Critical state mechanisms underlying self-initiated attention shift

Wei Wu1, Kazuya Kobayashi2, Dengzhe Hou2, Shin Ono2, Yoshiyuki Sato1,3, Yasuhiro Hatori1,2, Chia-huei Tseng1,2, Satoshi Shioiri1,2

1: Graduate School of Information Science, Tohoku University, Japan, 2: Research Institute of Electrical Communication, Tohoku University, Japan, 3: Advanced Institute for Yotta Informatics, Tohoku University

Introduction
Vision is indispensable for us to perceive and recognize the world, where large amount of information can be obtained from retinas at a time but with selection processes, which is referred as selective attention. Whereas visual attention is shifted without any cue (so the attention shift is self-initiated) in daily life, a cue is used to trigger a shift of attention in most experiments of attention studies. However, the underlying mechanism of self-initiated attentional shift is unclear. As criticality state is found to be optimal for information transmission and processing, it may be interrupted before attention shift, which suggests a non-optimal processing during a period of time before self-initiated attention shift.

Purpose
To investigate the criticality state related with self-initiated attention shift

Background

Attention shift by will: Control of top-down attention

Self-initiated attention

Most experiments used a cue to direct attention shift, whereas attention shift was self-initiated in daily life.

What’s the neural mechanism of self-initiated attention shift?

Criticality state

Our brain: a complex dynamical system

Optimal state for information transmission and processing, indicated by power exponent of avalanche distribution.

Hypothesis: brain system keeps optimal without change of attentional state.

Self-initiated attention shift causes the change of attentional state, expressed by change of power exponent.

Method to calculate the number of activated electrodes

Power exponent distribution during critical state

\[ P_s(x) = \begin{cases} \alpha x^{-\beta} & \text{if } \beta > 1 \\ \text{or otherwise} & \end{cases} \]

Number of Activated electrodes

Scale

Activation

Frequency Power exponent Power exponent

Result

Critical state

EEG

SSVEP (Steady-state visual evoked potential)

EEG signal is recorded by Neurofax EEG-9000 (Nihon Koden, Tokyo, Japan).

Amplitude increases at attending frequency.

Time estimation results

Time of attention shift:
50% change of SSVEP amplitudes between before (-3.5 ~ -2.5 s) and after (1 ~ 2 s) the key press for new location.

Time estimation of attention shift by SSVEP

Stimulus

Procedue

Subjects could shift attention freely in one trial whenever and wherever they liked during a 20s trial.

Task: Detection of Target ‘A’ in RSVP sequence

Press a key as quickly as possible when A is presented at the attended location.

To know where subjects were attending, key response was recorded, responded with the key corresponding to the location attended

(EEG recording during 20s of one trial)

EEG signal recorded by Neurofax EEG-9000 (Nihon Koden, Tokyo, Japan).

Amplitude increases at attending frequency.

Significant difference of power exponent between shift and no-shift conditions was found around 3 - 4 s before attentional shift when data from electrodes separately analyzed for frontal, parietal and occipital areas.

Conclusion

Power exponent of critical state could be a candidate index for self-initiated attention shift.