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The effect of monetary punishment on error evaluation in a Go/No-go task

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ABSTRACT

Little is known about the effects of the motivational significance of errors in Go/No-go tasks. We investigated the impact of monetary punishment on the error-related negativity (ERN) and error positivity (Pe) for both overt errors and partial errors, that is, no-go trials without overt responses but with covert muscle activities. We compared high and low punishment conditions where errors were penalized with 50 or 5 yen, respectively, and a control condition without monetary consequences for errors. Because we hypothesized that the partial-error ERN might overlap with the no-go N2, we compared ERPs between correct rejections (i.e., successful no-go trials) and partial errors in no-go trials. We also expected that Pe amplitudes should increase with the severity of the penalty for errors. Mean error rates were significantly lower in the high punishment than in the control condition. Monetary punishment did not influence the overt-error ERN and partial-error ERN in no-go trials. The ERN in no-go trials did not differ between partial errors and overt errors; in addition, ERPs for correct rejections in no-go trials without partial errors were of the same size as in go-trial. Therefore the overt-error ERN and the partial-error ERN may share similar error monitoring processes. Monetary punishment increased Pe amplitudes for overt errors, suggesting enhanced error evaluation processes. For partial errors an early Pe was observed, presumably representing inhibition processes. Interestingly, even partial errors elicited the Pe, suggesting that covert erroneous activities could be detected in Go/No-go tasks.

1. Introduction

Recent studies focusing on error monitoring have investigated whether and to which extent the error (−related) negativity (ERN; Falkenstein et al., 1990; Gehring et al., 1990) and the error positivity (Pe; Falkenstein et al., 1991) in event-related potentials (ERPs) may reflect the motivational significance of errors. In particular, it has been studied whether the ERN or Pe amplitude would increase with monetary punishment (Endrass et al., 2010) or aversive feedback in general (Riesel et al., 2012). However, to our knowledge, only one study has investigated this question for a Go/No-go task (Groom et al., 2013). In no-go trials, one often observes EMG activities for the hand that successfully withholds the overt response; such covert EMG activities in the absence of overt responses are referred to as partial errors. Although partial-error trials are classified as correct, they do elicit ERNs (e.g., Vidal et al., 2000). Therefore, it is of interest to study the partial-error ERN in successfully inhibited no-go trials, which might superimpose with the N2 component typically observed in correct no-go trials (Masaki et al., 2012).

Analyzing partial errors is useful to investigate the functional role(s) of the ERN (Burle et al., 2008; Carbonnell and Falkenstein, 2006; Vidal et al., 2000, 2003), for example, whether the overt-error ERN, partial-error ERN, and the correct response negativity (CRN; Ford, 1999) all reflect response conflict (Burle et al., 2008; Carbonnell and Falkenstein, 2006). Burle et al. (2008) found that the amount of conflict in overt-errors differed from that in partial errors. These results do not support the conflict monitoring theory (Burle et al., 2008; Carbonnell and Falkenstein, 2006). Hence, it was proposed that the partial-error ERN might reflect the on-line evaluation of responses (Carbonnell and Falkenstein, 2006; Yordanova et al., 2004) and the emotional evaluation of errors (Nieuwenhuis et al., 2003; Gehring et al., 2000; Vidal et al., 2000). Thus, further studies are needed to elucidate the effect of the motivational significance of errors on full and partial-error ERN and Pe.

Concerning the impact of motivational significance of errors on ERN in general, there are some discrepancies among previous findings. A number of studies reported that monetary punishment (Endrass et al., 2010; Potts, 2011) and aversive sounds (Riesel et al., 2012) increased

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ERN amplitude. Other studies reported null effects (Chiu and Deldin, 2007; Groom et al., 2013) or even decreased ERNs associated with more negative events (Ogawa et al., 2011; Stürmer et al., 2011).

As compared to the ERN, the Pe appears to be more sensitive to punishment, in line with the idea that the Pe reflects error evaluation and error awareness (for a review see Overbeek et al., 2005). Previous studies reported larger Pe amplitudes in monetary punishment than in neutral control conditions (Endrass et al., 2010; Maruo et al., 2016; but see also Groom et al., 2013). Thus, the increase of Pe amplitude in monetary punishment conditions may reflect enhanced error evaluation. According to previous studies (e.g., Masaki et al., 2012), the ERN on partial-error trials may overlap with the no-go N2, elicited by no-go signals and considered to reflect response inhibition (Kok, 1986) or response conflict (Nieuwenhuis et al., 2003). In addition, previous studies of the no-go N2 likely included partial errors in correct-rejection trials (successful no-go trials without incorrect covert muscle activity) because most of them did not measure covert muscular activity. The influence of partial errors on the no-go N2 has not been fully investigated. Although conflict monitoring theory asserts that pre-response conflict on correct trials can manifest in the N2 (Botvinick et al., 2001), no-go N2 in previous studies might reflect, at least to some extent, partial-error ERNs. More recently, on the basis of temporo-spatial ERP analyses Nguyen et al. (2016) suggested that the no-go N2 on partial inhibition trials – that is, for partial errors – may reflect error-related processing. If this is the case, no-go N2 should be larger in partial errors than in pure correct rejections in no-go trials.

In this study, we aimed to investigate the effects of the motivational significance of errors on the ERN and the Pe by applying monetary punishment for errors. We employed a Go/No-go task and compared amplitudes of the overt-error ERN, the partial-error ERN, and the Pe for low and high punishment, and a neutral control condition. If negative affect (fear of punishment) influences the ERNs (e.g. Endrass et al., 2010), their amplitudes should increase with the magnitude of monetary punishment if the overt-error ERN and the partial-error ERN share similar error monitoring processes (Maruo et al., 2016). If negative affect does not influence the ERN (Chiu and Deldin, 2007; Groom et al., 2013), they should not differ among punishment and control conditions. In contrast, if monetary punishment diminishes error detection (Stürmer et al., 2011), the ERN should even be smaller in the punishment than in the control conditions.

Because the Pe presumably reflects error evaluation (Endrass et al., 2010), its amplitude should increase with the severity of the penalty for errors. If the Pe reflects error evaluation independent of the ERN (Falkenstein et al., 1991), the impact of negative affect should be more pronounced for the Pe than for the ERN. In addition, Pe amplitude should be larger in the overt-error trials than in the partial-error trials, because partial errors in stimulus-response compatibility tasks are not consciously detected (e.g., Vidal et al., 2000).

We also aimed to test whether or not the partial-error ERN differs from overt-error ERN because the functional significance of the ERN is still under discussion. If the ERN reflects response conflict (Carter et al., 1998; Botvinick et al., 2001; Nieuwenhuis et al., 2003; Yeung et al., 2004), the ERN should be larger in – high conflict – overt-error than in – low-conflict – partial-error trials. However, if the ERN reflects on-line evaluation of responses (Carbonnell and Falkenstein, 2006), the ERN would not differ between overt error and partial error trials.

2. Method

2.1. Participants

Twenty-six male participants were recruited from Waseda University's Faculty of Sports Sciences. Nine participants were excluded due to a low number of error trials (< 5; Olvet and Hajcak, 2009). The final sample included 17 participants (*mean age* = 21.7 years: *SEM* = 1.16). Cohen's effect sizes were calculated to ensure the reliability of obtained results, adopting values of 0.10, 0.25, and 0.40 indicating small, medium, and large effect sizes, respectively (Cohen, 1992). To estimate how much our study was sufficiently powered to detect significant difference, we conducted a power analysis using G*Power 3 (Faul et al., 2007) and obtained 1-β values 0.13, 0.57, and 0.94 for small, medium, and large effect sizes, respectively. Participants had normal or corrected-to-normal vision and were remunerated with 2400 yen (about 28 U.S. dollars). Written informed consent was obtained; the study was approved by the Waseda University Ethics Committee.

2.2. Procedure

The participants performed a Go/No-go task where the letter "V", or "M" (0.7° × 0.7°) was presented in white on a dark computer monitor, placed at a viewing distance of 1 m. Forearms and palms rested comfortably on a table to minimize response-unrelated movements. Half of the participants were to respond to "V" but not to "M", and vice versa for the other half. The Go/No-go task consisted of 70% go trials and 30% no-go trials. Each trial began with a letter presented for 100 ms, followed by a blank screen for 1350 ms until the next trial started. If participants did not respond within 450 ms in go-trials, the feedback "Too Late!" was presented for 500 ms. Omitted go-responses were not regarded as errors but excluded from analyses.

Responses were recorded with a micro-switch that required an upward displacement for switch closure. Participants placed their middle finger on the end of a plate (30 × 20 × 1 mm) attached to a cantilever attached to the micro-switch. Lifting the finger resulted in switch closure defining the overt response onset. In high and low punishment conditions, participants were given a 1500 yen allotment and informed that they would lose 50 or 5 yen, respectively, for each incorrect response; they might lose their whole allotment but their total could never become negative. In the control condition no allotment was provided; participants were told that they would neither lose nor earn money. Participants were given 30 practice trials before the experiment proper and then performed four blocks of 100 trials each per condition (1200 trials total). The three conditions were conducted block-wise, counter-balanced in order across participants (e.g., AABBCCCCBBAA).

2.3. EEG recording

The EEG was recorded from 128 sites with Ag/AgCl electrodes. Horizontal electrooculograms were recorded from the left and right outer canthi, and vertical electrooculograms from above and below the left eye. These signals were recorded with DC and 205-Hz low-pass filters, using the Biosemi Active Two system (Biosemi Inc.). EMGs were bipolarly recorded from the extensor digitorum muscle of the responding forearm with Ag/AgCl electrodes, also using the Biosemi Active-Two system. Off-line, EMG signals were high-pass filtered at 5.31 Hz and full-wave rectified with Brain Vision Analyzer (Brain Products). All physiological signals were digitized at 1024 Hz.

2.4. Data analysis

Reaction time (RT) was measured as the interval between stimulus onset and microswitch closure. The error analysis reported here focused on no-go trials because in go trials there were only few errors. We classified trials as overt errors whenever participants responded to no-go signals. Responses in no-go trials were classified as partial errors if there was muscular activity in a time window ranging from 100 to 500 ms after no-go signal onset that did not lead to switch closure. The threshold for EMG onset was a deflection exceeding 4.0 SDs of the rectified EMG derived during a pre-response baseline of −700 to −550 ms, using a semi-automatic macro implemented in Brain Vision Analyzer. The validity of the EMG onsets was visually inspected for each trial and corrected manually if necessary (Vidal et al., 2000).