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Table 2: Classification accuracy for each subject across analyzed number of blinks and blinking eyes (1x, 2x, 3x – single, double, and triple blinks; L, R, B – left, right, and both eyes).

	L	**R**	**B**	**1x**	**2x**	**3x**	**All**
S1	91.7	100.0	100.0	100.0	100.0	91.7	**97.2**
S2	91.7	75.0	83.3	100.0	66.7	83.3	**83.3**
S3	100.0	91.7	75.0	91.7	91.7	83.3	**88.9**
S4	100.0	100.0	83.3	100.0	91.7	91.7	**94.4**
S5	83.3	100.0	83.3	91.7	91.7	83.3	**88.9**
S6	100.0	100.0	33.3	91.7	75.0	66.7	**77.8**
S7	100.0	100.0	91.7	100.0	100.0	91.7	**97.2**
S8	100.0	100.0	91.7	100.0	100.0	91.7	**97.2**
S9	100.0	100.0	100.0	100.0	100.0	100.0	**100.0**
S10	91.7	91.7	91.7	100.0	91.7	83.3	**91.7**
Mean	**95.8**	**95.8**	**83.3**	**97.5**	**90.8**	**86.7**	**91.7**

Finally, we aggregated the results obtained from different subjects to find out which of our 9 classification schemes was correctly recognized in most cases. The aggregated results are presented in Tab. 3. As it can be noticed in the table the best detection rate was obtained for single right eye blink (100%), then for single and double left eye blink (98%), and next for double right and single both eyes blink (95%). If instead of the nine blinking schemes, only the first four were used (excluding single blink with both eyes as spontaneous physiological activity), the average accuracy would reach exactly 97.5%.

Table 3: The mean classification accuracy for each of the nine blinking schemes; results aggregated over all subjects.

	Left	Right	Both	Mean
1 x	**97.50**	**100.00**	95.00	97.50
2 x	**97.50**	**95.00**	80.00	90.83
3 x	92.50	92.50	75.00	86.67
Mean	95.83	95.83	83.33	

CONCLUSION

As it was shown in the paper, the proposed detection algorithm can recognize a quite high number of control states with a high detection rate, without any external stimulations and with use of a very short (30 s) calibration. Therefore, for the users that can still control their eyelids muscles, it can provide a good alternative to the brain-computer interfaces.

The main outcomes from the experiment described in the paper are: 1) the overall detection rate calculated over nine blinking schemes and ten subjects was equal to 92%; 2) the detection rate calculated over four best blinking schemes was equal to 98%; 3) it was much easier to recognize left-right blinks (96% - right eye and 96% - left eye) than both eyes blinks (83%); 4) the detection accuracy dropped with the increasing number of blinks (98% - single, 91% - double, 87% - triple blinks).

We believe that the algorithm described in this paper might be further improved by enhancing the recognition of both eyes' blinks. Moreover, to formulate more valid conclusions we plan to conduct experiments with more subjects and a greater number of blinks.

REFERENCES

[1] Saeid S, Chambers JA. EEG signal processing, ch.1, pp. 1-18, John Wiley and Sons Ltd (2007)

[2] Li Y, He S, Huang Q, Gu Z, Yu ZL. A EOG-based switch and its application for "start/stop" control of a wheelchair. Neurocomputing, 2018, 275, pp. 1350-1357

[3] Ahmed KS. Wheelchair movement control VIA human eye blinks. American Journal of Biomedical Engineering, 2011, 1(1), pp. 55-58

[4] Brijil C, Rajesh S, Rameshwar J. Virtual keyboard BCI using Eye blinks in EEG. In: 2010 IEEE 6th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob), 2010. p. 466-470

[5] Rihana S, Damien P, Moujaess T. Efficient eye blink detection system using RBF classifier. In: Biomedical Circuits and Systems Conference (BioCAS), IEEE, 2012. pp. 360-363

[6] Di Flumeri G, Aricó P, Borghini G, Colosimo A, Babiloni F. A new regression-based method for the eye blinks artifacts correction in the EEG signal, without using any EOG channel. In 2016 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), IEEE, 2016. pp. 3187-3190

[7] Wang G, Teng C, Li K, Zhang Z, Yan X. The removal of EOG artifacts from EEG signals using independent component analysis and multivariate empirical mode decomposition. IEEE journal of biomedical and health informatics, 2016, 20(5), pp. 1301-1308.

[8] Królak A, Strumiłło P. Eye-blink detection system for human–computer interaction. Universal Access in the Information Society, 2012, 11(4), pp. 409-419

[9] Jasper HH, The ten-twenty electrode system of the international federation in electroencephalography and clinical neurophysiology, EEG Journal, 1958, Vol. 10, 371–375

[10] Renard Y, Lotte F, Gibert G, Congedo M, Maby E, Delannoy V. et all. OpenViBE: An Open-Source Software Platform to Design, Test and Use Brain-Computer Interfaces in Real and Virtual Environments, Presence: teleoperators and virtual environments, 2010, Vol. 19, No 1