Psychophysics and electrophysiology of flicker-induced subjective experiences

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Introduction/Methods

- stimulation with flickering, but spatially homogeneous light induces complex visual experiences of colour and form
- stimulation frequencies: 1 – 60 Hz
- stimulation duration: 20- 60s, 15 – 30s recovery time between stimulation epochs
- verbal free report or timed button response

Frequency specificity

- subjective experiences are induced by specific flicker frequencies
- subjective reports are interindividually reliable
- different experiences are characterized, but not entirely determined, by different frequency ranges
- figures show density estimates of the number of observers freely reporting an experience at a given stimulation frequency for form (left) and colour experiences (right)
- at the top of each figure frequency ranges with significantly high numbers of reports are symbolised by lines
- the first numbers on the lines denote the most effective stimulation frequency for each experience, while numbers in brackets indicate the number of participants (of a total of 9 observers) freely reporting the experience at this peak frequency

Interdependencies

- the perception of subjective colour and form follows interindividually consistent patterns of mutual dependencies between the experiences
- while some experiences tend to co-occur, others exclude their mutual appearance
- figures show intramodal dependencies for colour (left) and form experiences (middle), as well as intermodal patterns (right)
- experiences co-occurring significantly in at least half of the observers are connected by green lines, experiences with a significant likelihood of not co-occurring are connected by red lines

Phase specificity

- the experiences of subjective colour and form are related to the phase of the flicker stimulation
- opponent colours are reported at opponent phases of the flicker stimulation cycle
- the left figure shows a histogram of the response times of manual button responses to the perception of the colour blue relative to the phase of the flicker cycle; the arrow denotes the mean direction of this distribution
- the mean directions of all tested experiences are given in the middle (form) and right figure (colour)

Electrophysiological correlates

- the experience of subjective colour is preceded by a desynchronization of alpha band activity and by a synchronization of gamma band activity in the cortex
- the figures show significant increases (light) and decreases (dark) of synchronized brain activity in the lower alpha (left) and gamma (right) frequency range over a time period of 2s preceding the manual response
- results shown were significant in all three participants

Conclusion: theoretical model

- the different response latencies of the three retinal cone types interact differentially with the different flicker frequencies (Courtney & Buchsbaum, 1991)
- during flicker stimulation, the activity of colour opponent cells may be characterized by 180° phase-shifted oscillations
- high alpha activation in the cortex prevents processing of the information being transmitted from the retina
- following spontaneous alpha desynchronization, the activity which is at a maximum is further processed (resulting in phase specificity)
- alpha desynchronization allows cortical gamma synchronization induced by the retinal activity. The state of cortical gamma synchronization corresponds to the conscious perception of colour
- subjective forms show a high similarity to resonance phenomena in physical systems: lateral (retinal) connections with specific response latencies interact with the different flicker frequencies and induce resonance patterns of activation in the neuronal tissue, which are processed by the respective orientation columns in the cortex (Stwertka, 1993)
- patterns of co-occurrence suggest that especially red/green-coding cell assemblies enter into states of resonance during flicker stimulation due to their specific temporal characteristics