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Frequency specific objective AEP-based assessment of hearing perception in noise.

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Slide 1 (Title and authors):

Good morning, thank you very much. I'm Angel de la Torre and I'm presenting this contrinbution in the name of this research team.

Slide 2 (Motivation):

This contribution has two main motivations:

- On one hand, we want to share advanced tools for AEP recording, including the power line interference reduction and a flexible AEP recording system; the simultaneous recording of early and late response; and the multi-response deconvolution.
- On the other hand, we want to apply these tools to a new experiment, including stimulation with tone bursts of different levels, with ABR and MLR responses, under noise conditions, in order to study the effect of the noise over the evoked responses and age related differences.

So, we want to apply these new tools to study the hearing perception in noise.

Slide 3 (Overview of the presentation):

In this talk I will describe the recording procedure and these advanced tools. Then I will describe the stimulation pattern. Finally I will present the experiments and the results.

Slide 4 (Tools for AEP recording: PLI reduction):

First tool: we have designed a very efficient procedure for power line interference reduction. One important problem of this interference is its frequency drift, causing an expansion and shift of the harmonics (see the detail of the harmonics). Based on phase deconvolution of one harmonic, we cancel the frequency drift (see the detail of the harmonics after the frequency drift compensation) and then the reduction of the PLI becomes really easy. (The method is described in a patent currently under evaluation). Here we can see an electrocardiogram signal contaminated with PLI, its spectrum with a lot of harmonics, and here the same electrocardiogram after the PLI reduction (clean signal and no harmonics in the spectrum).

Slide 5 (Tools for AEP recording: PLI reduction):

And here we can compare, in the left side, the electrocardiogram contaminated (top), after applying a notch comb filter without frequency drift cancellation (center), and with the proposed frequency drift cancellation (bottom). And in the right side, a series of evoked responses obtained from a contaminated EEG (top), after notch comb filtering without frequency drift cancellation (center) and with frequency drift cancellation (bottom).

Slide 6 (AEP recording system):

This slide shows the AEP recording system. Thanks to the PLI reduction procedure, it is even simpler than the version we presented at IERASG-2023 (two years ago). A modular, low cost and flexible AEP recording system with all the hardware components commercially available in a music store.

Slide 7 (ABR+MLR responses: Latency Dependent Filtering):

We simultaneously obtain auditory brainstem responses and middle latency responses thanks to the Latency Dependent Filtering, and the deconvolution performed in the associated reduced subspace.

Slide 8 (Multi-response deconvolution):

And finally, we simultaneously obtain the response to several categories of stimuli (in this example independent responses for each stimulation level) by applying our procedure for multi-response deconvolution.

We have designed our experiment making use of all these tools.

Slide 9 (Stimulation pattern 1: clean):

The experimental design described in this contribution includes 3 scenarios.

In the first one, 2kHz tone-bursts of different intensities between 10 and 60 dB NHL are used as stimuli. The stimulation sequence includes burst in blocks of around one second, progressively increasing the intensity, then decreasing, then increasing again, etc. Here we can see a portion of the stimulation signal, the spectrogram (with the tone burst centered at 2 kHz) and the power spectral density for a block for each level.

Slide 10 (Stimulation pattern 2: noisy - white noise):

In the second scenario, the stimulation pattern is similar, but white noise at 30 dB NHL is added, which masks the bursts of lower intensity.

Slide 11 (Stimulation pattern 3: noisy - filtered noise):

And in the third scenario, instead of white noise, we add filtered noise, using a notch filter with the stop-band around 2 kHz.

Slide 12 (Stimulation pattern: 3 conditions):

In this slide we can compare the spectrum of the stimulation pattern for these three scenarios.

Slide 13 (Experiments: description):

The experiments include 10 participants aged between 18 and 55 years. The recording took between 10 and 20 minutes for each condition and participant. The responses were estimated in a latency range between 0.2 and 200 ms. Responses are presented to describe ABR (latency represented in linear scale) and ABR+MLR (latency represented in logarithmic scale).

Slide 14, 15, 16 (Results: subject A, 54):

(Slide 14, clean conditions) In this slide we can see the responses (ABR on the left, ABR+MLR on the right), corresponding to one 54 years old participant, with tone bursts presented in clean conditions.

We can see the artifact in the first miliseconds, waves III and V of ABR, and waves Pa and Pb of MLR (no later responses are identifiable due to the configuration of the stimulation and filters). We can also see that responses are clearly identifiable at 20 dB, and possibly at 10 dB.

(Slide 15, white noise) These figures represent the responses when the stimuli are presented in the present of noise. The identification of responses is more difficult, and no response can be identified at low stimulation level, because of the masking effect of the noise.

(Slide 16, white noise filtered with stop-band filter) And finally, when the stimulation is contaminated with filtered noise, we obtain these responses. No response can be identified at low stimulation level, and some responses are easier to be identified (compared to the previous case).

Slide 17, 18, 19 (Results: subject I, 18):

(Slide 17, clean conditions) In the next slides, we present similar plots, but for an 18 years old participant.

Under clean conditions, we can see the artifact, ABR components, MLR components, with more evident responses at low intensity (compared with the previous participant).

(Slide 18, white noise) Under noisy conditions, at low stimulation level the tone-burst are masked by the noise and no response is observed (as with the previous participant).

(Slide 19, white noise filtered with stop-band filter) And here, the responses when the stimulation is contaminated with filtered noise.

Slide 20 (Subject A, 54, all conditions):

Comparisons among the three scenarios are difficult. So, we include this figures in order to see the effect of the noise (and the type of noise). In the case of the older participant, we can see an increase of the wave V latency associated to noise as well as a moderate reduction of the latency of Nb (negative peak between Pa and Pb waves). Of course, responses are identifiable at lower stimulation levels under clean conditions. Finally, it is interesting to observe that identification close to the threshold seems to be easier with MLR components than with ABR.

Slide 21 (Subject I, 18, all conditions):

In the case of the younger subject, we can also see the changes in latency of waves V and Nb, associated to noise. It is remarkable that the change in wave V latency is larger in the young subject (mostly due to a delay of the wave V in clean conditions in the older participant). Again, the identification of waves around the threshold is easier with MLR components than with ABR.

Slide 22 (Grand average, all conditions):

This slide shows a grand average comparison (10 participants) among the three conditions. Again, the noise changes the latency of waves V and Nb, and again, responses are identification of waves around the threshold is easier with MLR than with ABR.

Slide 23 (Age groups, all conditions):

This slide shows a comparison taking into account the variable age. We have considered 3 groups (younger than 25, between 25 and 35, and older than 35). Some differences are observed regarding the PAM component, larger for the noisy conditions in the young-group, while larger for the filtered noise in the old-group (however, the PAM is associated to particular individuals in these experiments). The main age-related differences observed in these groups are associated to the thresholds under clean conditions (increased for the old-group) and to the changes in the latency of wave V (larger change in the young group).

Slide 24 (Conclusions):

To summarize the presentation:

- The presence of noise causes changes in the amplitude and latency of some waves.
- Regarding to the changes related to age, there are differences in the thresholds (lower for the younger group), but no important differences in the changes related to noise. The most remarkable difference is the larger change of the wave V latency observed in the younger group.
- Even though these are interesting results, the filtered noise seems to be not appropriately designed for this experiment, because the results with this and the white noise are too similar.
- Therefore, the results would benefit from some optimization of the experimental design.
- It is remarkable the utility of the simultaneous analysis of early and late components of the evoked responses. In these experiments, the identification of the threshold was easier with Pa MLR component than with wave V of ABR.

- The responses are afected by PAM in some participants. The presence of the PAM component makes the interpretation of responses more difficult. The AEP analysis would benefit if some procedure for PAM reduction was available. In our opinion, the study of the PAM and the design of method for reducing its effect in AEP responses would be very useful.

Slide 25 (Acknowledgements and thanks):

The authors acknowledge the participation of the volunteers in the recording sessions. Here you can see the sources of support for this study, and our web and emails.

Thank you very much for your attention.