Technology Brain Computer Interface for Autonomy: Patient-adapted ergonomic headset for dry-EEG P300 speller

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Abstract: Recent work demonstrates feasibility for ALS patients to communicate via P300 speller *[1]*, but end-user's expectations are not met concerning comfort and ease of use, particularly for patient under heavy pathology *[8]*. One challenge for daily use *[8],[9]* is to provide patients with gel-free headsets that are easy to put on and comfortable while providing enough signal quality for accurate P300 classification.

Our proposal is to custom design a silicone headset to fit patient's head morphology *[5]*, paying attention on good pressure distribution and hair layer penetration. We will firstly show feasibility of Dry P300Speller with State-of-the-Art amplifier, then analyze electrode impedance variation over time while the headset is worn, and its relation to P300 classification accuracy.

Challenges & Requirements

Overcome the gap between Wet (Fig.1) and Dry EEG (Fig.2)
- Adapted electronics
- Compromise between comfort and signal quality *[4]*
- Adapted Impedance threshold (e.g 20kOhm for wet (see Fig.3))

Ease of use [9]
- Easy to put on by a non-expert (<3 min)
- Gel-free operation
- Reduce numbers of channels *[2],[3],[6]* (<9) (especially occipital areas)
- Allow communication with correct Speed

Fit the patient's expectations
- Extract patient head shape from 3D scan *[5]*
- Being reliable for long time (12 months)
- Being worn comfortably during long time recording (weight supported by head <400g)

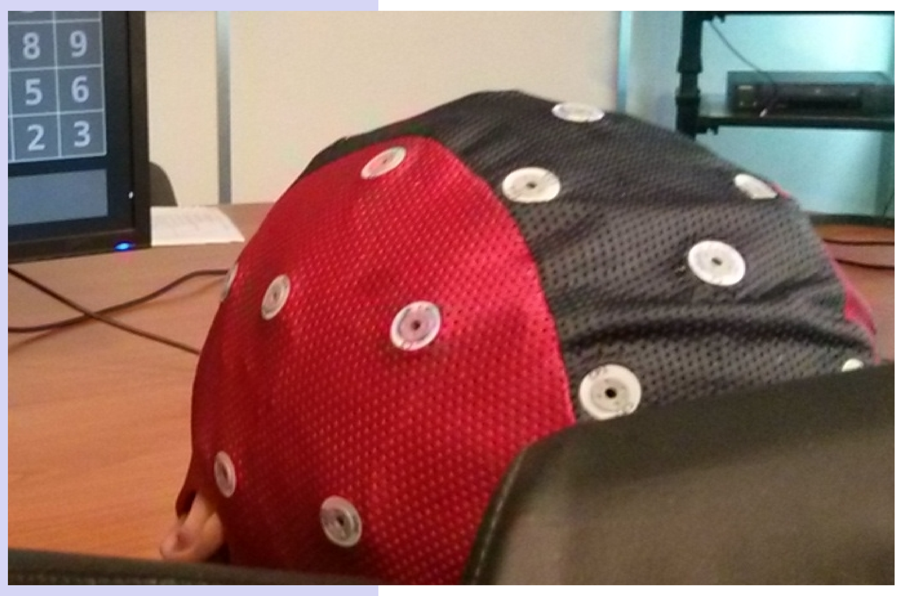

Fig. 1: Textile commercial headset, wet EEG

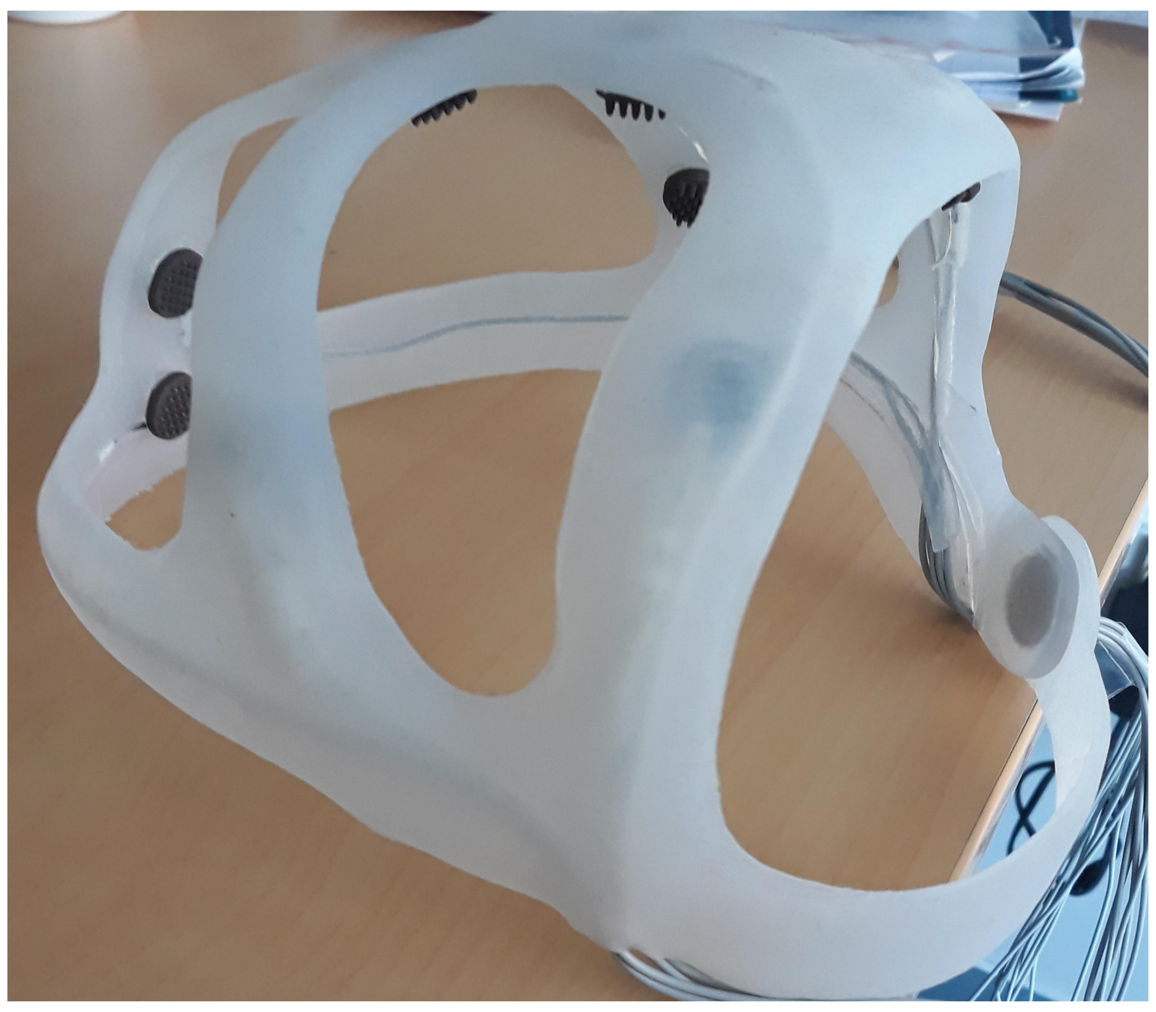

Fig. 2: Prototyping with silicone & dry electrodes ANT B.V

Impedance analysis (1h) for the working mode explicited by Fiedler *[4]*, revealed that our prototype stand with a **mean impedance of 50 kΩ** and a variability of 71.6 kΩ (see Fig.3), with the worst contact being 534 kΩ, still in the 1MΩ range defined by literature.

Impedances								total
Moyenne / channel	35.1	53.5	16.1	173.5	9.8	11.5	3.9	49.9
	Cz	Pz	P3	P4	Cpz	C3	C4	
Variabilité 2-60	242.3	111.5	30.4	38.4	3.2	4.1	0.1	71.6

Fig. 3: 1 hour Impedances Analysis per channel: mean and variability

System evaluation

I. Validation of the manufacturing process
- Classification Accuracy
- Speed of Use: Information Transfer Rate (ITR)
- Comparison with state-of-the-art system *[7]*

II. Repeatability of the process
- Good fit on multiple head with the same process

III. Feedback Questionnaire - Satisfaction
- VAS: Ergonomy / Tolerance / etc

C	H	A	L	E	U	R	E	U	X

```
Cross-validation test accuracy is 83.5953% (sig
  Cls vs cls        1      2
  Target  1:    33.4   66.6 %, 329 examples
  Target  2:     3.9   96.1 %, 1317 examples
Training set accuracy is 88.1531% (optimistic)
  Cls vs cls        1      2
  Target  1:    46.2   53.8 %, 329 examples
  Target  2:     1.4   98.6 %, 1317 examples
```

Fig. 4, 5: Experiment result- training acc.=88% charact. selection=90%

Conclusion

- **Good performance** compared to WET(see Fig.4,5)
- **Better usability**: gel-free operation but more flash needed
- **System simplification**: size & weight already reduced
- Effectiveness of the dynamic data collection: **early stopping**

Perspectives

- Better knowledge of aging process of electrodes
- Add mechatronic parts to increase efficiency (e.g active PCB for each electrodes)
- Increase portability by user-centered design
  - Reduce weight / Become wireless / Upgrade aesthetics & autonomy

Références : **[1]** Violaine Guy, Marie-Helene Soriani, Mariane Bruno, Theodore Papadopoulo, Claude Desnuelle, and Maureen Clerc. "Brain computer interface with the P300 speller: usability for disabled people with amyotrophic lateral sclerosis". In: *Annals of physical and rehabilitation medicine* 61.1 (2018) **[2]** Michael T McCann, David E Thompson, Zeeshan H Syed, and Jane E Huggins. "Electrode subset selection methods for an EEG-based P300 brain-computer interface". In: *Disability and Rehabilitation: Assistive Technology* 10.3 (2015) **[3]** Yuki Ijichi and Hisaya Tanaka. "Electrodes arrangement on brain-computer interface for the ALS's posture". In: *2016 IEEE International Conference on Systems, Man, and Cybernetics (SMC)*. IEEE. 2016 **[4]** Patrique Fiedler et al. "Contact pressure and flexibility of multipin dry EEG electrodes". In: *IEEE Transactions on Neural Systems and Rehabilitation Engineering* 26.4 (2018) **[5]** Daniël Lacko. "The application of 3D anthropometry for the development of headgear: a case study on the design of ergonomic brain-computer interface devices". PhD thesis. University of Antwerp, 2017 **[6]** Yang, T., Ang, K. K., Phua, K. S., Yu, J., Toh, V., Ng, W. H., & So, R. Q. (2018, July). EEG Channel Selection Based on Correlation Coefficient for Motor Imagery Classification: A Study on Healthy Subjects and ALS Patient. **[7]** Kam, Julia WY, et al. "Systematic comparison between a wireless EEG system with dry electrodes and a wired EEG system with wet electrodes." NeuroImage 184 (2019): **[8]** Wolpaw, J. R., Bedlack, R. S., Reda, D. J., Ringer, R. J., Banks, P. G., Vaughan, T. M., ... & McFarland, D. J. (2018). Independent home use of a brain-computer interface by people with amyotrophic lateral sclerosis. Neurology, 91(3) **[9]** Käthner, I., Halder, S., Hintermüller, C., Espinosa, A., Guger, C., Miralles, F., ... & Daly, J. M. (2017). A multifunctional brain-computer interface intended for home use: An evaluation with healthy participants and potential end users with dry and gel-based electrodes.

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