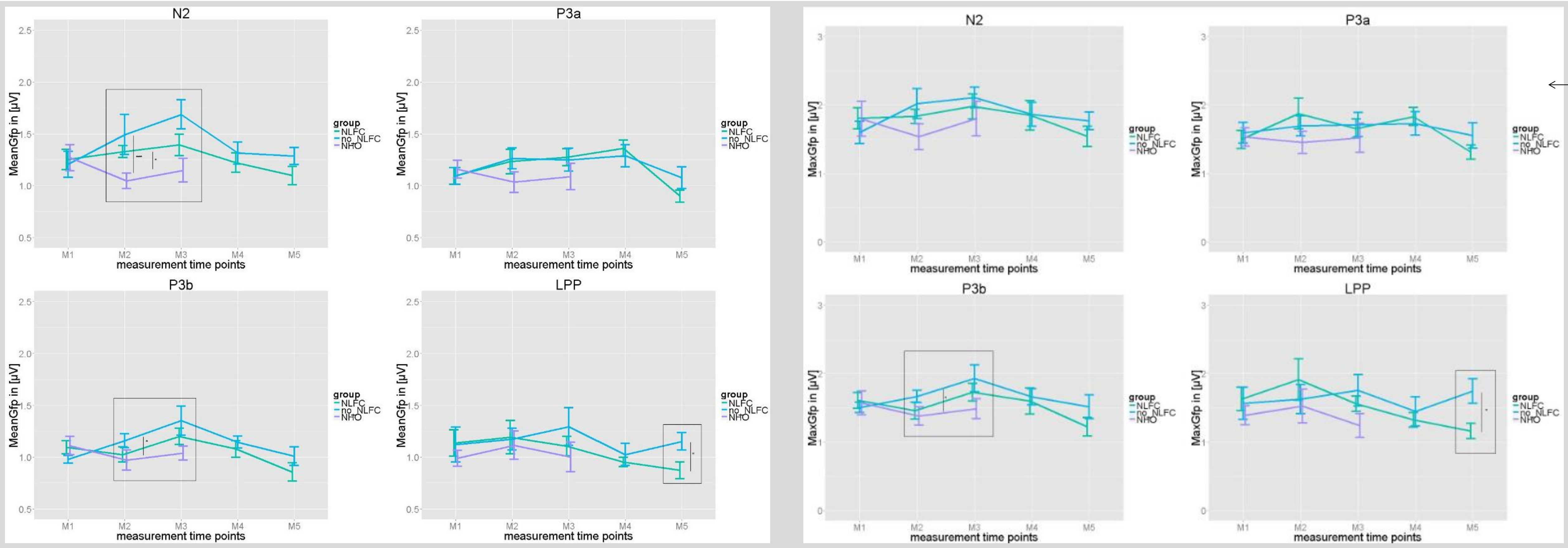

Fig 3: Mean GFP, max. GFP, duration, and time of max. GFP of each microstate were statistically compared between groups and time points.

RQ1: Does using NLFC for two weeks change the neural processing of speech? No, there was no sign. difference (p>0.05) between NLFC and no_NLFC at M2 for all microstates (t-test, two-sided).

RQ2: Does using NLFC change the neural processing of speech after a longer time interval? There were only significant differences between the groups at M5 in the LPP (t-tests at each M, two-sided).

RQ3: Is there a difference in the trajectory of speech (auditory learning) across four weeks between NLFC, no_NLFC and NHO? rANOVA with time (M2, M3) and group (3) . Main effect time revealed decrease of P3b duration and decrease of time of max. GFP of LPP. All main effects group are depicted in the graphs. There were no sig. interactions between time*group.

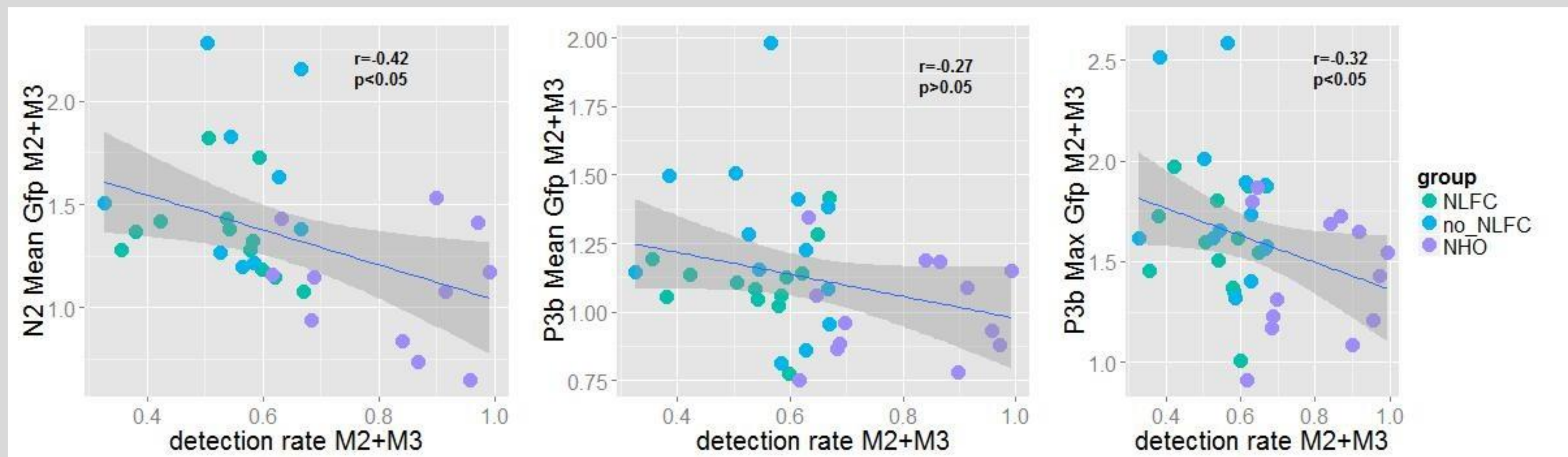

Fig 4: Correlations between microstates and behavioral detection rate averaged across easy, moderate and difficult condition. Both, microstate parameters and detection rate were averaged across time point 2 and 3.

4. Results: Deviant Detection

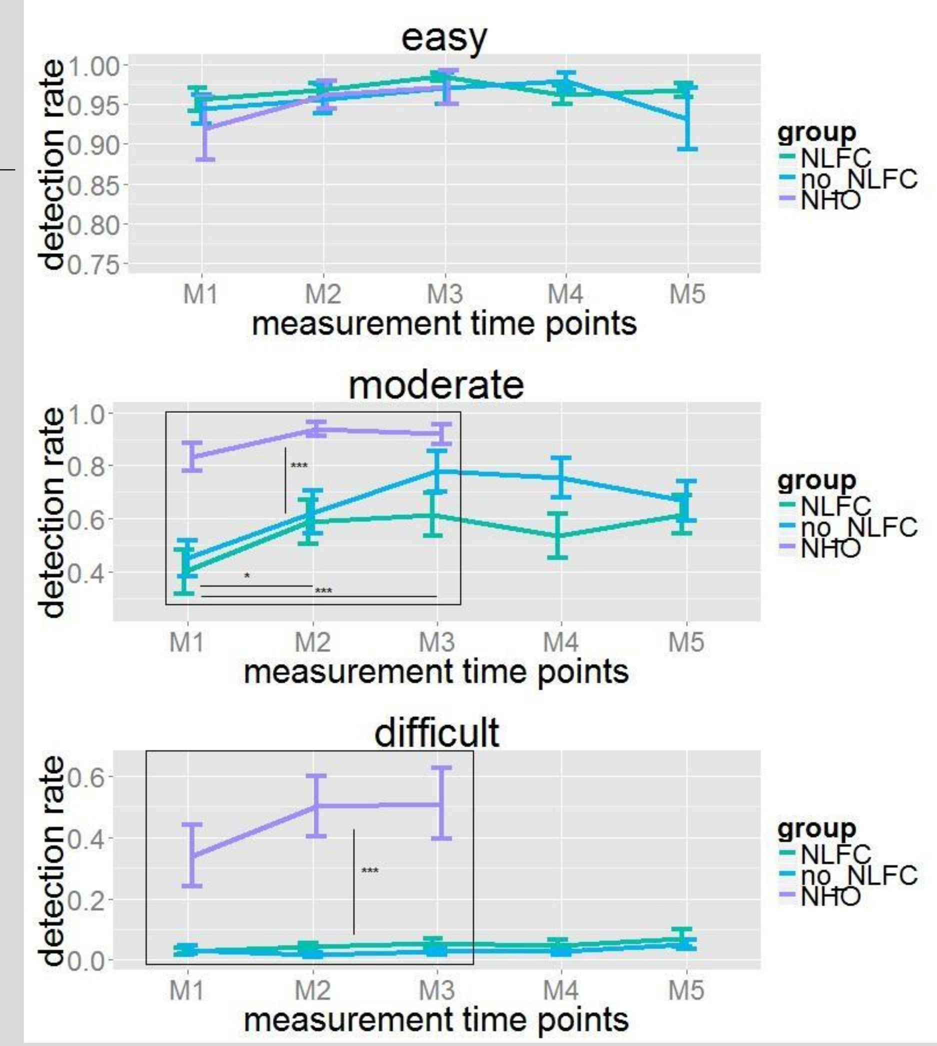

Fig 5: Behavioral detection rate of deviant stimulus asa and morphing steps depicted across time and for groups individually. NLFC and no_ NLFC were compared for each M with a two-sided t-test, while a rANOVA with time (M1, M2, M3) for all three groups was calculated.

5. Conclusion

- On a behavioral level, the NHO perrformed better than the hearing impaired groups, although they were aided. There were no sign. differences between the two hearing impaired groups.
- Using NLFC for two weeks does not change the neural processing of fricatives. NLFC did change the neural speech processing though, but only after 12 weeks of using it!
- The hearing aid algorithm NLFC influenced mainly top-down related listening effort (as reflected by the LPP [5]). NLFC influenced these processes positively: Since the behavioral performance was equal between the two groups, it can be inferred that NLFC needed less cells and therefore less neural effort to process the stimuli and to get to the same performance level.
- Auditory learning occured only at a top-down level (not bottom-up). Memory updating and later cognitive processes were performed shorter across time. This findings are similar to what we found in younger normal hearing adults [6].
- The amount of cells that were recruited for the bottom-up and top-down processes differed between groups (no_NLFC > NLFC > NHO), despite the same performance level for all groups. It can be inferred that NHO showed higher neural efficiency for fricative processing than NLFC users, while NLFC users showed higher neural efficiency than no_NLFC users. NLFC users are therefore closer to normal hearing adults than no_NLFC user in terms of neural efficiency.
- Since there are no time * groups interactions, it can be concluded that the longitudinal trajectories do not differ between groups.

References

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