The Neural Origins and Applications of Human Error Processing

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Introduction

The human brain has developed complex neural and cognitive mechanisms that deal with errors. Error awareness and processing is mediated by the supervisory cognitive control system. This system is concerned with the effortful activation and allocation of cognitive resources in the selection and processing of task-relevant information for the purposes of maximizing performance on tasks involving high difficulty, complexity, response conflict, or novelty [1]. Two components of control are distinguished: the *regulative control* is responsible for activation and implementation of control related processes; whereas the *evaluative control* deals with monitoring for the presence of errors and/or response conflicts and if needed with taking compensatory actions. Evaluative control is associated with the anterior cingulate cortex (ACC), which is also responsible for regulating emotional responses, while the regulative control is associated with various sites in the prefrontal cortex (PFC).

Objective

The objectives of this talk are: 1) to familiarize the audience with the brain mechanisms dealing with awareness of erroneous responses, 2) to explore options for measuring physiological correlates of such brain mechanisms, and 3) to present practical applications that can benefit from these measurements.

Brain responses to errors

Brain activity produces electromagnetic signals which result from the synaptic current flowing between the neurons in the brain cortex. These signals can be measured non-invasively along the scalp using an appropriate sensing technology, such as the electroencephalogram (EEG). EEG can be very useful in studying the functional role and the interaction between the different systems involved in various mental states and processes. *Event-related potentials* (ERP) are patterned voltage changes embedded in the ongoing EEG that reflect a process in response to a particular event.

The brain responses to errors can be also quantified using this technique. The electrophysiological reflection of the evaluative cognitive control function is called Error-related potential (ErrP). Depending of the source and the brain's awareness of the error different types of ErrPs can be distinguished. ErrP emerging shortly after an error made by a human subject, usually in a choice reaction task, requiring a quick response to a stimulus, is called error-related negativity (ERN) or response ErrP. Another type of ErrP, the feedback ErrP, appears shortly after feedback indicating an erroneous response from the subject, in e.g. a reinforcement learning task. Whereas these neural correlates of error awareness are manifested after errors committed by the subjects themselves, ErrPs are also present after an observation of an error, for example committed by the interface the subject is interacting with. These are known as interaction ErrPs.

Possible applications

Understanding the origins of the different types of error potentials, their characteristic features and the factors affecting them would allow for their application in various contexts including: ensuring higher levels of safety, performance, and user experience enhancement. Interaction ErrPs are already used in brain-computer interface (BCI) systems to adapt the pattern recognition algorithms and increase the classification accuracy. Other systems relying on automated pattern recognition, such as speech recognition, face detection, etc., can also benefit from similar approach. Detecting and preventing human errors when time-critical decision making is required, for

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professionals such as pilots, air-traffic controllers, surgeons, or drivers, can significantly improve safety. Error recognition can also help in optimal behavior learning by decreasing the likelihood of repeating erroneous decisions in the same context (biofeedback).

References

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