

# ERROR MONITORING IN PERCEPTUAL DECISIONS

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## INTRODUCTION

An important function of the human brain is to adapt behavioral actions based on both correct and erroneous decisions. Event related potentials (ERPs) have been revealed to be a powerful tool for studying performance monitoring associated with correct and erroneous outcomes. Two ERP components associated with errors have been described, but their functional meaning remains unclear. The first component, called the error-related negativity (ERN), appears about 80-100 ms after human subjects make errors in a reaction time task. The second component, called error positivity (Pe), is a slow positive wave that peaks about 200-450 ms after an incorrect response and that usually follows the ERN. One property of the ERN is that it can be elicited following presentation of error feedback. This waveform, named the feedback-related negativity (FRN), is a fronto-central negative deflection that peaks about 250-350 ms after negative feedback stimuli.

The main objective of this study is to understand the functional meaning of the error-related components. We have recorded the ERPs while human subjects performed in a perceptual length discrimination task (LDT) in which they have to discriminate the length of lines. Subjects received feedback after correct or incorrect behavioral responses.

Trial-by-trial and population analyses confirmed that, when feedback was provided, the FRN wave followed incorrect choices. Interestingly, a positive wave not previously described, the feedback-related positivity (FRP) followed incorrect choices.

## MATERIAL & METHODS

### SUBJECTS

n= 12 (4 males and 8 females), mean age= 22.6, Sd= 2.41

### STIMULI

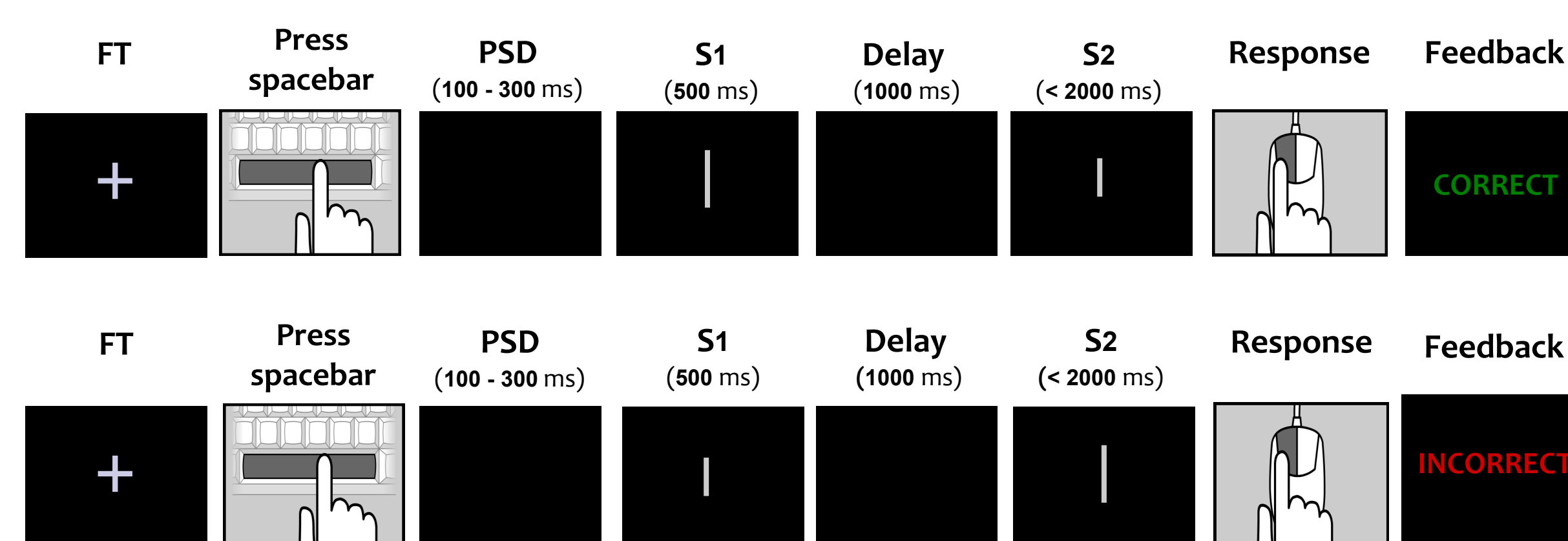
■ **First stage:**  
In the first session **three First Stimuli (S1)** (vertical lines 1.6°, 2° and 2.4° length) x **ten Second Stimuli (S2)** for each S1 (5 shorter and 5 larger from 1.1° to 2.9° in 0.1° steps) were used for all subjects.

■ **Second stage:**  
In the recording sessions **four First Stimuli (S1)** x **four Second Stimuli (S2)** for each S1 (2 shorter and 2 larger) were used for all subjects.

Individual psychophysical functions obtained in session 1 were used to select the stimuli for the second stage.

### TASK

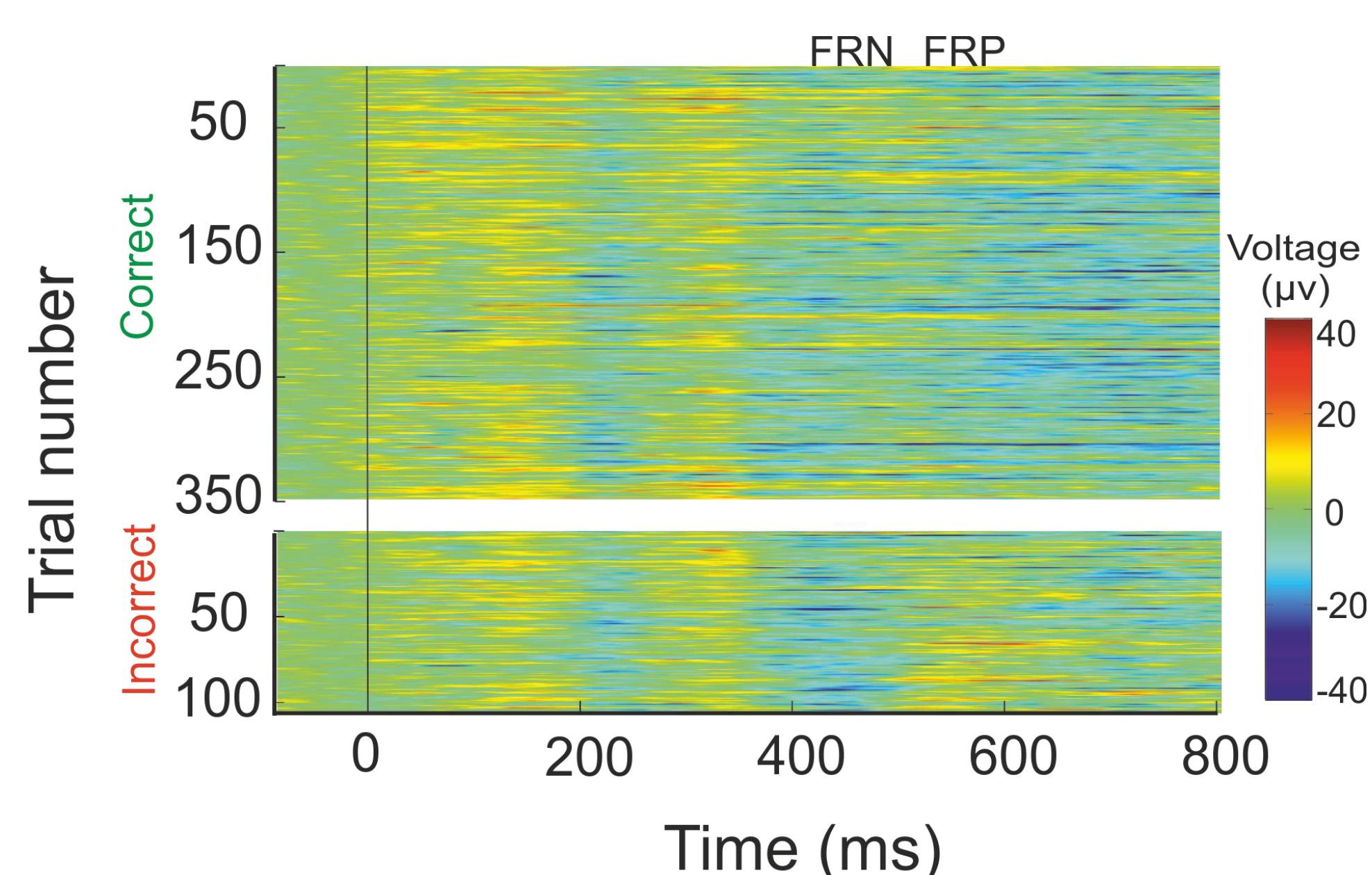
Subjects had to decide whether a second line (S2) was shorter or larger than a previous one (S1). Electroencephalography (EEG) was recorded from 60 standard channels while participants performed in a length discrimination task (LDT).



**Figure 1.** Sequence of events during the length discrimination task. FT (fixation target) PSD (pre-stimulus delay).

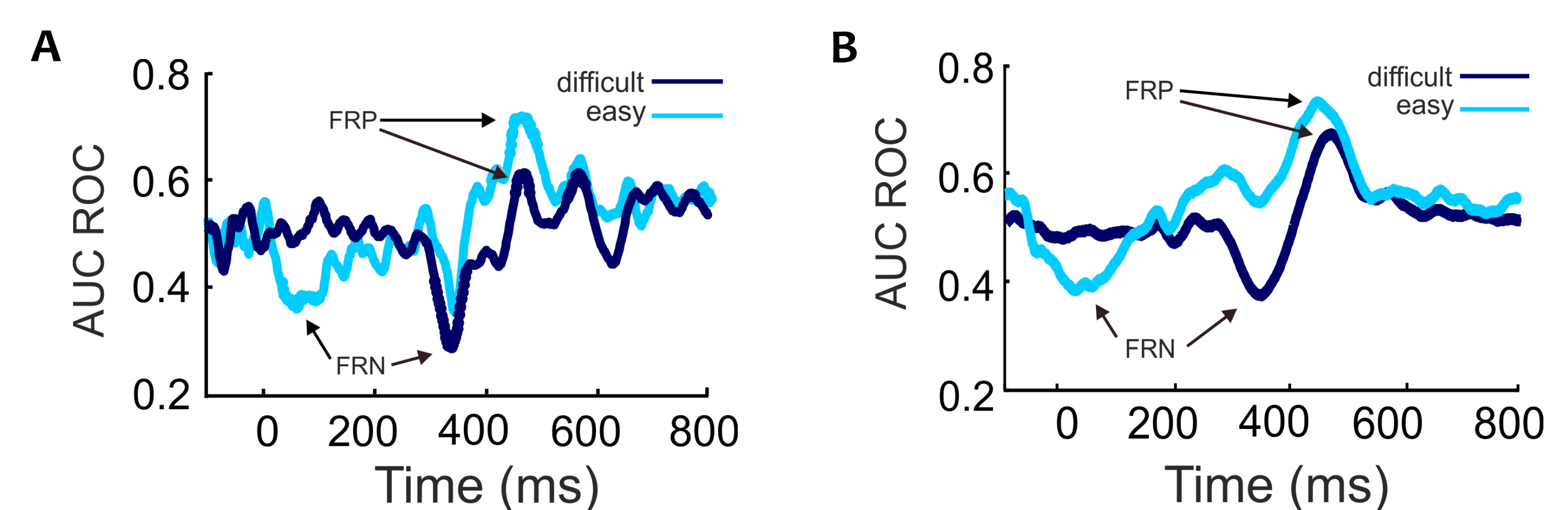
## RESULTS

### OUTCOMES – RELATES ERP COMPONENTS

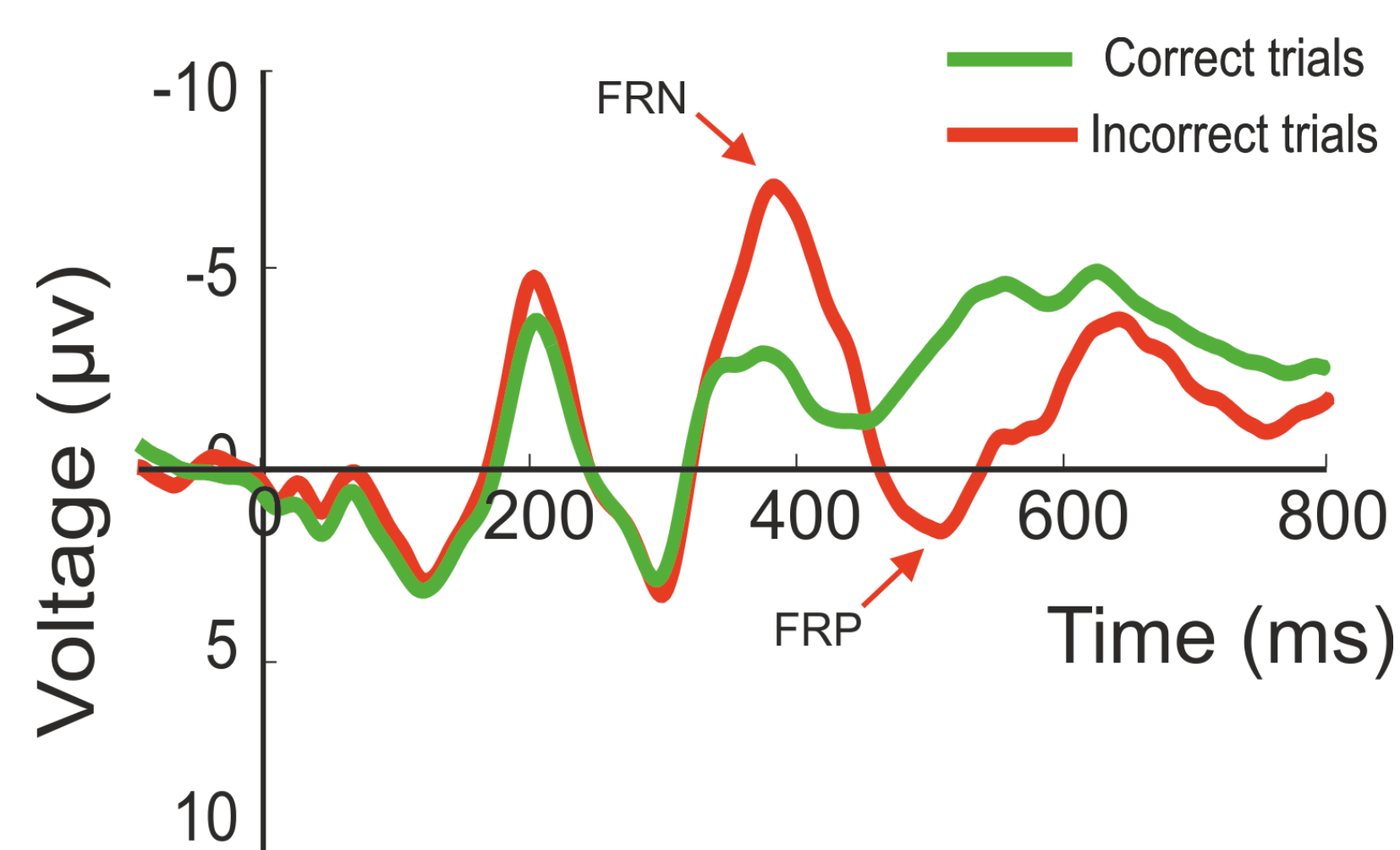


**Figure 2.** Single-trial analysis reveals the existence of two components the FRN and FRP that are different for correct and incorrect trials. Each line represents the voltage as a function of time, recorded at frontal electrode (Fz) for one subject, time-locked to feedback onset (time zero) for correct and incorrect trials. Negative voltages on incorrect trials around 400 ms correspond to FRN component and positive voltages on incorrect trials around 550 ms correspond to FRP component.

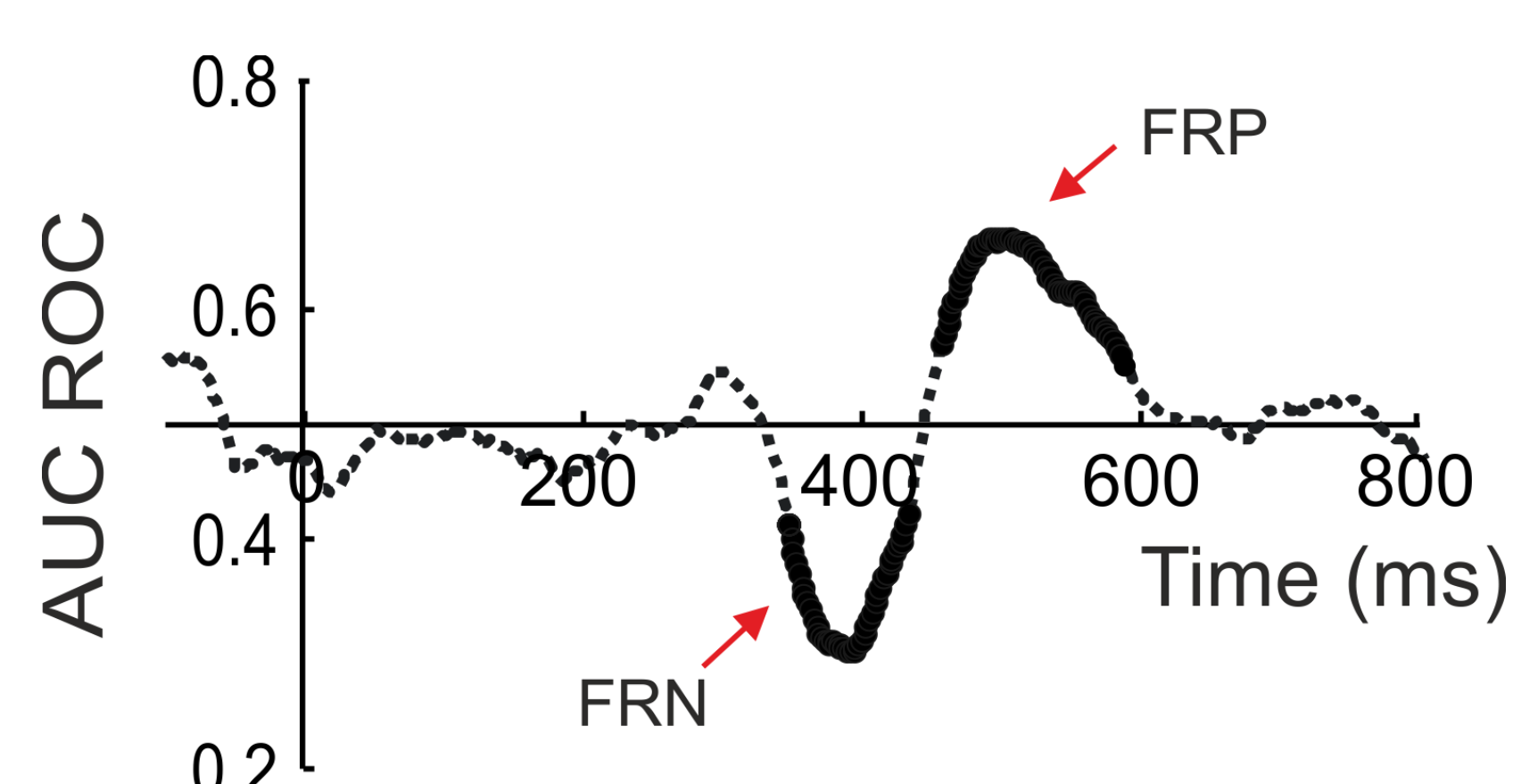
### EFFECT OF THE DIFFICULTY ON FRN AND FRP COMPONENTS



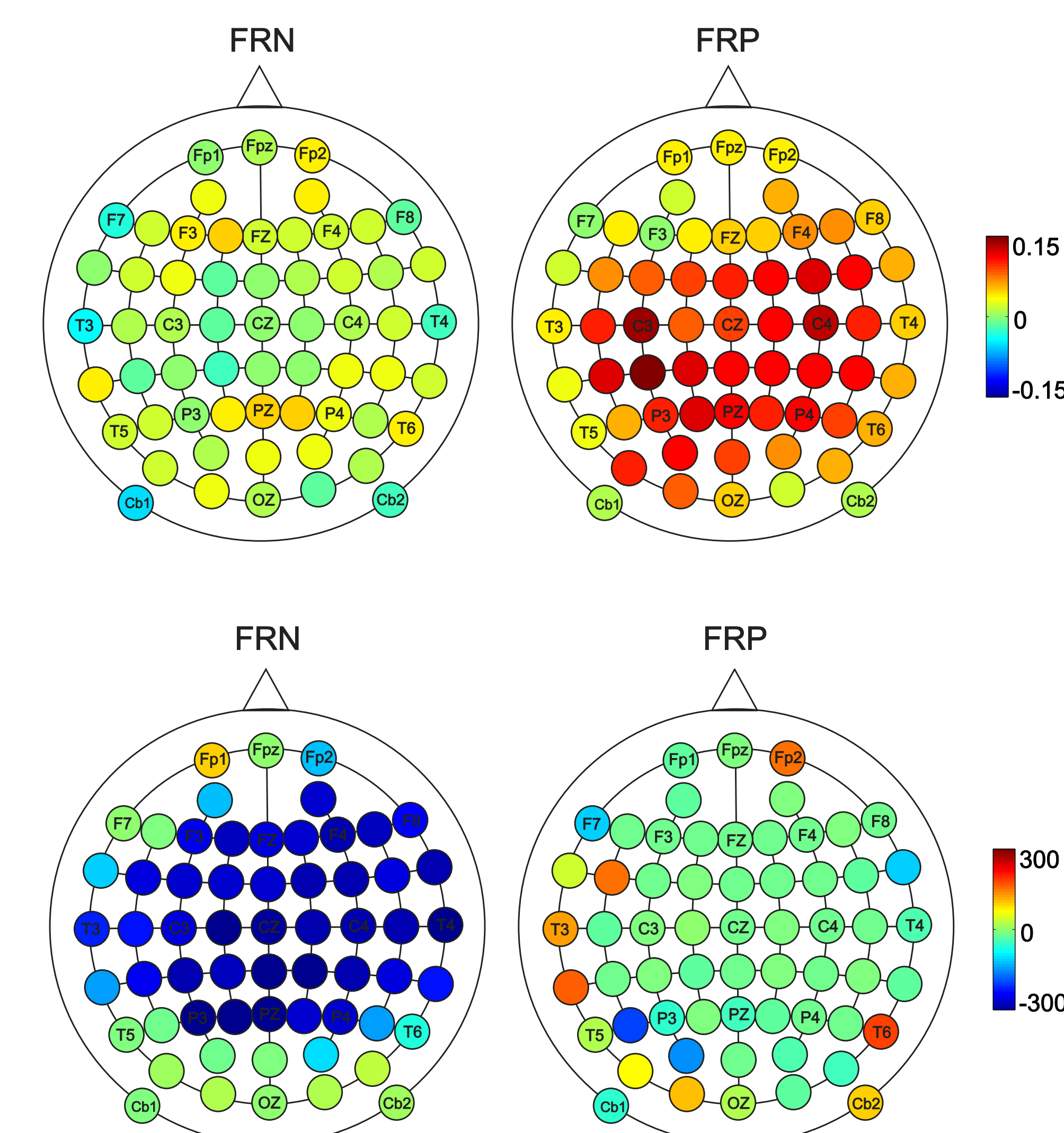
**Figure 5.** Area under the ROC curve (AUC ROC) as a function of time for one subject (figure A), and for all sample (N=9) (figure B), comparing the ERPs after easy (soft line) and difficult (dark line) trials at electrodes F8 and C2A respectively. Thicker traces indicate ROC periods significantly different from 0.5 (permutation test, n=200). The latency of FRN is significantly shorter for easy than for difficult trials and the amplitude of FRP is higher for easier than for difficult trials.



**Figure 3.** Mean ERP waveforms at electrode Fz for correct (green line) and incorrect (red line) trials as a function of time for the same subject. Zero on abscissa indicates the feedback onset. Negative is plotted up by convention. Arrows indicate the peak of the FRN and the FRP in the waveform associated with negative feedback after incorrect responses



**Figure 4.** Area under the ROC curve (AUC ROC) as a function of time comparing the ERPs after incorrect and correct trials at electrode Fz. Blue and red thicker traces indicate ROC periods significantly different from 0.5 (permutation test, n=200), that correspond with the two components FRN and FRP, respectively.



**Figure 6.** Effects of the difficulty on FRN and FRP components comparing correct vs incorrect trials.

Effects of the maximum value (upper panel) and on the latency of maximum value (lower panel) of the AUC ROC comparing correct vs incorrect trials for easy vs difficult comparisons.

## CONCLUSIONS

The results shown here suggest that the FRN and FRP components are related to performance monitoring and reflect different cognitive processes:

- FRN could be related to an automatic error detection system because its latency is shorter in the easy trials than in the more difficult ones. This system could be responsible for fast behavioral corrections.
- FRP could be reflected conscious evaluation of the previous decision processes. This evaluation would be related to long-term changes in the decision processes and could be useful for improving future decisions.