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UTN.BA UNIVERSIDAD TECNOLÓGICA NACIONAL FACULTAD REGIONAL BUENOS AIRES

Evaluation of the performance of permutation entropy variants for classifying auditory evoked potentials

W. Legnani, M. Baldiviezo, C. Bontempo, Y. Corsaro, J. Fernandez Biancardi, A., M. Hernando, Matías Rodriguez and Juan Barberia

Objective and Scope

The aim of the present work was to investigate the performance of entropic tools to classify, subjects with normal hearing and those with pathologies in the auditory pathway, using short-latency records of auditory evoked potentials **(AEP)**. To accomplish with this objective, traditional permutation entropy **(PE)** [1], weighted permutation entropy **(WPE)** [2] and a modified version of the original permutation entropy **(MPE)**, correcting the count of the missing or forbidden patterns was applied [3-5].

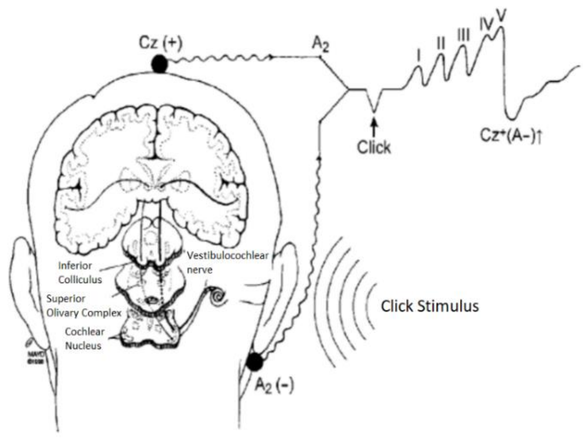

Figure 1: Location of the surface electrodes in the EAP studies. The roman numbers represent the characteristic peaks of the waves [1].

Advantages of the Permutation Entropy

- Low sensitive to noise.
- Does not require any assumptions about the statistical distribution of data in the signal.
- Provides information about causality in the signal.
- Their implementation is computationally efficient.

Data Acquisition and Computation of Permutation Entropies

Data and Methodology

- The database consisted of two age groups, one of minors aged from a few months to four years and the other of older aged over 18 years.
- 24 signals of minor patients, 12 normal and 12 pathological.
- 28 signals of older patients, 14 normal and 14 pathological.
- All patients were conscious.
- Stimuli called clicks between 70 and 90 dB of intensity
- The location of the electrodes are shown in Figure 1.
- The signals was not prefiltered to compute the entropies.
- The PE, WPE, and MPE were computed for every signal.
- The embedding dimension is set to 4 and the offset to 1.
- Hypothesis test for difference of means was applied to analyze the groups at a significance level of 99.9 %.
- After compute the values of the different kind of entropies, the receiver operating characteristic curves (ROC) [6] was constructed with the results to select the best one.

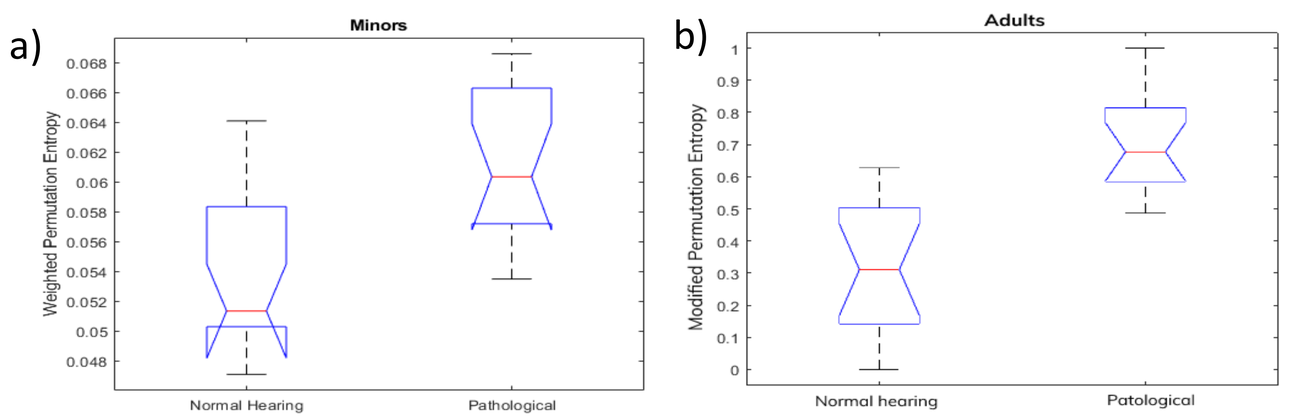

Figure 2: boxplots for both groups. a) Minors and b) Adults

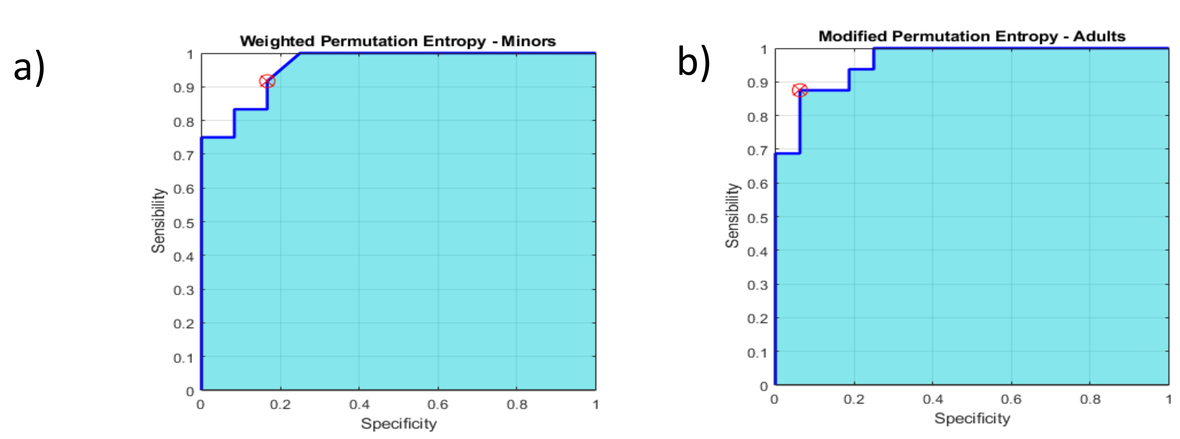

Figure 3: a) ROC curve for minors group using WPE, b) ROC curve elder group using MPE

Results

Minors	PE	WPE	MPE
Sensibility	0,7500	0,9167	0,6875
Precision	0,7188	0,8750	0,7500
Specificity	0,6875	0,8333	0,8125
Area under the ROC curve	0,7734	0,9618	0,7656
Adults	**PE**	**WPE**	**MPE**
Sensibility	0,9375	0,7857	0,8750
Precision	0,8750	0,7857	0,9063
Specificity	0,8125	0,7857	0,9375
Area under the ROC curve	0,9375	0,8776	0,9609

Table 1: Results for both groups (minors and adults) calculating sensitivity, precision, specificity and area under the curve calculated from WPE and MPE values.

Conclusions

- In the case of minors, the weighted permutation entropy was the best classifier, with the maximum sensitivity, precision, specificity and area under the curve with respect to the others.
- For the case of adults, it was the modified permutation entropy.
- The result of the calculated entropies of pathological patients was greater than that of normal hearing patients, and the response of the auditory nerve is, in some sense. more random.

Future work

The next steps are to expand the database by incorporating a larger number of signals to improve the statistics and to test other alternatives based on permutation entropy to further evaluate its ability to discriminate normal patients from those with pathology in the auditory pathway.

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Acknowledgements

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