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Nonlinear analysis of saccade speed fluctuations during combined action and perception tasks

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HIGHLIGHTS

- Saccadic peak speed fluctuations are multifractal.
- Saccade multifractality strength differs in simple decision and dual decision task.
- Similar results for Lempel–Ziv analysis show different complexity measures.
- Multifractal parameter proposed for action–perception interaction in visual process.

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ABSTRACT

Background: Saccades are rapid eye movements used to gather information about a scene which requires both action and perception. These are usually studied separately, so that how perception influences action is not well understood. In a dual task, where the subject looks at a target and reports a decision, subtle changes in the saccades might be caused by action–perception interactions. Studying saccades might provide insight into how brain pathways for action and for perception interact.
New method: We applied two complementary methods, multifractal detrended fluctuation analysis and Lempel–Ziv complexity index to eye peak speed recorded in two experiments, a pure action task and a combined action–perception task.
Results: Multifractality strength is significantly different in the two experiments, showing smaller values for dual decision task saccades compared to simple-task saccades. The normalized Lempel–Ziv complexity index behaves similarly i.e. is significantly smaller in the decision saccade task than in the simple task.
Comparison with existing methods: Compared to the usual statistical and linear approaches, these analyses emphasize the character of the dynamics involved in the fluctuations and offer a sensitive tool for quantitative evaluation of the multifractal features and of the complexity measure in the saccades peak speeds when different brain circuits are involved.
Conclusion: Our results prove that the peak speed fluctuations have multifractal characteristics with lower magnitude for the multifractality strength and for the complexity index when two neural pathways are simultaneously activated, demonstrating the nonlinear interaction in the brain pathways for action and perception.

1. Introduction

Saccades are rapid eye movements initiated by activation of neurons widely distributed across the cerebrum, the cerebellum, and the brain stem. Study of saccades is popular since they can intermediate ways of studying motor control, cognition and memory. From saccade analysis it has been possible to identify distinct populations of neurons from brainstem to cerebral cortex that

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