Global attentional selection of visual features is not mirrored in a selective modulation of posterior alpha-band activity

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Introduction

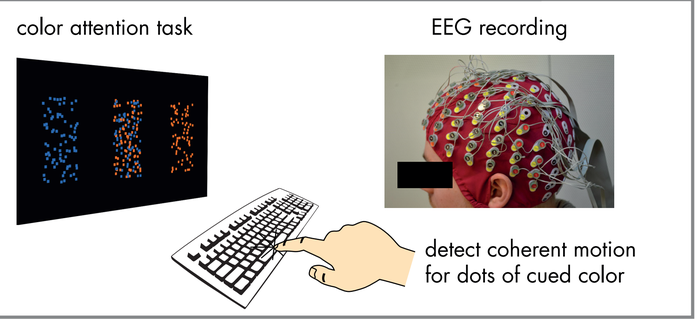
Features of visual stimuli such as a particular color, movement direction, or orientation can be top-down attentionally selected to allow efficient interaction with the environment. Behaviorally this helps to improve task performance for objects sharing the selected feature(s) amongst distinct stimuli (Rossi & Paradiso, 1995; White & Carrasco, 2011). On a neural level, feature-based-attention (FBA) is linked to globally enhanced processing of attended over unattended features (Treue & Trujillo, 1999). How are these effects instantiated in the brain? Alpha- band activity has been proposed to be a likely candidate for altering neural information processing, specifically relevant for attentional selection (Foxe & Snyder, 2011). To probe the role of alpha-band activity for feature selection, we used an FBA shifting design with EEG measurements to capture 1) neural signatures of the global selection of attended colors and 2) potentially related modulations of parieto-occipital alpha-band activity.

Methods

Participants

34 subjects (35 female, Age: M = 22.97, range 20 to 32)

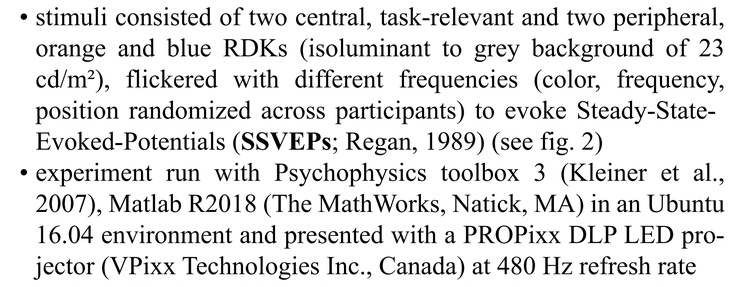
Fig 1 Experimental Procedure



Stimuli, Procedure, Task

- Participants were color-cued to attend to one of two centrally presented Random-Dot-Kinematograms (RDKs) and detect brief (300 ms) coherent motion events of 40 % of the dots of the cued color and ignore uncued events (1-2 events in 50% of all trials; see fig. 1)
- stimuli consisted of two central, task-relevant and two peripheral, orange and blue RDKs (isoluminant to grey background of 23 cd/m²), flickered with different frequencies (color, frequency, position randomized across participants) to evoke Steady-State-Evoked-Potentials (**SSVEPs**; Regan, 1989) (see fig. 2)
- experiment run with Psychophysics toolbox 3 (Kleiner et al., 2007), Matlab R2018 (The MathWorks, Natick, MA) in an Ubuntu 16.04 environment and presented with a PROPixx DLP LED projector (VPixx Technologies Inc., Canada) at 480 Hz refresh rate
- total of 480 trials with 3750 ms average duration separated by ITI of 1 s presented in 8 blocks of 60 repetitions
- EEG measurend from 64 Ag/AgCl electrodes with an ActiveTwo Amplifier (BioSemi, Amsterdam); sampling rate of 512 Hz and low-pass filter of 104 Hz

Fig 2 Stimulus Display and Design



Analysis

- analysis of SCD-transformed EEG for trials without events (-1 to 2s rel. to cue); trials with blinks, eye movements and excessive noise discarded; channels interpolated (Junghöfer et al., 2000); M_{trials} = 95.61 (SD = 14.94) per condition and participant

SSVEPs as marker of early sensory gain

- analysis of FFT derived pre- (-1000 to 0 ms) to post-cue (500 to 1500 ms) amplitude modulations for attended and unattended colors of central and peripheral RDKs

alpha-band activity (8 to 12 Hz)

- analysis of FFT derived pre- to post-cue modulations contralateral to peripheral stimuli of attended and unattended color
- Gabor-filter-based (FWHM = ±1 Hz/±220.636 ms) time-resolved anlysis of alpha-band modulations contralateral to peripheral stimuli of attended/unattended color

Results

Behavior

- on average 151.47 (SD = 19.71) correct responses to 180 targets (mean hit rate = 84.150 %; SD = 10.95) with a mean reaction time of 623.51 ms (SD = 43.96)
- on average 22.29 (SD = 19.27) responses to 180 distractors (mean false alarm rate of 12.39 %; SD = 10.70).

SSVEP modulations (fig. 4)

- $ANOVA_{RM}$: main effect of **ATTENTION** ($F(1,33) = 112.395$, $p < .001$, $\eta_g^2 = 0.455$)
- significant interaction **ATTENTION and POSITION** ($F(1,33) = 29.289$, $p < .001$, $\eta_g^2 = 0.206$)
- no main effect **POSITION** ($F(1,33) = 0.452$, $p = .506$, $\eta_g^2 = 0.004$).

Alpha-band modulations for peripheral stimuli (fig. 5, 6)

- significant negative pre- to post-cue modulation contralateral to the attended ($t(33) = -10.339$, $p < .001$, $d = -1.800$) and unattended color ($t(33) = -7.907$, $p < .001$, $d = -1.376$).
- comparable modulations contralateral to attended and unattended color ($t(33) = -0.952$, $p = .348$, $d = 0.163$); Bayes Factor (standard JZS prior of $\sqrt{2}/2$) favoring null hypothesis with $BF01 = 3.696$)

Fig 4 Measured SSVEP Modulations

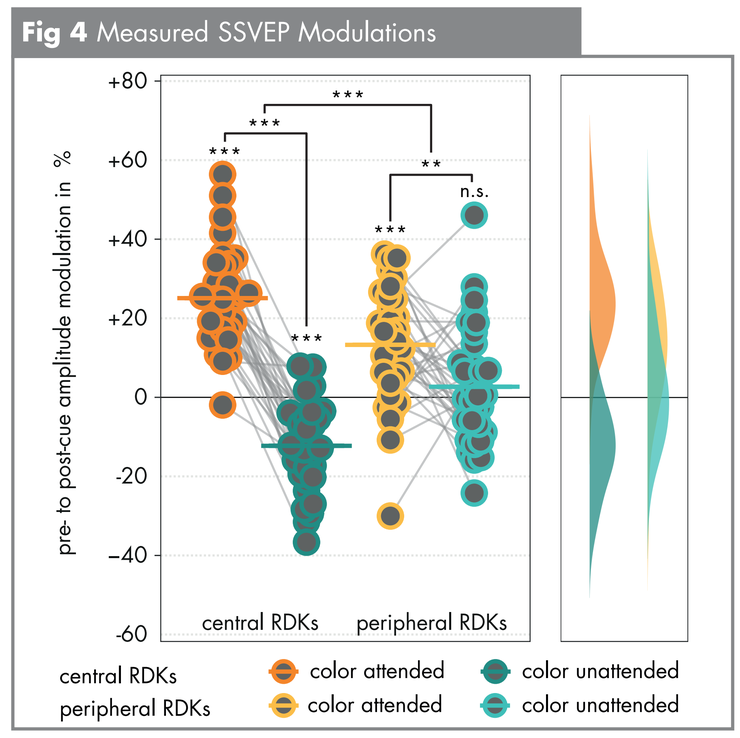


Fig 3 SSVEP Spectra and Topographies

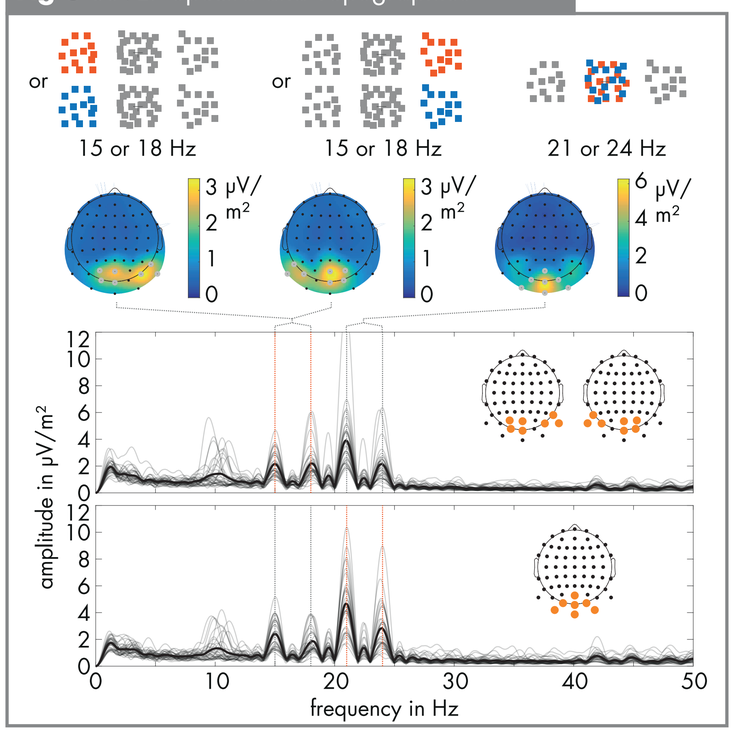


Fig 5 Hypothesized Alpha-Band Modulations

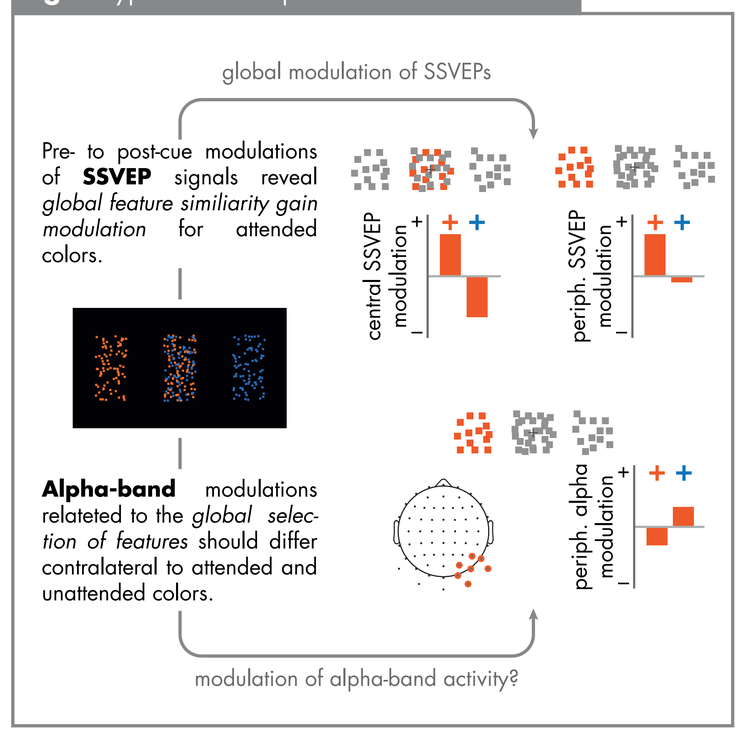
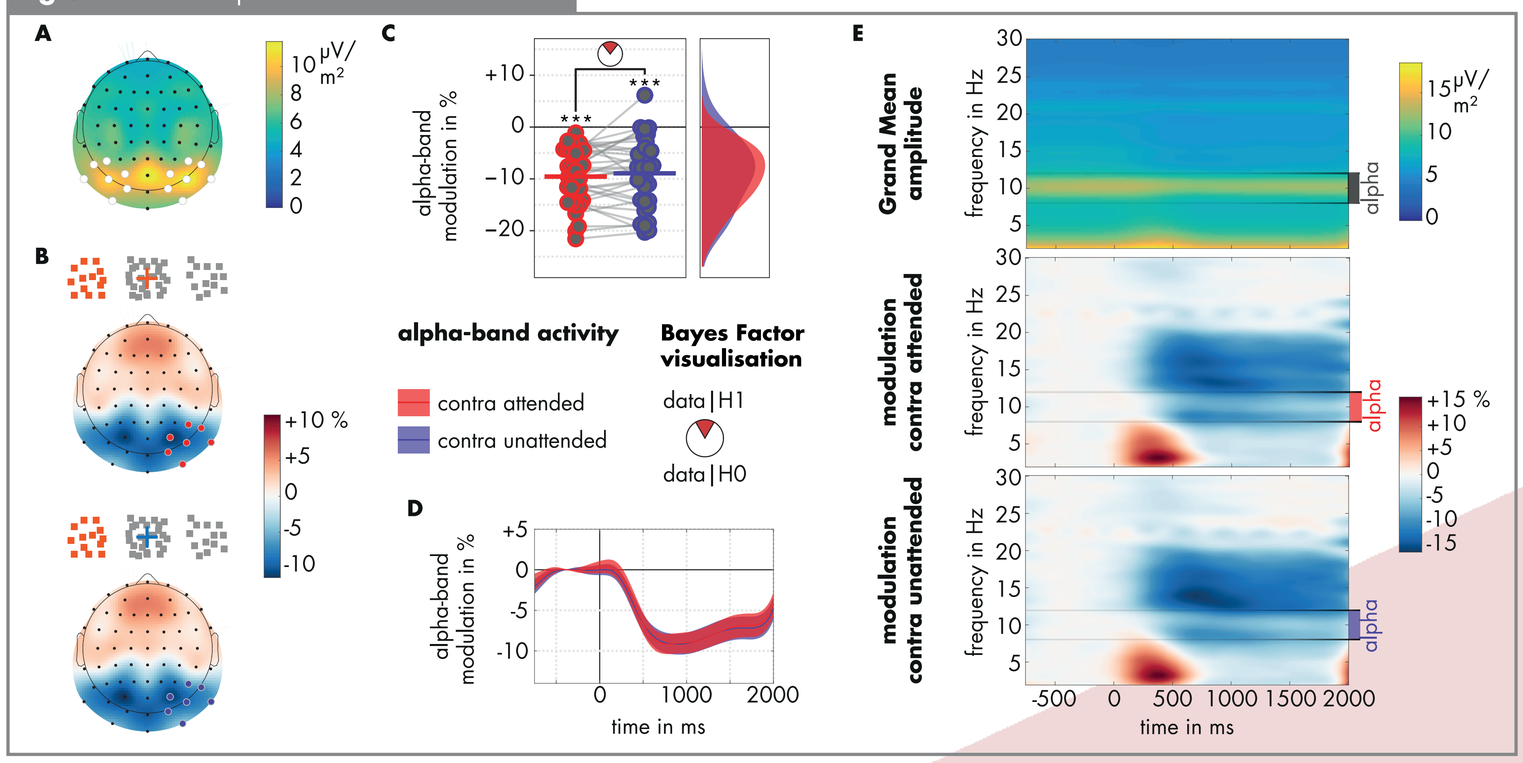


Fig 6 Measured Alpha-Band Modulations



(A) Topographic representation of Grand Mean pre-cue (-1000 to 0 ms) FFT derived alpha-band amplitudes. **(B)** Mirrored and collapsed pre- (-1000 to 0 ms) to post-cue (500 to 1500 ms) alpha-band modulations. Right hemisphere is contralateral to attended (top) or unattended (bottom) color in periphery. Relevant lateral electrodes marked. **(C)** Pre- to post-cue alpha-band modulations contralateral to attended and unattended color in periphery. **(D)** Gabor-filter based representation of alpha-band modulations contralateral to attended and unattended color relative to pre-cue baseline (-500 to -250 ms). Shaded area: ± SEM for each time point. **(E)** Total time-frequency representation of raw (top) and baseline corrected (middle, bottom; -500 to -200 ms) signals recorded at lateral electrodes contralateral to the attended (middle) or unattended (bottom) color.

Summary and Discussion

We probed the role of alpha-band activity as an index of sustained global feature-based attentional selection by measuring alpha-band activity at electrodes contralateral to peripheral stimuli sharing the centrally attended or unattended color. The overall pattern revealed no difference in pre-to-post-cue modulations of alpha-band activity contralateral to the attended or unattended stimulus. In other words, alpha-band activity did not selectively index or follow the global attentional selection of a single feature within a feature dimension.

Open Issues

- Do modulations of alpha-band activity play a role in the attentional selection between feature dimensions (Snyder & Foxe, 2011)?
- Are alpha-band modulations rather relevant for the expectation than the selection of relevant features?
- Is the general unspecific pre- to post-cue modulation of alpha-band activity relevant for attentional processes?
- What is the functional relevance of alpha-band activity?
- Which neural mechanisms are employed to allow for a global and distributed sensory gain modulation of relevant features?

References

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