Towards a covert visual attention BCI for patients with oculomotor impairment

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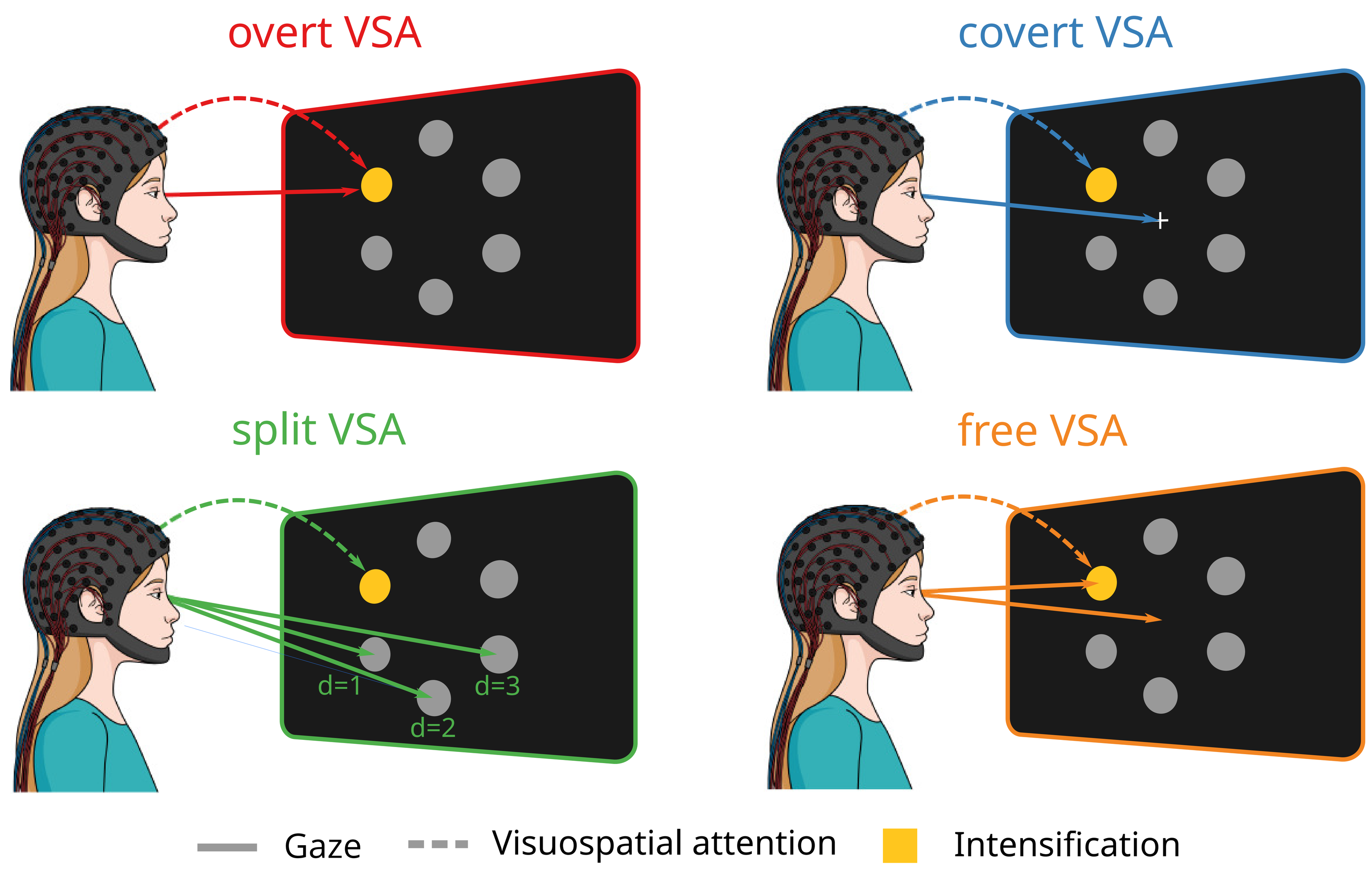
1 Context

Communication BCIs have a target population consisting of patients in various stages of paralysis or Locked-in Syndrome, often suffering from oculomotor impairments. This reduces their performance operating visual event-related potential (ERP) BCIs, since they are unable to comfortably redirect their gaze at the desired target, i.e., overt visuospatial attention (VSA). Instead, they are forced to operate in covert VSA, where the gaze and VSA do not coincide. Several studies show that performance drops in covert VSA [2, 1], necessitating gaze-independent solutions. Our previous study [3] indicates gaze-independent performance can be improved in healthy subjects using a suited decoding strategy. Currently, we aim to verify this in patients.

2 Visuospatial attention experiment

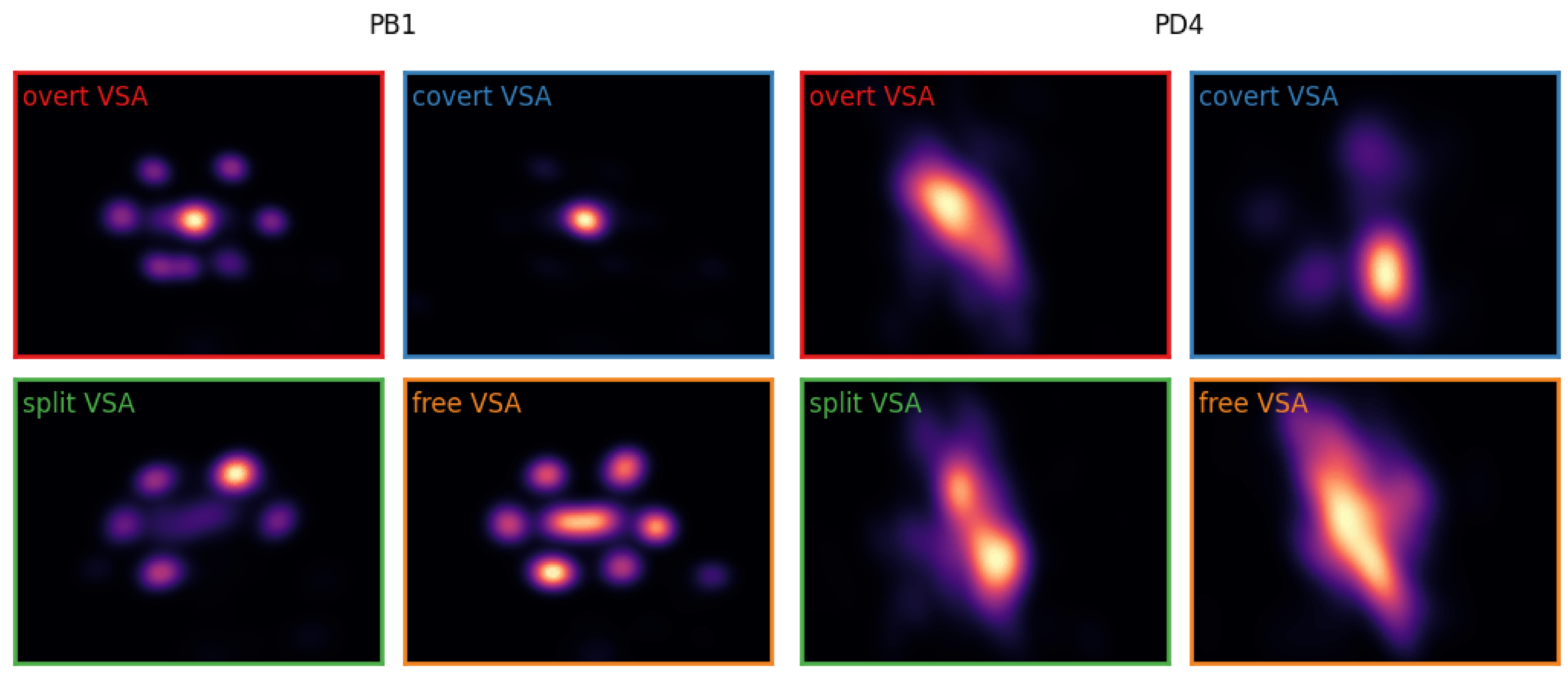
We carry out an ERP BCI experiment using an interface similar to the visual Hex-o-Spell [2], in different VSA conditions while recording EEG and gaze.



3 Patients

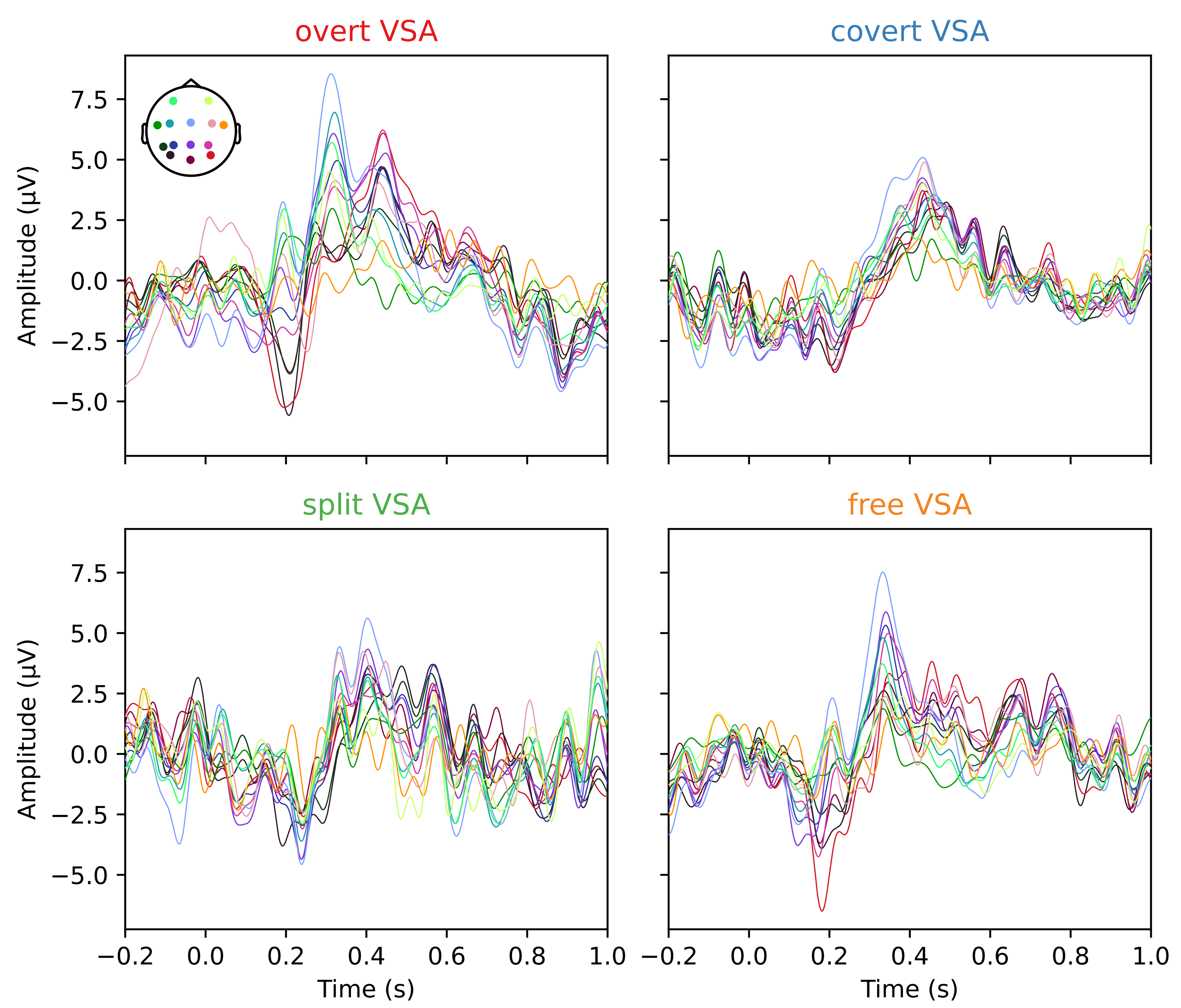
id	age	path.	speech	trach.	comm.	oculomotor condition
PA1		DMD	intact	no	verbal	
PA2	24	DMD	intact	no	verbal	
PA5	26	DMD	intact	no	verbal	
PA6	29	DMD	intact	no	verbal	
PA7	29	DMD	intact	no	verbal	
PA8	22	DMD	intact	no	verbal	
PB1	58	ALS	anarthria	no	tablet	
PC1	41	FA	dysarthria	no	verbal	impaired pursuit, fixation fatigue/discomfort, tremor
PC2	43	FA	dysarthria	no	verbal	tremor, fixation fatigue/discomfort
PC3	27	TBI	anarthria	no	tablet	deviation R, fixation fatigue/discomfort
PC4	48	FA	dysarthria	no	verbal	impaired pursuit, tremor, fixation fatigue/discomfort
PD2	43	stroke	anarthria	yes	eyes	tremor, fixation fatigue/discomfort, partial ophthalmoplegia
PD3	43	stroke	anarthria	yes	letterboard	partial ophthalmoplegia L, ophthalmoplegia R, R closed, involuntary saccades, tremor, fixation fatigue/discomfort
PD4	54	stroke	anarthria	yes	letterboard	deviation L

4 Gaze tracking data



Patients are not always able to perform the cued VSA condition, including covert VSA, depending on the degree of eye motor impairment. In free VSA, their oculomotor condition leads some patients to operate using covert or split VSA. For patients suffering from partial ophtalmoplegia (PD2, PD3), mobile eye trackers cannot measure gaze accurately.

5 Event-related potential data



Covert and split VSA lack most early VEPs related to visual processing, but can be distinguished. Eye motor impaired patients, like PC2, can exhibit differences in N1 and P3 amplitude between overt and free VSA, related to the fact that they do not operate comfortably in overt attention.

6 Conclusions and future directions

Classical interfaces forcing sustained overt or covert VSA are unsuited for some patients in the BCI target population. We aim to develop a flexible, gaze-independent interface, eliminating the need for gaze fixation. We will compare ERP classification algorithms to find out which patients and which VSA settings benefit from specific decoding strategies, and incorporate gaze tracker data in the decision making process.

References

[1] Ricardo Ron-Angevin et al. "Impact of speller size on a visual P300 brain-computer interface (BCI) system under two conditions of constraint for eye movement". In: *Computational Intelligence and Neuroscience* 2019 (2019).

[2] Matthias S Treder and Benjamin Blankertz. "(C) overt attention and visual speller design in an ERP-based brain-computer interface". In: *Behavioral and brain functions* 6 (2010), pp. 1–13.

[3] Arne Van Den Kerchove et al. "Correcting for ERP latency jitter improves gaze-independent BCI decoding". In: *Journal of Neural Engineering* (in review).

Pathologies

DMD: *Duchenne's Muscular Dystrophy*, ALS: *Amyotrophic Lateral Sclerosis*, FA: *Friedreich's Ataxia*, TBI: *traumatic brain injury*, stroke: *brain-stem or cerebellar stroke*