Inter-individual differences in spectrotemporal modulation processing despite similar audiograms: Could they be used to assess supra-threshold hearing distortions?

Emmanuel Ponsot[1,2] **Peter Neri**[2]

[1] Hearing Technology @ WAVES, Department of Information Technology, Ghent University, Technologiepark 126, 9052 Zwijnaarde, Belgium
[2] Laboratoire des systèmes perceptifs, Département d'études cognitives, École normale supérieure PSL University CNRS 75005 Paris, France
ponsot.manu@gmail.com

ABSTRACT

The large heterogeneity observed among individuals with similar audiograms for understanding speech-in-noise poses an important challenge for current auditory sciences. In this talk, we will discuss the extent to which spectrotemporal modulation signals may be exploited to develop a better account of supra-threshold hearing capacities. We will present a novel integrated experimental-computational framework that was developed to assess spectrotemporal modulation processing characteristics in each individual. We will discuss recent psychophysical and modeling results obtained from normal-hearing and hearing-impaired individuals within this framework. Overall, this approach should pave the way for new research avenues to further determine the respective contribution of peripheral and central auditory mechanisms towards inter-individual differences in speech-in-noise intelligibility.

1. INTRODUCTION

The large heterogeneity observed among individuals with similar audiograms for understanding speech-in-noise (SPiN) poses an important challenge for current auditory sciences, and highlights the fact that audiometric profiles only provide a limited account of hearing problems as they manifest in daily life [1]. It is hypothesized that supra-threshold auditory distortions, i.e. related to processes above detection threshold and which are not accounted for by pure-tone audiometry, play a prominent role in these inter-individual differences. However, a precise view of where and how distortions arise along the auditory processing hierarchy is lacking. To address this issue, it is critical to develop a psychophysical characterization of hearing capacities based on supra-threshold signals [2]. In this talk, we will discuss the extent to which spectrotemporal modulation signals can overcome this challenge, and become a tool to study inter-individual differences in SPiN intelligibility.

2. METHODS

Spectrotemporal modulations (STM) – noise carriers whose envelope is jointly modulated in time and frequency as a tractable and parameterized model of speech formants – offer a unified mathematical framework to probe supra-threshold auditory processes as they are recruited with speech signals [3]. We developed a methodological framework based on psychophysical reverse-correlation [4] deployed in the modulation space to characterize the mechanisms engaged by listeners to detect or discriminate STM signals embedded in noise. This framework was used to characterize the perceptual filters of young normal-hearing (NH) and older hearing-impaired (HI) individuals. The richness of the perceptual filters returned by these measurements was exploited using two types of modeling tools. We first adopted a system identification approach to assess the overall structure of the processing cascade and identify potential nonlinearities. This identification allowed us to constrain the decision device of a biologically inspired auditory model, namely the (temporal) modulation-filterbank model [5], which we subsequently used to infer the origins of the differences observed between individual perceptual filters.

3. RESULTS

These analyses show that the modulation-filterbank model with normal cochlear tuning accounts well for the average pattern of the NH group, and that a two-to-threefold broadening of cochlear tuning accounts for the average pattern of the HI group. This result is consistent with the theoretical view that broadening of cochlear filters is the primary deficit associated with sensorineural hearing loss [6]. However, our analyses also demonstrate idiosyncratic behaviors in both groups that could not be captured by cochlear tuning alone, highlighting the need to consider variability

originating from additional mechanisms, which will be discussed. This result supports previous studies suggesting that the ability of HI listeners to detect STMs patterns in noise reflects supra-threshold processes beyond the cochlear level [7]. Interestingly, it also suggests that individual differences in STM masking thresholds reported among young NH individuals – which had remained unaccounted for so far – would similarly reflect supra-threshold processing differences [8].

4. CONCLUSION

Altogether, the present results show that STM signals are well suited for psychophysical characterization of supra-threshold hearing processes, for individuals that present clinically normal as well as impaired audiograms. The integrated experimental-computational approach we developed offers a principled way to determine the origins of the distortions in each individual, and could thus be used to further investigate inter-individual differences in SPiN intelligibility that cannot be explained by audibility alone.

5. REFERENCES

[1] Ruggles, D., Bharadwaj, H., & Shinn-Cunningham, B. G. (2011). Normal hearing is not enough to guarantee robust encoding of suprathreshold features important in everyday communication. Proceedings of the National Academy of Sciences, 108(37), 15516-15521.

[2] Lesica, N. A. (2018). Why do hearing aids fail to restore normal auditory perception?. Trends in neurosciences, 41(4), 174-185.

[3] Elliott, T. M., & Theunissen, F. E. (2009). The modulation transfer function for speech intelligibility. PLoS computational biology, 5(3), e1000302.

[4] Murray, R. F. (2011). Classification images: A review. Journal of vision, 11(5), 2-2.

[5] Dau, T., Kollmeier, B., & Kohlrausch, A. (1997). Modeling auditory processing of amplitude modulation. I. Detection and masking with narrow-band carriers. The Journal of the Acoustical Society of America, 102(5), 2892-2905.

[6] Moore, B. C. (2007). Cochlear hearing loss: physiological, psychological and technical issues. John Wiley & Sons.

[7] Bernstein, J. G., Danielsson, H., Hällgren, M., Stenfelt, S., Rönnberg, J., & Lunner, T. (2016). Spectrotemporal modulation sensitivity as a predictor of speech-reception performance in noise with hearing aids. Trends in hearing, 20, 2331216516670387.

[8] Oetjen, A., & Verhey, J. L. (2015). Spectro-temporal modulation masking patterns reveal frequency selectivity. The Journal of the Acoustical Society of America, 137(2), 714-723.