Direct electrophysiological metrics of visual surround suppression in humans

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Surround suppression is a well known phenomenon whereby the perceived intensity of a stimulus is lowered by the relative intensity of its surroundings. Psychophysical work has demonstrated the influence of a variety of stimulus factors, including similarity of features between the "foreground" (center) and "background" (surround). Such behavioral indices have provided novel insights in clinical studies testing for inhibitory dysfunction, for example in schizophrenia. Surround suppression effects have also been demonstrated in functional imaging work, in which it was established that it is expressed most strongly in primary visual cortex (V1). However, up until now, technical challenges have precluded its direct measurement in non-invasive EEG, which is arguably the most clinically practical recording modality. In this study, we report a novel paradigm that exploits simple signal processing, sensory physiology and psychophysical principles in order to extract a direct index of surround suppression (reduction of "foreground" stimulus response as a function of background contrast) from the primary visual cortex (V1) using non-invasive human electroencephalography (EEG).

Surround suppression effects were measured using steady state visually evoked potentials (SSVEP) elicited by the flickering of a "center" stimulus on a static "surround". Two different stimulus configurations were presented: peripheral, consisting of four flickering discs, and foveal, consisting of a single central disc. Discs of radius 2 deg were cut out of a full-screen vertical sinusoidal grating of spatial frequency 2 cpd. Low and high flickering frequencies (7.2Hz and 25Hz) were tested. We varied the "center" contrast across five levels 0, 25, 50, 75 and 100% to generate individual contrast response functions corresponding to three "surround" contrast levels 0, 50 and 100%, and also evaluated the influence of center-surround feature similarity by presenting orthogonal as well as parallel surrounding grating patterns.

EEG data were recorded from sixteen healthy subjects (7 female) while passively viewing a randomized sequence of the above described stimuli on a CRT monitor. There were 6 trials per condition, each of them lasting 2.5 seconds. Data acquisition was done at a sampling frequency of 500Hz from 96 electrodes. We measured SSVEP amplitudes from dorsal midline EEG channels referenced to average mastoids, and computed a Fast Fourier Transformation for 2-s windows during stimulus presentation.

Across the population in study, there was a significant main effect of foreground contrast, a main effect of background contrast, and a significant interaction between the two, reflecting the fact that the contrast response function was reduced in proportion with the background contrast level. This effect was observed for both foveal and peripheral stimuli, and for both flicker frequencies tested. There was a main effect of the background orientation, further explained by an interaction between orientation and both background and foreground contrast, driven by a stronger suppression effect for the parallel background. To our knowledge, this is the first definitive demonstration of a surround suppression effect in the visual evoked potentials of humans, and paves the way for the first definitive measurement of the relative contributions of under-inhibition and over-excitation to hyperexcitability in epilepsy.