

# Chapter 29

## Feedback–Related Negativity and its Clinical Implications

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### ABSTRACT

*Appropriate processing of feedback information is critical for human executive functions that guide goal-oriented behavior. Feedback-related negativity (FRN) measurements are feedback signals that are recorded through the scalp and convey unpredicted bad/negative information. This study attempts to characterize FRN in the context of individual psychological disposition, specifically impulsivity. The results show that non-planning individuals produce smaller FRN signals than planning individuals when performing both monetary (experiment 1) and non-monetary (experiment 2) gambling tasks, suggesting that impulsive individuals are prone to make risky choices and to show less evaluation processing and lower negative feedback. Furthermore, the clinical utility of FRN measurements was examined with regard to assessing frontal lobe functions in patients with brain lesions. Reductions in FRN amplitudes in response to go-nogo tasks were associated with impaired inhibition responses. These findings suggest that FRN measurements are useful for electrophysiological assessments of patients with impaired inhibitory control.*

### INTRODUCTION

Monitoring responses and outcomes is an executive function that guides goal-oriented behavior, enabling corrections and adjustments when actual outcomes do not match expected or intended

outcomes. There are three types of event-related evoked potentials (ERP) elicited when the brain monitors performances and outcomes: error-related negativity (ERN) (Gehring, Coles, Meyer, & Donchin, 1995), correct-response negativity (CRN) (Vidal, Hasbroucq, Grapperon, & Bonnet, 2000), and feedback-related negativity (FRN) (Nieuwenhuis et al., 2002).

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A current theory suggests that FRN is generated when a negative learning signal (a punishment) is conveyed to the anterior cingulate cortex via the mesencephalic dopamine system. This signal is used by the anterior cingulate cortex to modify performance during the task at hand. Such negative prediction error signals are used to improve performance on subsequent tasks. When the monitoring system in the basal ganglia detects outcomes that are worse than expected, it produces phasic decreases in dopamine signals and disinhibits the anterior cingulate cortex neurons. This process appears as a negative ERP component on the front-central scalp. Converging evidence suggests that three ERPs (ERN, CRN and FRN) are generated by the medial frontal regions, although there is controversy regarding the precise locations of their sources. Although a large number of psychophysiological experiments have been undertaken to construct a theoretical framework of cognitive processes for response monitoring, their clinical implications have not yet been established. In this chapter, we attempt to characterize the FRN component in the context of individual psychological disposition and to associate FRN with frontal lobe functions in a group of patients suffering from brain infarctions.

## **THEME 1: FRN AND IMPULSIVITY**

Impulsivity is a trait that, lacking forethought regarding possible outcomes, yields hasty and unplanned responses to internal or external stimuli (Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001). In studies exploring the neurobiological bases of impulsivity, measurements of impulsivity are usually based on the reward-discounting model, in which impulsivity is defined as the inability to wait for a delayed, more substantial reward (Monterosso & Ainslie, 1999), or the rapid-response model, in which impulsivity is defined as responding without adequate assessment of context (Yeung & Sanfey, 2004). We hypoth-

esized that FRN responses might be a marker of impulsivity, because impulsive individuals fail to learn from negative feedback. In the first study, we investigated the relationship between self-reported impulsivity and subtracted FRN during monetary gambling tasks in healthy adults (Onoda, Abe, & Yamaguchi, 2010).

### **First Experiment**

Prior to the experiment, 19 healthy adult participants (fourteen female, mean age = 23.3 years) were asked to complete the Barratt Impulsiveness Scale (BIS) (Patton, Stanford, & Barratt, 1995). The BIS has a total score based on thirty items and subscores for the following three subcategories: motor impulsivity (physically acting without thinking), cognitive impulsivity (making decisions quickly), and non-planning (lack of prior planning or future orientation).

In the experiment, each participant performed a gambling task. At the start of each trial, a choice stimulus was displayed for 1 s. It consisted of two numbers, 10 and 50 (representing money valued in Japanese yen), on the left and right side of the screen. The participant was instructed to select one number by pressing the left or right. The feedback stimulus indicated a gain (+) or loss (–) followed by their selected number (+50 or –50 for the choice of 50, and +10 or –10 for the choice of 10). The probability of gain and loss were equal (50%).

A 128-channel Netstation system (EGI Inc.) was utilized to record EEG signals using a band-pass of 0.02 – 100 Hz and a sampling frequency of 250 Hz. Each continuous EEG was divided into a 200 ms pre-stimulus period and an 800 ms feedback period. The FRN was measured as the largest negative peak occurring in the subtraction waveform (loss – gain) in the latency window of 250 – 400 ms.

The average reaction time for the gambling task was  $513 \pm 70$  ms, and the average risky choice ratio was  $0.54 \pm 0.11$ . The selection of the large amount rather than the small amount amounted to

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