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Sleep deprivation impacts speech spectro-temporal modulations

E. Thoret^a, T. Andrillon^b, C. Gauriau^c, D. Leger^c and D. Pressnitzer^a

^aLaboratoire des systèmes perceptifs, Département d'études cognitives, École normale supérieure, PSL University, CNRS, 75005 Paris, France

^bUniv Paris Descartes, Sorbonne Paris Cité, APHP, Hôtel Dieu, Centre du Sommeil et de la Vigilance & EA 7330 VIFASOM, Turner Institute for Brain Mental Health School of Psychological, Sciences Monash University, Melbourne, Australia

^cUniv Paris Descartes, Sorbonne Paris Cité, APHP, Hôtel Dieu, Centre du Sommeil et de la Vigilance & EA 7330 VIFASOM, 75006 Paris, France
etiennethoret@gmail.com

Lack of sleep drastically affects many aspects of human behavior. The early detection of sleepiness is thus a major challenge for health and security reasons. Here, we investigated the effect of sleep deprivation on the acoustic properties of human speech. Twenty-four participants were sleep deprived for two days (two successive nights with only 3 hours of sleep). They were recorded reading a short text aloud before and after sleep deprivation. An auditory model, based on spectro-temporal modulations, was used to analyse the acoustic properties of their speech and served as a front-end to machine-learning classifiers. Results showed that sleepiness could be accurately detected with individually-trained classifiers. However, we were not able to fit a generic classifier for all participants. As we relied on an auditory-inspired model, we could identify and interpret the acoustic features impacted by sleep deprivation. Again, no simple diagnostic feature could be easily identified in the group-level analyses of the speech signals. We therefore developed a novel probing method, combining signal detection theory and noise activation of the classifier, to understand what made the classifier successful for each participant. This led to a diagnostic map for each participant, specifying which frequency region and modulation rates were impacted by sleep deprivation for this particular individual. In addition to suggesting a practical machine learning algorithm to detect sleep deprivation, combining our probing method with considerations about voice production could help uncover the physiological impact of sleep deprivation at the level of each individual.

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