

Introduction

Although it is commonly assumed that humans and apes have lost their ability to re-orient their ears when focusing attention on external sounds, some weak, ineffectual auricular muscle activation may remain [1]. In two consecutive studies, we investigated whether these vestigial auricular muscle activity contain traces of the direction of auditory attention. We assessed exogenous attention towards transient novel sounds presented randomly from four lateral speakers and endogenous attention in a dichotic-listening paradigm with two competing short stories.

Methods

auricular electromyograms (aEMG) signals

- Bipolar surface aEMGs were recorded with Ag/Cl electrodes at the following left & right muscles (Fig. 1): auricularis posterior (PAM), superior (SAM), anterior (AAM), transversus auriculæ (TAM) and sternocleidomastoideus.
- aEMG sampling: 9.6 kHz; bandpass: 10-1000 Hz; reference: forehead

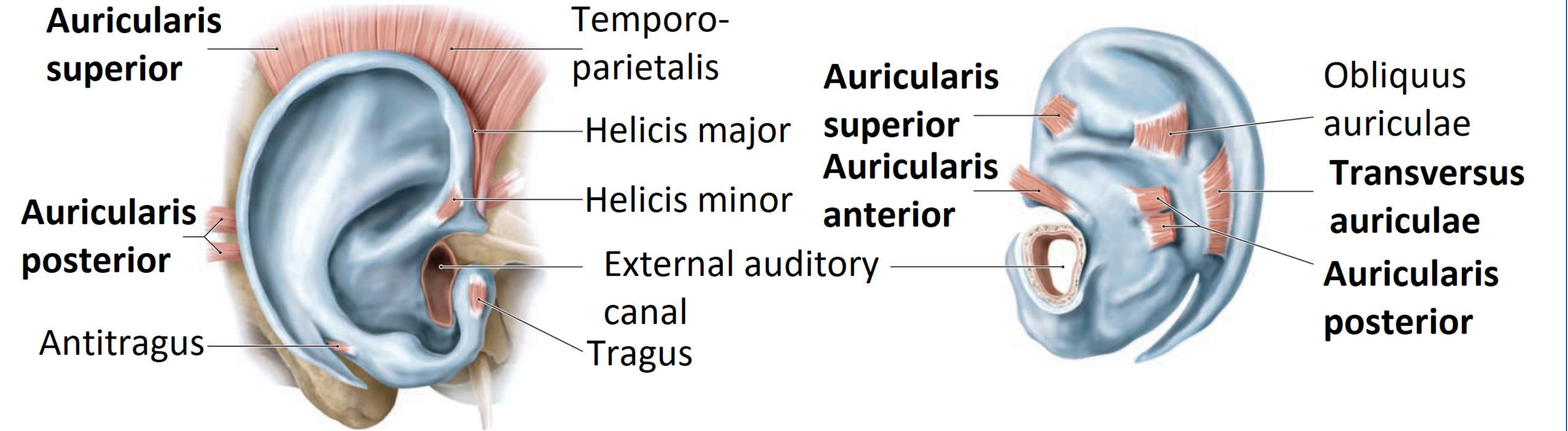


Figure 1. Auricular muscles. Activity recorded from muscles in bold (adapted from [2])

Participants

- 28 normal hearing subjects
- Younger Group: N = 12, M = 62.7 ± 5.9 years; PTA < 20 dB
- Older Group: N = 16, M = 24.1 ± 3.1 years; PTA < 40 dB

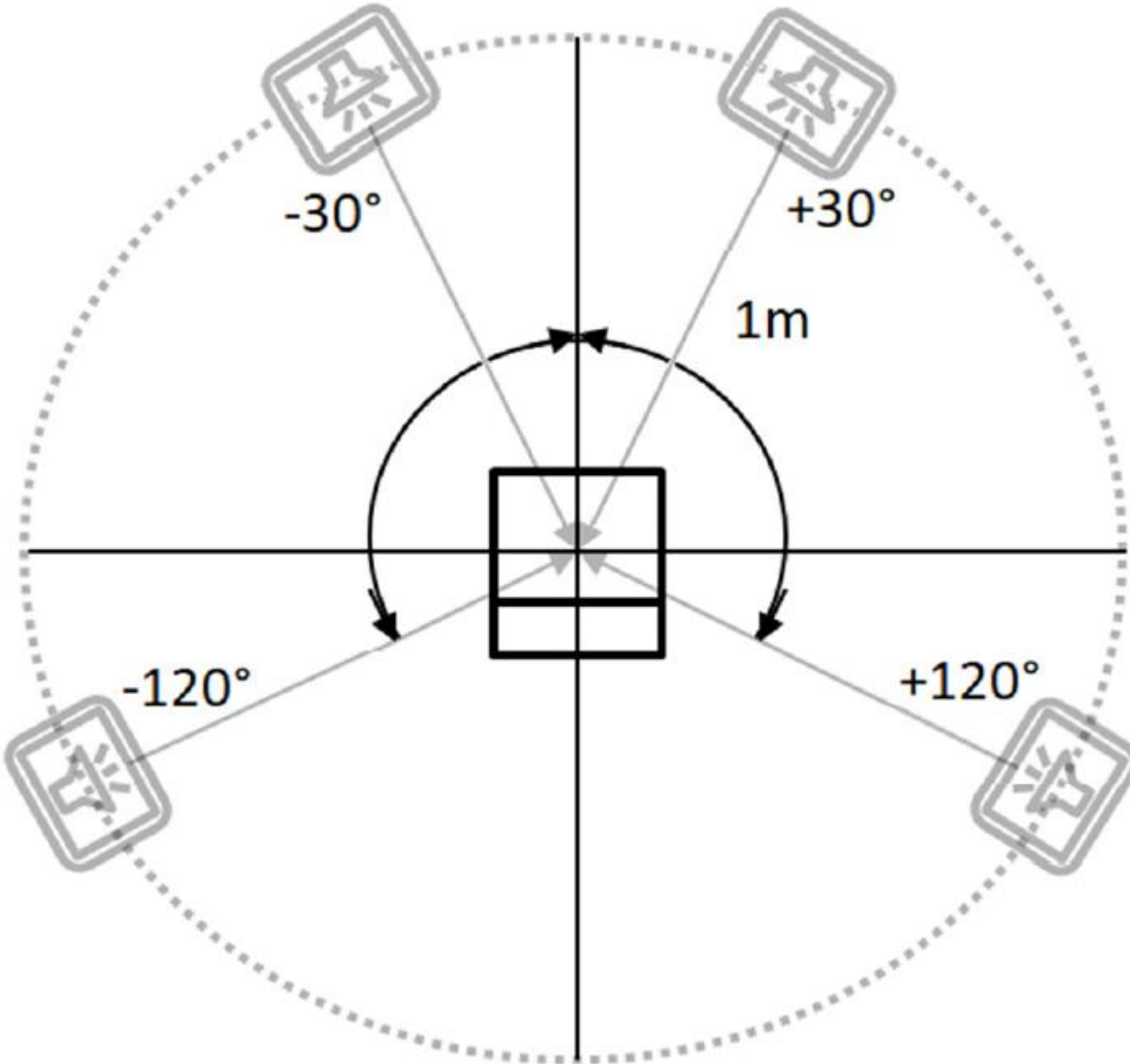


Figure 2. Loudspeaker setup during both experiments. Subjects faced 0° on a chinrest.

- #### 1) Exogenous Attention (= “automatic”, stimulus-driven)
- participants placed their head on a chinrest facing 0°
 - task: “read the story in front of you”
 - 9 different novel sounds, e.g., dog barking, baby crying, foot steps..., presented randomly from four different speakers @65-70 dB LC_{peak}
 - interstimulus interval between 10 and 40 seconds
- #### 2) Endogenous Attention (= “voluntary”, goal-directed, intended)
- two competing short stories presented from either ± 30° or ±120°
 - duration: 5 min
 - average intensity of 50 dB La for younger and 60 dB La for older group
 - task: “listen to your favorite story”

Results: Exogenous Attention

- interaction between the factors ipsi/contra and anterior/posterior for PAM, AAM, and TAM yields $F(1; 26) = 40.4, 14.9, \text{ and } 23.6$, respectively; $ps < 0.002$
- there were no interactions involving age group
- larger amplitudes for ipsilateral presented stimuli for PAM, AAM, and TAM [$F(1; 26) = 47.44, 17.01, \text{ and } 47.53$, resp.; $ps < 0.001$] but not for SAM
- larger aEMG to sounds emanating from the back speakers for PAM, AAM, and TAM [$F(1; 26) = 32.1, 12.0, \text{ and } 19.9$, respectively; $ps < 0.003$]
- no changes in electrooculographic (EOG) and sternocleidomastoideus EMG recordings → aEMG are no artifacts of head / eye-movement

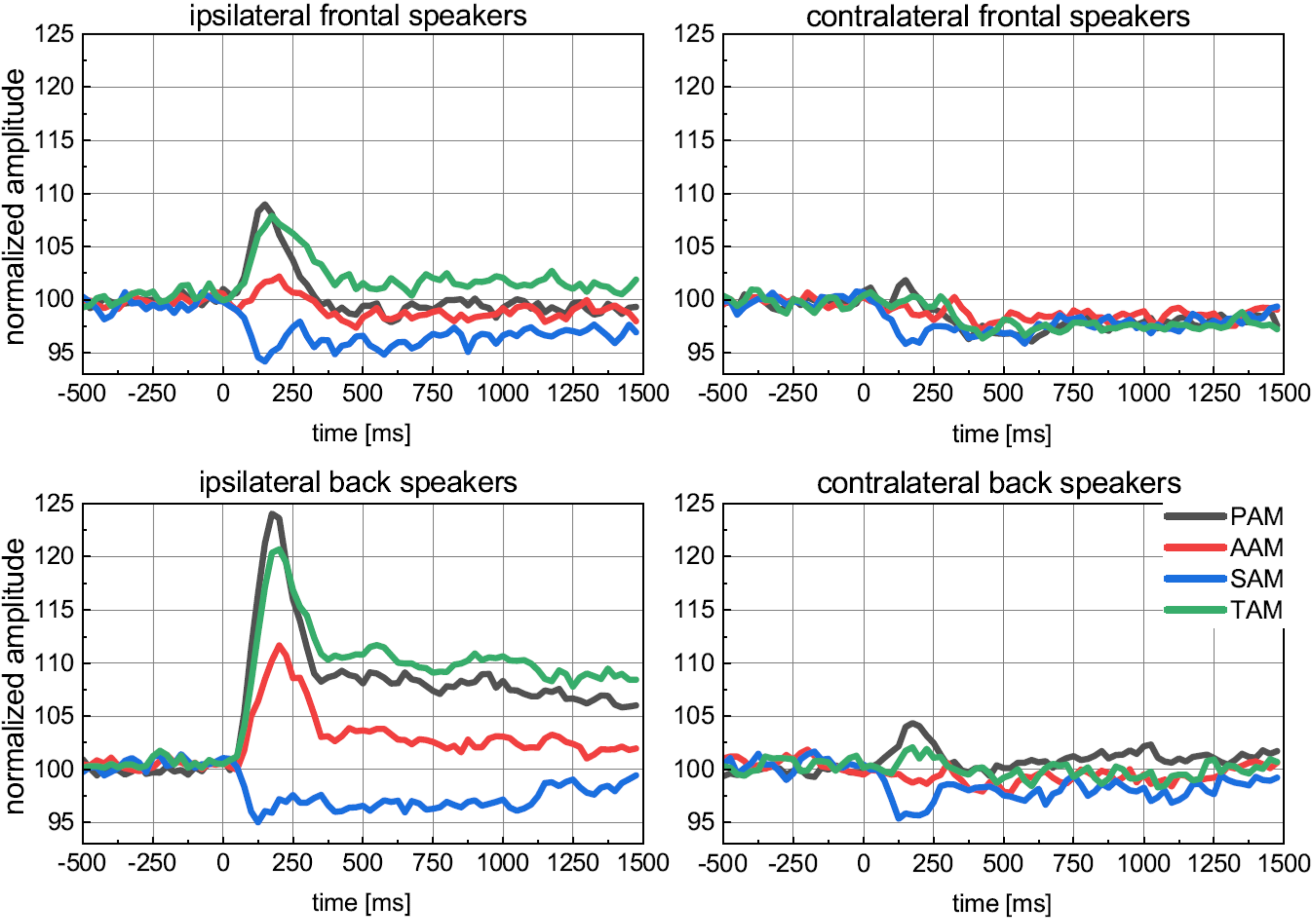


Figure 3. Grand average of the baseline corrected and normalized event-related aEMGs at the four auricular muscles for the recording ipsilateral and contralateral to the stimulation;

Results: Endogenous Attention

- aEMG at PAM or AAM was largest on the side to which attention was focused [Fig. 4 top; $F(1, 19) = 15.2 \text{ and } 4.6$, respectively; $p = 0.001 \text{ and } 0.04$]
- larger mean EMG energy at SAM for ipsilateral ear [$F(1,19) = 16.3$; $p = 0.001$]
- no difference for TAM [not shown here]
- aEMG energy is clearly sustained across the 5 min sessions [Fig 4, bottom]
- activation of all four muscles was slightly enhanced when participants listened to one of the two speakers at ±120°
- no interaction with age or other factors

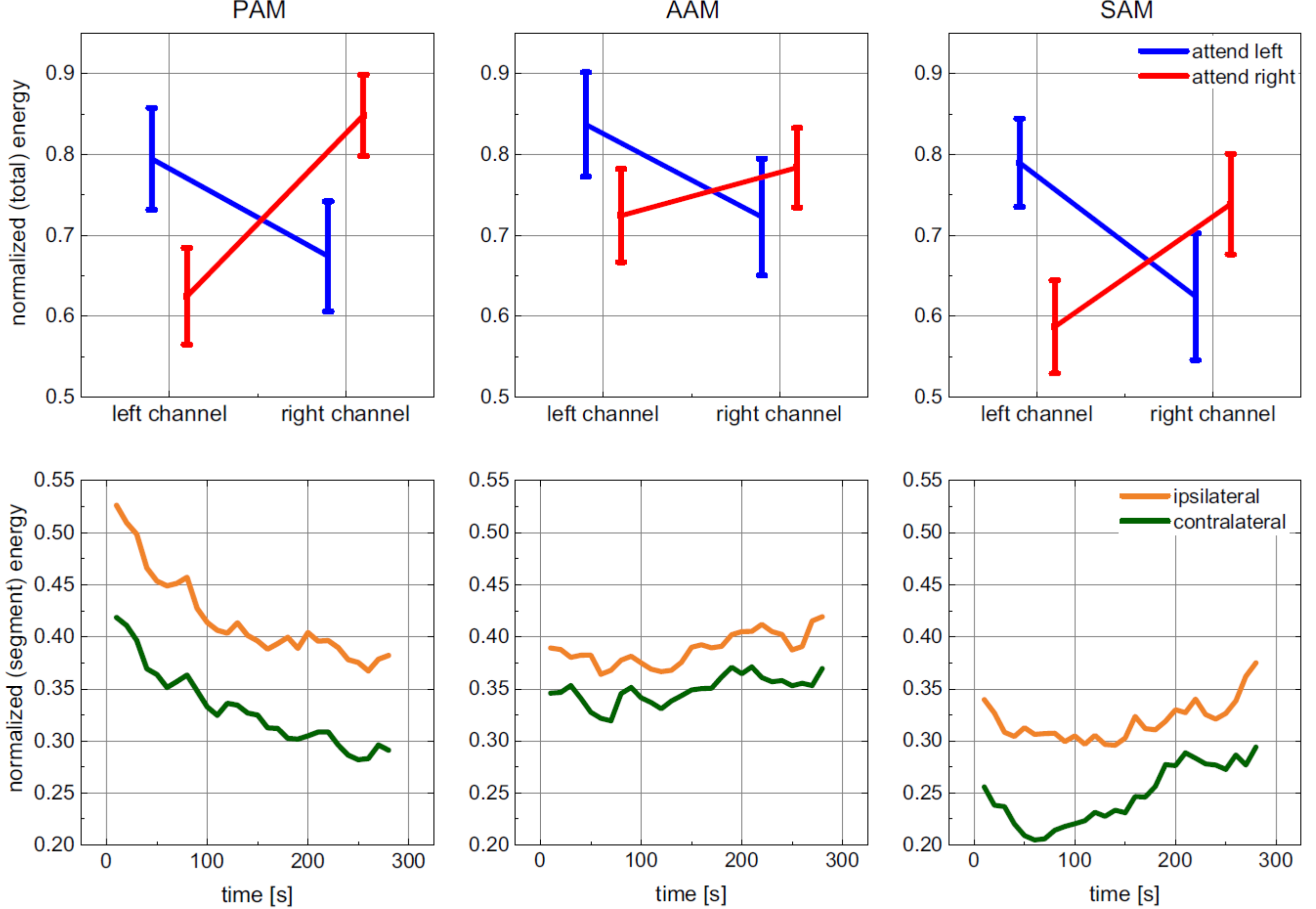


Figure 4. Grand average of the normalized aEMG for the PAM, AM, and SAM activity
Top: normalized (total) energy of the left/right recording channels during attention to the left or right story (bars represent the standard error) for stories played from speakers ±120
Bottom: 1sec-time-averaged aEMG after pooling the ipsi- and contralateral signals

Conclusions

- humans feature a vestigial pinna-orienting system during both exogenous and endogenous modes of attention accessible by surface aEMG [3]
- differential activity patterns allow for differentiation between both modes of attention: whereas TAM was indicative for stimulus-driven attention, SAM showed differential patterns for goal-directed attention

References:

[1] Hackley, S. A. Evidence for a vestigial pinna-orienting system in humans. Psychophysiology 52, 1263-1270 (2015).

[2] M. Schuenke, THIEME Atlas of Anatomy – Head and Neuroanatomy. Stuttgart: Georg Thieme Verlag, 2010, p. 141

[3] Strauss, D. et al. Vestigial Auriculomotor Activity Indicates the Direction of Auditory Attention in Humans, submitted