The drive to control : how affect and motivation regulate cognitive control

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Electrophysiology of Reward and Conflict Adaptation

"The gyrus cinguli is the seat of dynamic vigilance by which environmental experiences are endowed with an emotional consciousness."

James W. Papez

This chapter is based on:

van Steenbergen, H., Band, G.P.H., & Hommel, B. (submitted for publication). Reward counteracts conflict-driven attentional adaptation: Electrophysiological evidence.

Abstract

Recent findings suggest that positive feedback counteracts the attentional adaptation to conflict triggered by incompatible distracting information. Here we hypothesize that these compensatory effects of reward on conflict processing may regulate subsequent behavioral optimization and perceptual focusing via the Anterior Cingulate Cortex (ACC). We recorded EEG while participants performed an arrow flanker task with monetary gain or loss as arbitrary feedback between trials. As predicted, we found a reduction in conflict adaptation for trials in which conflict was followed by monetary gain, a behavioral effect accompanied by a modulation in early visual processing related to the processing of the distracters. Moreover, time-frequency analyses showed that reward inhibits ongoing frontocentral theta oscillations induced by previous conflict, an interaction presumably reflecting ACC modulation. These data provide a first important step towards understanding the neural mechanism underlying the affective regulation of conflict-driven behavior.

Introduction

When people face adverse events, they typically adapt their attentional resources to deal with this demand. This adaptation of cognitive effort and attentional control has been reported for numerous changes in situational demands varying from increases in task difficulty (Botvinick et al., 2001; Dreisbach & Fischer, 2011; Gratton et al., 1992; Hillgruber, 1912), the experience of stressful and aversive stimulation (Easterbrook, 1959; Finkelmeyer et al., 2010) to the registration of performance errors (Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004). More recent work shows that positive affective states may undo or neutralize the impact of these adverse events, as measured by self-report, behavioral, physiological, and neural measures (Cabanac, 1971; Fredrickson et al., 2000; Leknes & Tracey, 2008; van Steenbergen, Band, & Hommel, 2009). Thus, aversive and rewarding events may compensate for each other's effects, possibly via a common mechanism that aims at behavioral optimization (Cabanac, 1992; Botvinick, 2007).

The anterior cingulate cortex (ACC) is thought to play an important role in this optimization process (Botvinick et al., 2001; Gehring & Willoughby, 2002; Holroyd, Pakzad-Vaezi, & Krigolson, 2008). Event-related brain potential (ERP) studies have shown that the ACC generates a mediofrontal negativity wave, called the N2 component, which can be elicited by conflict, as triggered by competing responses in tasks where participants need to focus on a relevant target while ignoring distracting information (Forster, Carter, Cohen, & Cho, 2011; Yeung, Botvinick, & Cohen, 2004). It has been suggested that feedback stimuli signaling positive events and reward may inhibit this neural conflict signal, as evidenced by an opposite, positive-going, deflection in the ERP with a similar temporal and spatial distribution as the N2 component (Holroyd et al., 2008; Holroyd & Coles, 2002). These and other data suggest that unexpected monetary rewards may have a neutralizing effect on conflict monitoring activity in the ACC, presumably via phasic dopamine signaling from the midbrain (Jocham & Ullsperger, 2009; Munte et al., 2008; Schultz, 2007).

The present study was designed to investigate whether these neutralizing effects of reward on neural conflict monitoring may account for the recent observation that unexpected reward prevents the adaptive upregulation of attentional control in conflict-inducing flanker tasks (van Steenbergen et al., 2009). In flanker tasks, participants respond to centrally presented visual targets while ignoring surrounding non-targets that may signal the same or a different response as the target (Eriksen & Eriksen, 1974). The degree to which performance is worse in response-

incompatible as compared to response-compatible trials can be taken to reflect the participant's ability to focus on relevant information in the face of distraction. Interestingly, the size of this compatibility effect is typically reduced in trials following incompatible trials (the so-called conflict-adaptation effect; Gratton et al., 1992), which has been taken to reflect a conflict-induced sharpening of the attentional focus (e.g., Botvinick et al., 2001; Egner, 2007). However, we have recently shown that unexpected positive feedback presented immediately after a response in an incompatible trial (cf. Figure 1A) eliminates the conflict-adaptation effect, presumably by counteracting attentional adaptation to conflict (van Steenbergen et al., 2009). Given the well-known role of the ACC in producing adaptive behavior, this effect of reward on subsequent adaptation might be driven by a modulation of ongoing oscillatory neural activity produced by previous response conflict (Botvinick et al., 2001; Cohen, Ridderinkhof, Haupt, Elger, & Fell, 2008; Kerns et al., 2004).

Traditional ERP techniques are not suitable to address this hypothesis because averaging single-trial EEG traces will reveal only neural activity that is phase-locked to the onset of the stimulus (cf. Luu, Tucker, & Makeig, 2004; Yeung et al., 2004). In contrast, time-frequency decomposition analyses such as complex wavelet convolutions can assess sustained conflict-related processing in flanker, Stroop, and Simon tasks (Cavanagh, Cohen, & Allen, 2009; Cohen et al., 2008; Hanslmayr et al., 2008). Wavelet analyses are sensitive to oscillatory activity that varies in phase from trial to trial and can provide measures of instantaneous power (i.e., energy at different frequencies, a.k.a. induced activity) and inter-trial phase coherence (i.e., consistency of oscillation onset across trials, a.k.a. evoked activity). Cumulating evidence suggest that ongoing fronto-central midline theta (4-8 Hz) power measured at the scalp can be modulated by conflict (Cohen et al., 2008; Hanslmayr et al., 2008) and feedback processing (Cohen, Elger, & Ranganath, 2007; Cohen, Elger, & Fell, 2009). As implied by intracranial recordings, this theta effect may originate from the ACC and the surrounding medial frontal wall (Cohen et al., 2008). Based on these observations, we hypothesized that oscillations in the theta band may reflect the actual conflict parameter and the compensatory effects of reward on the conflict state, and thus show a conflict-induced increase that is attenuated by subsequent unexpected positive feedback.

A second aim of the present study was to test the idea that conflict and reward do not only co-modulate subsequent selective attention and the resulting behavioral adaptation (cf. van Steenbergen et al., 2009), but also alter early distracter processing in the visual cortex. Thus, if conflict on a previous trial intensifies the

attentional focus on the target on the subsequent trial, this should lead to a shallower processing of the surrounding flankers (cf. Treue, 2001). Reward may counteract this effect. Evidence for distracter-related modulation in the visual cortex in humans has mainly been provided by fMRI studies on the effect of perceptual and working memory load on attentional focus (for a review, see Lavie, 2005). Reduced distracter activation in visual cortex has also been reported during post-error adaptation (Danielmeier, Eichele, Forstmann, Tittgemeyer, & Ullsperger, 2011). However, there is no evidence yet that conflict in correct responses triggers a similar adaptation (Egner & Hirsch, 2005). In order to test this possibility, our task used vertically moving flankers that elicit a motion-sensitive ERP component in the visual cortex known as the motion visual evoked potential (motion VEP; for a review, see Heinrich, 2007). Using the motion VEP as an index of distracter-related processing, we hypothesized it to be sensitive to the modulation of attentional focus triggered by the interaction between reward and conflict on the preceding trial.

To summarize, we predicted that 1) conflict induced by incompatible flankers increases fronto-central midline theta oscillations and sharpens the attentional focus, thus decreasing distracter-related visual processing and behavioral compatibility effects in the subsequent trial; and 2) the presentation of a rewarding stimulus immediately after an incompatible trial counteracts these neural and behavioral effects. This was tested in a flanker task by providing unpredictable monetary gains or losses during the response-stimulus interval (see Figure 1A). Neutral trials, without gain or loss, were also included to provide a baseline condition.

Methods

Participants

Thirty-three right-handed university students participated (18–27 years of age; 6 men and 27 women). They were informed about the duration of the experiment (2 hours, including EEG preparation) and that they would earn € 13 (or course credits), plus a bonus that could increase to a few euros if they were lucky. Three participants were excluded from analyses because of technical problems during the acquisition of the physiological data. The experiment was conducted in accordance with relevant regulations and institutional guidelines and was approved by

the local ethics committee from the Faculty of Social and Behavioral Sciences. All students read and signed informed consent.

Experiment

Subjects were informed about the task and that positive, negative, and neutral cartoon faces (smilies, grumpies, and neutral faces) would appear between trials independent of their responses. The computer would add € 0.20 to their bonus if a smiley appeared and would subtract € 0.20 if a grumpy appeared. Neutral cartoon faces were not associated with any gain or loss. Subjects were encouraged to make quick and accurate responses with their index fingers, to the central target of an arrow stimulus array. After informed consent, EEG preparation and a 6-min resting state EEG measurement, participants performed 24 practice trials in which they were given accuracy feedback for 600 ms at the end of each trial. Following this practice block, subjects performed a motion localizer block with 168 flanker trials using moving and still flankers (not followed by any faces or feedback). These trials started with a fixation cross (800 – 1000 ms, jittered), after which the stimulus array was presented until a response was given (maximum duration of 1,000 ms).

Task instructions were repeated before the test trials started. Participants were informed about the seven blocks in which they would earn money, each lasting about 5 min. Self-paced break screens were shown in between. We did not tell the subjects that the last test block annexed a filler block of 36 trials, where gain trials were overrepresented. This resulted in a random bonus payoff of between € 1.60 and € 4.00 for each person. The stimuli were presented on a white background on a 17-in. CRT monitor (1025 x 768 pix), and participants viewed the monitor from a distance of about 60 cm. Each of the 840 test trials started with a fixation cross (900 - 1100 ms, jittered), followed by the stimulus array (99 x 7 pix) that always comprised a target without motion and four vertically moving flankers (using a triangle wave function, amplitude = 10 pixels, period = 200 ms). Targets and flankers were black arrows pointing either left or right. We used the same number of compatible (flankers in the same direction as the target) and incompatible (flankers opposite to the target) trials. Almost immediately (30 ms) after a response to the stimulus array or, in the case of omission, after 1,000 ms, a yellow line-drawn face (200 x 200 pix) was presented for 750 ms, after which the next trial started. The three types of cartoon faces appeared with equal probability and served to indicate monetary gain or loss.

EEG recording

Electroencephalographic (EEG) activity was recorded over positions AFz, F5, Fz, F6, FC3, FCz, FC4, C5, C3, C1, Cz, C2, C4, C6, TP7, CP3, CPz, CP4, TP8, P7, P3, Pz, P4, P8, PO7, POz, PO8, O1, Oz, and O2 of the 10/10 standard. Horizontal eye movements were calculated by bipolar derivations of electro-oculogram (EOG) signals over the left and right outer canthus. Vertical eye movements were calculated by bipolar derivations of signals above and below the left eye. Monopolar recordings were referenced to the common mode sensor (CMS) and drift was corrected with a driven right leg (DRL) electrode (for details see http://www.biosemi.com/faq/cms&drl.htm). In order to re-reference the data off-line, two electrodes were placed at the left and right mastoid. Signals were DC amplified and digitized with a BioSemi ActiveTwo system at a sampling rate of 512 Hz.

Data analysis

Behavioral data

Repeated measures analysis of variance (ANOVA) and t-tests were used to analyze correct reaction time (RT) and error rates for test trials at Trial N+1, as a function of the compatibility of Trial N+1 (I vs. C); the compatibility of Trial N (incompatible / conflict vs. compatible / no conflict); and the reward signal (gain, neutral, or loss), shown as arbitrary feedback after Trial N, see Figure 1A. To provide a stable baseline for conflict and reward at the trial N, we only included those trial sequences that followed correct responses and neutral feedback. In addition, the first two trials of each block, trials following an error, and trials with RTs not fitting the outlier criterion (2 SDs from the individual condition-specific mean) were excluded from the analysis.

EEG analyses

Off-line analyses were performed with Brain Vision Analyzer. After rereferencing the channels to the average mastoid, data were high-pass filtered 0.01 Hz (24 dB/oct), and ocular artifacts were corrected using the standard Gratton, Coles, & Donchin (1983) method. EEG artifacts were automatically identified using four criteria: 1) bad gradient (> 50 μV / sample), 2) bad max-min difference (> 200 μV / 200 ms), 3) bad amplitude (absolute value > 1000 μV), 4) low activity (< 0.50 μV / 100 ms). Before this procedure was applied, artifacts caused by high scalp impedance of a particular electrode were corrected on an individual basis (2 participants), using a linear derivation of surrounding electrodes. Artifacts elicited by power line noise were also corrected on an individual basis (15 participants) using

a low-pass 50 Hz filter (24 dB/oct). Stimulus-locked artifact-free segments were created for EEG activity during the motion localizer block and during the test trials. For the test trials we used exactly the same trials as those used for behavioral RT analyses, provided they were artifact free (see above).

Fronto-central theta oscillations as a function of compatibility and reward at Trial N segments were analyzed using a Continuous Wavelet Transformation as implemented in Brain Vision Analyzer (Morlet Complex waveform, frequency range from 2.5 to 50 Hz in 30 logarithmic steps, Morlet parameter c = 4.5). Induced power was calculated by averaging across trials after a percent change baseline correction from -300 to -100 ms. The amount of phase coherence was estimated using the Phase Locking Factor solution (version 1.1; 103), and was baselined from -300 to -100 ms for statistical analyses. After visual inspection, statistical analyses were conducted by entering average theta band (4-8 Hz) power and phase coherence values from 200 to 500, 500 to 800, and 600 to 700 ms windows for each condition into repeated measures ANOVAs and paired t-tests. For these analyses, we focused on data from electrode Cz because it showed the maximum modulation of reward on conflict-induced theta oscillation. One subject was excluded from these analyses because of an insufficient number of trials available (20 trials per condition on average) to perform reliable wavelet analysis.

Motion VEPs were identified in the motion localizer block by comparing ERPs elicited by moving flankers and still flankers. The Motion VEP was measured as the average ERP values from a window of 160 to 220 ms in occipital and occipito-temporal electrodes, using a 200-ms pre-stimulus baseline (cf. Heinrich, 2007). Statistical analyses (repeated-measures ANOVAs) of motion-related ERPs in the test trials at Trial N+1 segments were focused on electrode sites that showed a motion VEP maximum in the localizer block. Similar to earlier described methods (Heinrich, Schilling, & Bach, 2006), subjects with motion VEP amplitudes not exceeding a 2 uV threshold in both hemispheres during the motion localizer block were excluded from analyses in order to keep a sufficient signal-to-noise ratio (16 participants). Greenhouse-Geisser correction was applied whenever appropriate. For illustrative purposes, a 50-Hz low-pass filter was applied to all grand averages shown in Figure 3.

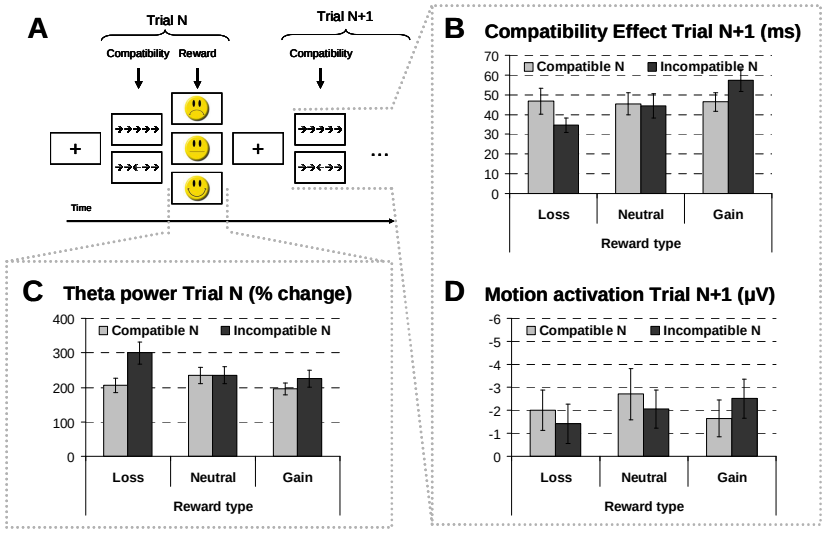

Figure 1. A. *Illustration of the experimental design. It was hypothesized that conflict induced by incompatible trials at Trial N is counteracted by subsequent gain feedback; this would reduce conflict-driven attentional focusing at Trial N+1.* ***B-D.*** *Summary of the main findings: In comparison to the loss condition, gain reduced conflict-induced fronto-central theta power measured at the 600 – 700 ms interval at Trial N (**C**), and reduced conflict-driven focusing at Trial N+1 both as measured in behavioral compatibility effects (**B**) and distracter-related visual processing as indexed by the Motion VEP in a 160 – 220 ms interval (**D**).*

Results

Behavioral data

As shown in Table 1, the flanker task produced standard RT compatibility effects indicating faster performance on compatible than on incompatible trials. Moreover, as Figure 1B shows, a standard conflict-adaptation effect (i.e., reduction of the flanker-compatibility effect after incompatible as compared to compatible flankers in the previous trial) was obtained in the loss condition, $t(29) = 1.88$, $p_{1\text{-sided}} < .05$, although not in the neutral condition, $t(29) = 0.12$, $p = .90$). Replicating our earlier observation (van Steenbergen et al., 2009), a direct comparison of the gain and the loss conditions confirmed the predicted effect of reduced conflict adaptation in the gain versus the loss condition for RT, as shown by a significant

CompatibilityN (2) x Reward (2) x CompatibilityN+1 (2) interaction, $F(1,29) = 6.04$, $p = .02$, $MSE = 333.73$ (see Table 1 for details). The Reward (2) x CompatibilityN+1 (2) interaction was also significant, $F(1,29) = 5.46$, $p = .03$, $MSE = 345.21$.

An ANOVA including all three levels of reward suggested a trend for a 3-way interaction effect, $F(1,58) = 2.54$, $p = .087$, $MSE = 396.48$. Subordinate ANOVAs showed that the effect of reward on conflict-adaptation modulated the compatibility effect adjustment following conflict (incompatible) trials, $F(2,58) = 6.60$, $p = .003$, $MSE = 594.49$, but did not affect the compatibility effect adjustments after

Table 1. *Behavioral data for each condition*

Condition	RT (ms)	Error rate (%)
Loss feedback		
Compatible trial following a compatible trial (cC)	387	1.0%
Compatible trial following an incompatible trial (iC)	391	0.4%
Incompatible trial following a compatible trial (cI)	433	6.4%
Incompatible trial following an incompatible trial (iI)	426	2.5%
Compatibility effect	41	3.8%
Conflict-adaptation effect	12	3.3%
Neutral feedback		
Compatible trial following a compatible trial (cC)	385	1.6%
Compatible trial following an incompatible trial (iC)	388	0.4%
Incompatible trial following a compatible trial (cI)	430	6.7%
Incompatible trial following an incompatible trial (iI)	432	4.2%
Compatibility effect	45	4.4%
Conflict-adaptation effect	1	1.2%
Gain feedback		
Compatible trial following a compatible trial (cC)	388	1.0%
Compatible trial following an incompatible trial (iC)	383	0.0%
Incompatible trial following a compatible trial (cI)	434	6.8%
Incompatible trial following an incompatible trial (iI)	441	2.6%
Compatibility effect	52	4.1%
Conflict-adaptation effect	-11	3.2%

Note. The compatibility effect was calculated from reaction times or error rates according to the following formula: (cI + iI)/2 - (cC + iC) / 2. The conflict-adaptation effect was calculated as follows: (cI - cC) - (iI - iC).

no-conflict (compatible) trials, $F(2,59) = 0.02$, $p = .98$, $MSE = 843.52$. A planned t-test focusing on trials following incompatible trials indicated a smaller compatibility effect for gain in comparison to the neutral, $t(29) = 2.09$, $p = .045$, and the loss condition, $t(29) = 3.81$, $p = .001$, which resulted in a reversed conflict-adaptation effect for the gain condition, $t(29) = 2.04$, $p = .05$. Error rate data showed significant main effects for CompatibilyN+1 (indicating more errors for incompatible trials) and CompatibilyN (indicating less errors after incompatible trials), but no (higher-order) interactions (see Table 1 for details). Thus, the modulation of conflict-adaptation in RT was not accompanied by a speed-accuracy trade off.

Theta frequency dynamics

Figure 2 shows the power and phase coherence measures of theta oscillations as induced by flanker compatibility at trial N and subsequently modulated by the feedback immediately following a key press to the stimulus array. An initial phase-locked theta response to the stimulus array was observed to be greater for incompatible than compatible trials, $F(1,28) = 4.67$, $p = .039$, $MSE = .029$, as was also visible in the power measure, $F(1,28) = 15.66$, $p < .001$, $MSE = 46952.06$. Moreover, as predicted, induced theta power sustained longer for incompatible versus compatible flankers during a subsequent 500 – 800 ms interval after loss feedback, $t(18) = 3.02$, $p = .005$ but not after gain feedback, $t(18) = 1.15$, $p = .59$, or neutral feedback, $t(18) = .37$, $p = .71$. As shown in Figure 2 (see also summary in Figure 1C), this modulation of reward on ongoing theta activity was maximal at the 600 – 700 ms interval, yielding a CompatibilityN (2) x Reward (3) interaction effect, $F(2,56) = 3.26$, $p = .046$, $MSE = 10013.82$. No interaction was observed in phase coherence ($F < .5$).

Distracter-related visual processing

As Figure 3A shows, moving flankers in comparison to still flankers elicited a standard motion VEP dominated by an occipito-temporal negativity that peaked around 200 ms and reached its maximum value in both hemispheres at electrode-pair P3/4. A direct comparison of the loss and gain conditions revealed a CompatibilityN (2) x Reward (2) interaction in the motion VEP elicited by the Trial N+1 for electrode P4, $F(1,13) = 5.29$, $p = .039$, $MSE = 1.41$, but not for electrode P3, $F(1,13) = 1.62$, $p = .226$, $MSE = 1.48$. Figure 3B and Figure 1D illustrate this interaction. A planned t-test indicated increased distracter-related motion activation following incompatible trials after gain in comparison to loss, $t(13) = -2.54$, $p = .024$, which mirrors the behavioral effect. However, when ANOVAs included the

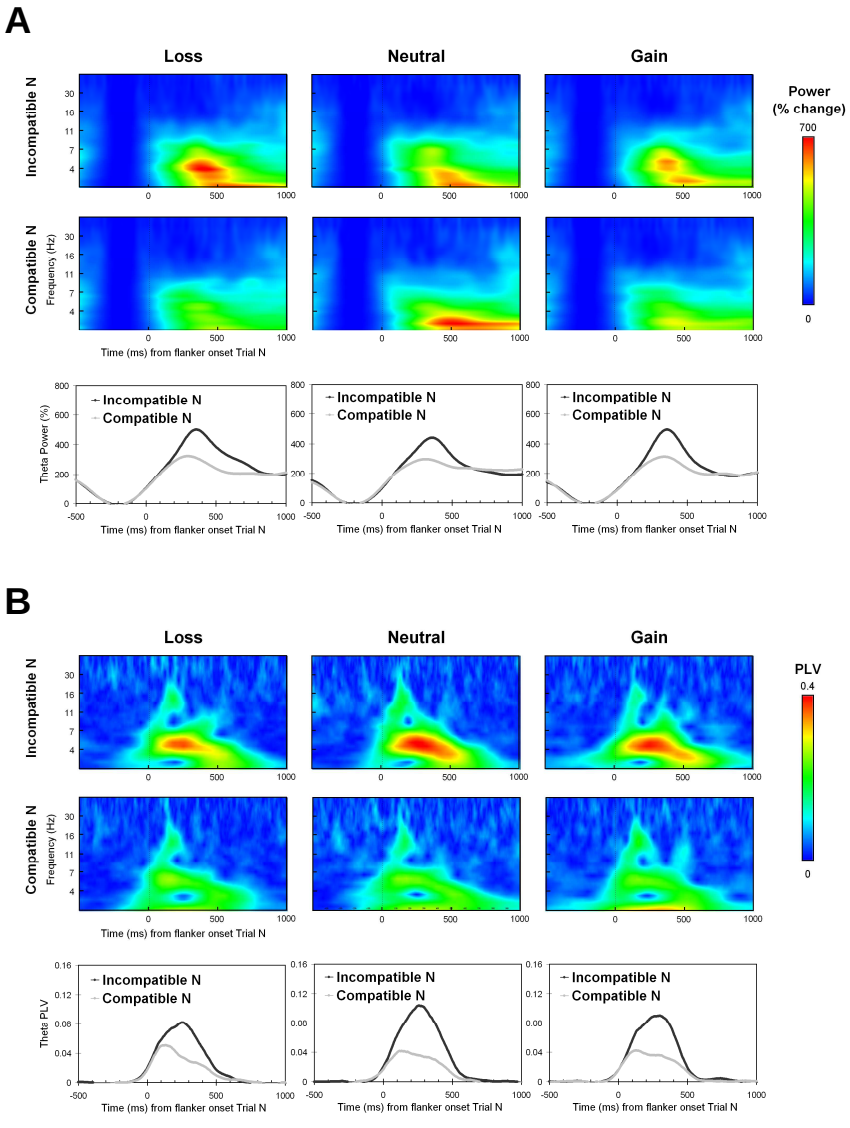

Figure 2. *Effect of conflict and reward at Trial N on frequency power (**A**) and phase coherence as indicated by Phase Locking Value (**B**) at electrode Cz. In comparison to gain feedback, induced theta (8-12 Hz) power sustained longer for incompatible versus compatible flankers after loss feedback.*

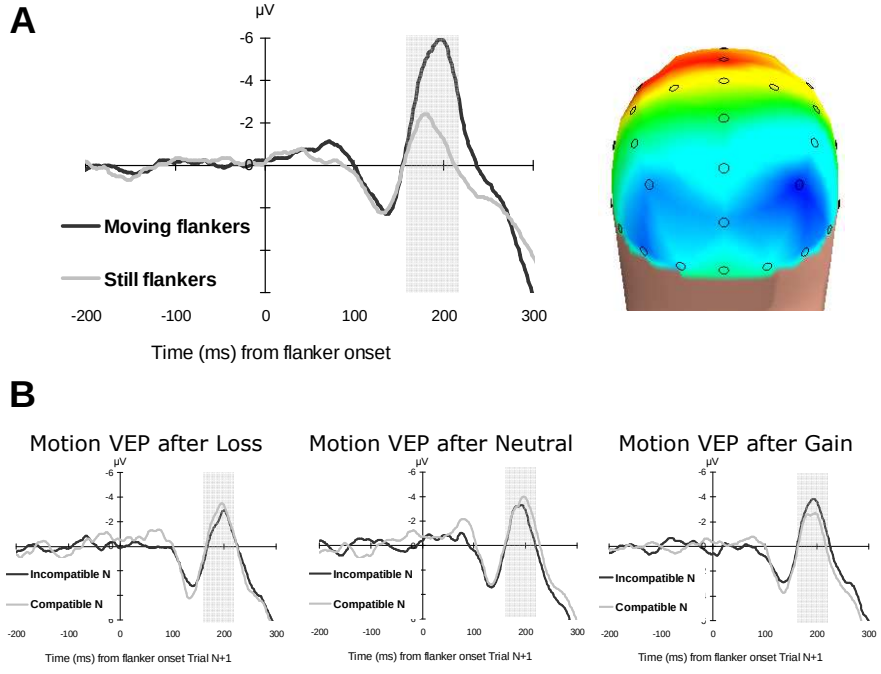

Figure 3. A. *In the motion localizer block, moving flankers in comparison to still flankers elicited a standard motion VEP with an occipito-temporal scalp distribution.* ***B.*** *During test trials, conflict and reward at Trial N modulated the motion VEP elicited at Trial N+1. All data are taken from electrode P4.*

neutral condition, no significant interactions emerged ($p > .15$), probably because the increased noise observed in the neutral condition reduced statistical power.

Discussion

The goal of the present study was to investigate the impact of interactions between conflict and reward processing on behavioral and neural adaptation. The behavioral effects replicated our earlier study (van Steenbergen et al., 2009) in showing reduced conflict-driven attentional adaptation in the gain condition. However, while in the previous study conflict adaptation was present in the neutral condi-

tion, this was not the case in the current study. This general reduction of adaptation might have been due to the fact that our study took about 2 hours to finish. As compared to the 15 minutes of our earlier study, this was likely to influence motivation and deplete attentional resources—conditions that are known to work against conflict adaptation (Fischer, Dreisbach, & Goschke, 2008).

Our study yielded two novel findings. First, as predicted, fronto-central theta power appears to reflect the compensatory effects of reward on conflict-related neural activity, as was shown by a sustained theta response during monetary loss, which was absent in the gain condition. This theta oscillation response may originate from the ACC and may represent a signal that indicates the need for more cognitive control, thus driving the sharpening of the attentional focus observed on the subsequent trial (Cohen et al., 2008). Such modulation may involve dopamine signaling from the midbrain. According to the theory by Holroyd and co-workers (Holroyd et al., 2008; Holroyd & Coles, 2002), negative and positive events interact via dopamine modulation, which drives ACC activity. More recent evidence suggests that the ACC may also provide feedback signals conveyed down to the midbrain, where it can inhibit dopamine neurons (Frank, 2005). It has been hypothesized that such fronto-striatial interactions may lower prefrontal dopamine concentrations, which shifts the balance of receptor activation towards D1 receptors, thus reducing distraction and improving attentional focusing (Jocham & Ullsperger, 2009). Our data suggest that theta oscillations may play an important role in this modulation. However, note that we can not claim that theta oscillations provide a unique neural signature of conflict- and reward-related processing, given that fronto-central oscillations have also been observed for other processes, such as attention and memory (e.g., Basar-Eroglu & Demiralp, 2001; Onton, Delorme, & Makeig, 2005; Wang, Ulbert, Schomer, Marinkovic, & Halgren, 2005). Altogether, our data leave open the possibility that theta oscillations that originate from the same ACC region serve different functions in different tasks and circumstances. Further research is needed to understand the functional role of theta oscillations in the presumed interactions with dopamine neurons and other brain areas involved in the regulation of cognitive control.

The second novel finding concerns the modulation of distracter-related motion activation in the visual cortex as assessed by means of the motion VEP in the right hemisphere. Behavioral adaptation in the subsequent trial was accompanied by a corresponding adaptation in attentional focus as measured by an early modulation in distracter activation in the visual cortex (cf. Figure 1B and D). Note that an earlier study by Egner and Hirsch (2005) using fMRI did not find a distracter-

related attenuation after conflict in a Stroop task. Our study points to the interesting possibility that ERP studies may actually be more sensitive to this modulation than BOLD responses are. Alternatively, it is possible that Stroop performance relies on different strategies than flanker task performance (cf. Lavie, 2005).

Two limitations of the present study need to be mentioned. First, as in the previous report, the reward manipulation affected behavioral and neural adaptation rather mildly, even though our sample was relatively large (N = 30). Second, when the neutral condition was included in the comparisons, statistical power to detect reward-related differences dropped, especially for the motion VEP analyses. One possible explanation of the larger inter-individual differences in the neutral condition might be that participants showed more variation in their appraisal of the situation of neither losing, nor winning any money. In other words, participants may have experienced the neutral condition as either a positive or negative situation, depending on subjective expectancies and affective state context (cf. e.g., Larsen & Norris, 2009).

To conclude, this study demonstrates that conflict triggered by incompatible trials in a flanker task increases fronto-central midline theta oscillations and sharpens the attentional focus, thus decreasing distracter-related visual processing and behavioral interference in the subsequent trial. We showed that adaptation effects in behavior and visual cortex are counteracted by unexpected monetary reward, which also involved the inhibition of ongoing theta oscillations. These data provide a first important step towards understanding the neural mechanism underlying the affective regulation of conflict-driven behavior.

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