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Erroneous and Correct Actions Have a Different Affective Valence: Evidence From ERPs

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The accuracy of actions is swiftly determined through specific monitoring brain systems. Event-related potential (ERP) studies have shown that error commission is associated with the generation of the error-related negativity (ERN/Ne), whereas correct actions are associated with the correct-related negativity (CRN). Although the exact functional meaning of the ERN/Ne (and CRN) component remains debated, some authors have suggested that it reflects the processing of the emotional significance of actions. However, no study to date has directly linked amplitude changes at the level of the ERN/Ne-CRN to the affective processing of actions. To decode the emotional valence of actions performed during a go/no-go task, the authors used an evaluative priming method in this study. After each action following the go/no-go stimulus, participants had to categorize an evaluative word as either positive or negative. Behavioral results showed that response errors (i.e., false alarms, FAs) performed during the go/no-go task led to a faster categorization of negative than positive words. Remarkably, this evaluative priming effect was related to the magnitude of the ERN/Ne component generated during the go/no-go task. Moreover, ERP results showed that the processing of evaluative words following FAs was influenced early on after word onset (early posterior negativity-EPN effect), while it was influenced later following correct as well as incorrect actions (late positive potential-LPP effect). Altogether, these ERP results suggest that the action-related ERN-CRN component encodes the perceived emotional significance of actions, such that early stages of evaluative word processing following these actions are influenced by this automatic process.

Keywords: action-monitoring, emotional valence, event-related potentials, evaluative priming, word-processing

In daily life situations, we have to rapidly evaluate the goal conduciveness of actions and adapt behavior accordingly in those cases where mismatches between actions and goals/intentions are detected. For example, if the current action turns out to deviate from the intended one, subsequent action execution can be slowed down in order to prevent further errors and maladaptive behavior. Although the evaluation of the goal conduciveness of actions seems to occur automatically, few studies have actually corroborated this assumption. More specifically, little is known about whether and to which extent the decoding of the valence of actions occurs in a rapid and effortless manner, early on following the onset of these actions. The lack of empirical knowledge about this process stands in stark contrast to its current theoretical importance. According to the reinforcement learning framework (Frank, Woroch, & Curran, 2005; Holroyd & Coles, 2002), for instance, the accuracy of actions is swiftly determined via dedicated frontostriatal loops in the brain. These monitoring systems quickly detect any deviance between the actual and intended action, and in turn trigger a cascade of alerting reactions and remedial processes, when such a discrepancy is noticed (Rabbitt, 1966). Previous studies have shown that these alerting reactions concern not only changes in cognitive control but also in emotion control brain processes (Carter et al., 1998; Hajcak & Foti, 2008; MacDonald, Cohen, Stenger, & Carter, 2000; Ochsner & Gross, 2005; Ridderinkhof, Nieuwenhuis, & Braver, 2007; van Veen & Carter, 2006). For example, action errors committed during standard laboratory interference tasks have been associated with larger skin conductance reactions and a greater heart rate deceleration than correct actions (Hajcak, McDonald, & Simons, 2003b), as well as a larger startle potentiation (Hajcak & Foti, 2008) and differential early activation in the amygdala (Pourtois et al., 2010).

In a recent study (Aarts, De Houwer, & Pourtois, 2012), we sought to assess whether actions were indeed not only swiftly marked as being correct or not but also as being positive or negative by dedicated affective monitoring systems. To address this question, we developed a new paradigm in which actions performed during a speeded go/no-go task were quickly (i.e., after 300 ms) followed by evaluative words (either positive or negative) that had to be categorized as either positive or negative. We conjectured that if actions were automatically appraised along a valence dimension, this process should influence the speed with which the subsequent evaluative word was categorized as either

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positive or negative. More specifically, in line with a typical evaluative priming effect (Fazio, Sanbonmatsu, Powell, & Kardes, 1986; Hermans, De Houwer, & Eelen, 1994), participants should be slower at categorizing "incongruent" words (i.e., positive words following incorrect actions or negative words following correct actions) than "congruent" words (i.e., negative words following incorrect actions or positive words following correct actions). These predictions were confirmed in our earlier behavioral study (see Aarts et al., 2012), thus, providing support for the idea that actions are quickly tagged by metacognitive systems (Fernandez-Duque, Baird, & Posner, 2000; Winkielman, Schwarz, Fazendeiro, & Reber, 2003), not only as being correct or not but also as being positive or negative depending on their match–mismatch with the goals set out by the task.

In this study, we used event-related potentials (ERP) methods to gain further insight into the possible electrophysiological correlates of this action-based evaluative priming effect. Previous ERP studies have already extensively shed light on the electrophysiological markers of action evaluation or performance monitoring more broadly. More specifically, several converging ERP studies reported a specific ERP component associated with the early detection of response errors within the anterior cingulate cortex (ACC), that is, the error-related negativity (ERN) or negativity error (Ne; Dehaene, Posner, & Tucker, 1994; Falkenstein, Hohnsbein, Hoormann, & Blanke, 1991; Gehring, Coles, Meyer, & Donchin, 1990; Gehring, Goss, Coles, Meyer, & Donchin, 1993). The ERN/Ne corresponds with a negative deflection peaking ~50 ms following the onset of an unwanted response error, with a maximum amplitude over frontocentral midline recording sites, consistent with underlying brain generators likely located in the ACC (Dehaene et al., 1994; Holroyd, Dien, & Coles, 1998; van Veen & Carter, 2002). Correct actions performed under speed pressure are also associated with the generation of a similar but smaller negative component at the same frontocentral recording sites and early latency following response onset (i.e., the correct-related negativity or CRN; Allain, Carbonnell, Falkenstein, Burle, & Vidal, 2004; Vidal, Burle, Bonnet, Grapperon, & Hasbroucq, 2003; Vidal, Hasbroucq, Grapperon, & Bonnet, 2000). According to some authors, the CRN shares generic brain generators in the ACC with the ERN/Ne (Roger, Bénar, Vidal, Hasbroucq, & Burle, 2010). This early action monitoring deflection (ERN/Ne errors; CRN-correct responses) is usually followed by a large error-related component, the error positivity (Pe), which peaks ~150–400 ms postresponse onset over centroparietal recording sites along the midline (Falkenstein et al., 1991; Falkenstein, Hoormann, Christ, & Hohnsbein, 2000; Nieuwenhuis, Ridderinkhof, Blow, Band, & Kok, 2001; Overbeek, Nieuwenhuis, & Ridderinkhof, 2005). Unlike the ERN/Ne that is mostly reflecting an automatic (in the sense of preconscious) stage of error detection, the Pe is thought to reflect a more elaborate (conscious) stage of error detection, likely reflecting the accumulation of (sensorimotor) evidence that an error has been committed (Dhar, Wiersema, & Pourtois, 2011; Nieuwenhuis et al., 2001; Steinhauser & Yeung, 2010).

Although the ERN/Ne is thought to reflect primarily a reinforcement learning mismatch signal that rapidly informs the organism about a discrepancy between the actual and the expected motor outcome (Frank et al., 2005; Holroyd & Coles, 2002) or perhaps about the occurrence of a response conflict between an erroneous and error-correcting response (Botvinick, Braver, Barch, Carter, & Cohen, 2001), other studies have emphasized the link between the ERN/Ne amplitude and affective variables. Overactive error-monitoring processes and increased ERN/Ne (but not Pe) amplitudes have, for example, been observed systematically in individuals with high levels of anxiety, negative affect, or both (Aarts & Pourtois, 2010; Endrass, Klawohn, Schuster, & Kathmann, 2008; Gehring, Himle, & Nisenson, 2000; Hajcak, McDonald, & Simons, 2003a, 2004; Hajcak & Simons, 2002; Johannes et al., 2001; Moser, Moran, & Jendrusina, 2012; Nieuwenhuis, Nielen, Mol, Hajcak, & Veltman, 2005). In line with these studies, Luu, Collins, and Tucker (2000) initially suggested that the ERN/Ne component may actually reflect the enhanced emotional significance of an error. However, no study to date has directly linked amplitude changes at the level of the ERN/Ne to the selective affective processing of these specific events.

By contrast, the functional significance of the negativity related to correct actions (i.e., CRN) is less clear than the ERN. Research has already shown that increases in CRN amplitude are related to increases in response competition (Suchan, Jokisch, Skotara, & Daum, 2007), uncertainty (Pailing & Segalowitz, 2004), and response expectancy violations (Meckler et al., 2009). Moreover, the CRN amplitude has also sometimes, but not always (Gehring et al., 2000; Hajcak, Franklin, Foa, & Simons, 2008; Ruchsow et al., 2005; Stern et al., 2010), been shown to be increased in psychopathological conditions, including anxiety (Endrass et al., 2008, 2010; Hajcak et al., 2003a, 2004; Hajcak & Simons, 2002). Given that correct actions are presumably linked to reward and positive affect, it might therefore be that the CRN component reflects the counterpart of the ERN regarding a rapid and automatic emotional tagging of actions. In this framework, a relatively small CRN component would correspond with a positive evaluation of the action (i.e., less negative than when the CRN is larger). This hypothesis is supported by empirical data showing that ERN/Ne and CRN components most likely reflect the activity of a generic evaluative process (Vidal et al., 2000, 2003), with shared neural effects within the rostral cingulate zone (Roger et al., 2010).

Therefore, a first goal of the present study was to assess whether such a brain–behavior relationship could be found. More specifically, we sought to demonstrate that, if the ERN/Ne and the CRN both capture the automatic affective evaluation of actions, then it should be related to the evaluative priming effect, that is, the reaction time (RT) facilitation during evaluative word categorization based on the congruency with the preceding action. Such an outcome would provide more direct evidence for the involvement of this early action monitoring ERP components in the automatic affective evaluation of actions (Luu et al., 2000; Pourtois et al., 2010).

Moreover, the use of ERPs enabled us to track the time-course of the evaluative priming effect. Hence, the second goal of our study was to use this time-resolved neurophysiological technique to explore which stages of processing during evaluative word processing were reliably influenced by the perceived valence of the preceding action. To address this question, we primarily focused on two well-defined ERP components, namely the early posterior negativity (EPN) and the late positive potential (LPP) that have been shown to vary in amplitude with the arousal values of visual stimuli, including written words (Kissler, Assadollahi, & Herbert, 2006). Depending on the task demands and the specific verbal stimulus sets used, early, late, or a combination of both effects can be seen following emotional word onset. Usually an enhanced EPN has been found ~200–250 ms poststimulus onset for emotional in comparison with neutral words (Herbert, Junghöfer, & Kissler, 2008; Kissler, Herbert, Peyk, & Junghöfer, 2007; Kissler, Herbert, Winkler, & Junghöfer, 2009; Schacht & Sommer, 2009a). Emotional words also lead to a larger ERP signal than neutral words at the level of the P300 component (Naumann, Bartussek, Diedrich, & Laufer, 1992) or the LPP (Naumann et al., 1992). These two differential ERP effects (EPN and LPP) for emotional relative to neutral words are thought to be related primarily to the processing of the arousal value of the words (Kissler et al., 2006). Accordingly, we explored whether the processing of positive versus negative words was different at the level of the EPN and/or LPP when the preceding action was either an FA or a correct action.

As expected, given the constant and short-time interval between action onset and word onset (i.e., 300 ms), the action-word sequence led to a substantial distortion of the ERP signal locked to the onset of the evaluative word in our study. This distortion was primarily accounted for by large residual effects (occurring in the prestimulus baseline) of the preceding actions (especially in the case of FAs eliciting prominent ERN/Ne and Pe components) onto the visual ERP generated in response to the evaluative words. These words were always presented 300 ms (fixed interval) following action execution, in accordance with our previous behavioral study (Aarts et al., 2012) where we found that this specific interval between the offset of the action and the onset of the word was optimal to obtain a substantial evaluative priming effect (speed). However, this specific setting was not immediately compatible with the recording of artifact-free ERP components generated in response to the visual evaluative word. To overcome this limitation and to be able to identify nonetheless reliable EPN- and LPP-like effects with high confidence, the EPN and LPP components were identified for the same participants based on an independent data set collected during an additional task. Unlike the main experimental session where the go/no-go task was combined with an evaluative word categorization task, during this auxiliary (where participants were required to perform a one-back repetition task), the same written words (positive, neutral, or negative) were presented one by one with a long interstimulus interval (ISI; without any interleaved go/no-go stimulus) such that we could obtain independent evidence ("functional localizer," see Saxe, Brett, & Kannwisher, 2006) for their differential processing. These ERP effects were then used as spatiotemporal seeds during the main evaluative priming task to assess whether and when the valence of the action could influence emotion word processing (hence, with a focus on the EPN and LPP components).

Method

Participants

Twenty-three undergraduate students (20 female; age, M = 21.74, SEM = 0.36) took part in the present study. The data of five participants had to be excluded from the subsequent analyses because the number of EEG epochs per condition was too small for calculating reliable ERP waveforms (i.e., <10, n = 4) or because of excessive noise in the continuous EEG data (n = 1). The final sample contained 18 participants (16 female; age, M = 21.4, SEM = 0.38). They were all right-handed, native Dutch speakers who did not have a history of neurological or psychiatric disease (based on self-report) and had normal or corrected-to-normal vision. The study was approved by the local ethics committee. All participants were compensated 20 Euro.

Stimuli

Go/No-go task. Visual stimuli consisted of an arrow (subtending 11.4 × 0.05 of visual angle at a 60-cm viewing distance) that was presented in the center of a white homogenous background and oriented either upward or downward (see Figure 1). The arrow was first black and could then turn either green or turquoise. The two colors were matched for luminance. These different combinations of color and orientation were used as cues in the go/no-go task.

Evaluative categorization task. Targets were 30 positive and 30 negative words, either nouns or adjectives (see Table 1), and were selected from the Dutch affective rating list of Hermans and De Houwer (1994). *T* tests showed that these positive and negative words differed significantly on the affective (i.e., valence) dimension, $t(58) = 36.57$, $p < .001$, but not on the familiarity dimension, $t < 1$, nor with respect to the number of letters, $t < 1$.

Word repetition detection task. We used the same 30 positive and 30 negative words that were presented in the evaluative categorization task plus 30 neutral words. *T* tests showed that neutral words were significantly different from negative and positive words on the affective (i.e., valence) dimension, $F(2, 89) = 620.72$, $p < .001$, but not on the familiarity dimension, $F(2, 89) = 1.48$, $p > .10$, nor with respect to the number of letters, $F < 1$.

Procedure

Go/No-go task and evaluative categorization task. Participants performed a standard speeded go/no-go task (Vocat, Pourtois, & Vuilleumier, 2008) interleaved with a visual word categorization task (see Figure 1). Actions performed during the speeded go/no-go task actually served as primes, whereas words were used as targets in analogy with a conventional prime–target sequence during evaluative priming. Each trial started with a fixation cross that lasted for 500 ms. Afterward, a black arrow, oriented up or down, was presented at the position previously occupied by the fixation cross. After a variable interval ranging from 1000 ms to 2000 ms, the black arrow became either green or turquoise while its orientation could remain identical or shift in the opposite direction compared to the initial black arrow. When the black arrow turned green and the orientation remained unchanged, participants were instructed to press a predefined button of the response box as fast as possible with the index finger of their left hand (go trials). However, participants had to withhold responding when either the arrow became green but changed orientation, or when the arrow became turquoise and kept its initial orientation, enabling two no-go trial types. Instructions emphasized both speed and accuracy, such that not only accuracy but also the perceived speed was later evaluated as being either correct or incorrect.

For each trial, speed was evaluated using an individually calibrated RT limit (M = 223; range = 196–326 ms) computed during a training block that preceded each session of two test blocks. This

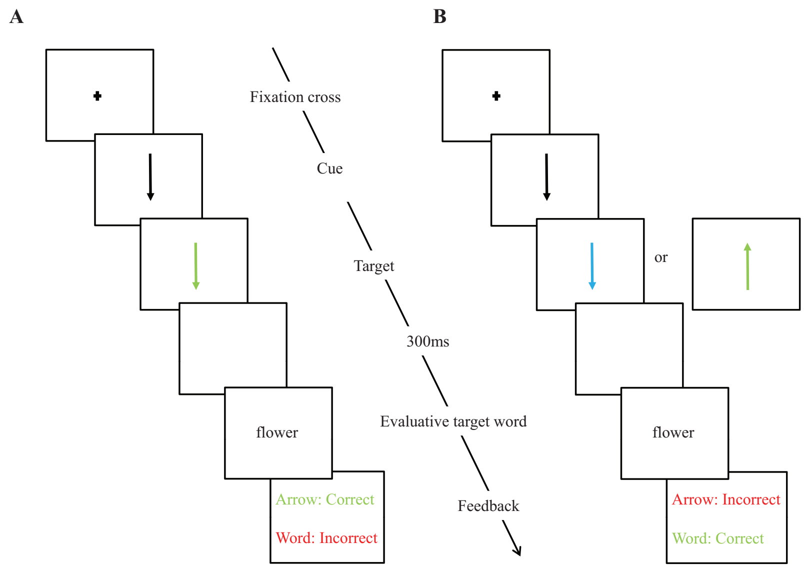

Figure 1. Stimuli and task. On each trial, a black arrow was presented (either upright or inverted). After a variable interval of 1000–2000 ms, the black arrow turned either green or turquoise. Participants had to respond by pressing a button of the response box as fast as possible with their nondominant hand only when the arrow became green and kept its initial orientation (A), but not otherwise (B). This first action was then followed by either a positive or negative target word that had to be classified as either positive or negative by pressing one of two predefined keys on the response box using their dominant hand. After this emotional word categorization, participants received a general feedback about their performance for the two tasks for this specific trial. Accuracy regarding the speed for correct responses (on go trials) was determined based on a stringent procedure and response deadline (see Method section).

limit was, thus, calculated and updated three times in total (before Blocks 1 and 2, i.e., Session 1; before Blocks 3 and 4, i.e., Session 2; and before Blocks 5 and 6, i.e., Session 3). This procedure allowed us to deal with unspecific learning effects over time and maintain a high number of response errors throughout the experimental session. For the first session, the upper limit was set to 70% of the mean RT from the first training block. For the two subsequent sessions, this upper limit was updated and set to 80% of the mean RT during the respective training block. Hence, this procedure required participants to respond at least 30% faster (first session) or 20% faster (second and third sessions) on go trials than their average speed during the respective training block. This procedure ensured a sufficient number of response errors on no-go trials and allowed us to distinguish between *fast hits* (i.e., correct responses on go trials that were made faster than the individually titrated RT limit) and *slow hits* (i.e., correct responses on go trials that were made slower than the RT limit). Errors were formally defined as overt responses on no-go trials, that is, false alarms (FAs), whereas correct inhibitions corresponded with correctly withheld responses on the same no-go trials.

Table 1
Target Words Selected From the Dutch Affective Rating List of Hermans and De Houwer (1994)

Positive targets		Negative targets	
Hawaii (Hawaii)	trouw (fidelity)	ruw (rude)	stank (stench)
engel (angel)	lente (spring)	haat (hate)	drugs (drugs)
goud (gold)	baby (baby)	moord (murder)	virus (virus)
regenboog (rainbow)	parfum (parfume)	aids (aids)	puist (pustule)
bruid (bride)	knuffel (hug)	vals (false)	zweer (sore)
applaus (applause)	feest (part)	pijn (pain)	oorlog (war)
hemel (heaven)	oprecht (sincere)	dief (thief)	kanker (cancer)
geboorte (birth)	zomer (summer)	dood (dead)	hitler (hitler)
vrede (peace)	humor (humor)	graf (tomb)	geweren (guns)
spel (game)	bloemen (flowers)	sluw (sly)	ongeval (accident)
geschenk (gift)	omhelzing (embrace)	hoer (hore)	brutaal (impudent)
cadeau (present)	vakantie (holiday)	koud (cold)	vulgair (vulgar)
trots (proud)	droom (dream)	zwak (weak)	ongezond (unhealthy)
melodie (melody)	leven (life)	spin (spider)	hatelijk (hasty)
romantiek (romanticism)	liefde (love)	vuil (dirty)	vijandig (hostile)

Three hundred milliseconds after an action was executed, a target word that was randomly selected from a list containing 60 evaluative words (30 negative and 30 positive; see Stimuli section) was presented. Accordingly, repetitions of words occurred, but these repetitions were on average balanced and fully nonpredictable. For correct inhibitions, the target word was presented 1800 ms after the presentation of the colored arrow. Participants were instructed to categorize the valence of the target word (positive or negative) as fast and as accurately as possible by pressing one of two predefined keys of the response box using their dominant hand. Hence, the evaluative word categorization task was executed with a different effector than the go/no-go task. The target word remained on the screen until the participant responded or 3000 ms elapsed. In order to balance the presentation of positive versus negative words following fast hits, slow hits, correct inhibitions, and FAs, we selected the target word that was presented following an action randomly on each trial. After the word categorization, participants received feedback informing them about their accuracy for the two consecutive tasks. The feedback for the go/no-go task indicated whether the performed action was correct (and fast enough), incorrect or too slow, whereas the feedback for the word categorization could be either correct or incorrect. Both feedback signals remained on the screen for 2000 ms.

After a practice phase including 24 trials, the experiment was divided into three sessions, each starting with a training block (containing 28 trials: 20 go and 8 no-go trials), followed by two test blocks (each containing 72 trials: 48 go and 24 no-go trials). Note that participants were unaware that training blocks were actually used as calibration blocks to compute the RT limit used during the two following test blocks. Trial presentation was randomized within blocks. Between blocks, a small break (no longer than 5 min) was introduced. The whole task included 540 trials and lasted on average 50 min. Stimulus presentation and response recording were controlled using E-prime software (V2.0., http://www.pstnet.com/products/e-prime/).

Word repetition detection task (localizer). In this task that followed the go/no-go plus evaluative categorization task, participants had to press a predefined button on the response box when they detected a word that was identical to the previous one (i.e., one-back task). Hence, we used a memory task requiring a lexical and semantic processing of the words, whereas task demands were balanced across the three emotion word conditions. These words were the same negative and positive words that were presented during the main evaluative categorization task, whereas 30 neutral words were added in this word repetition task (see Stimuli section). Every word ($N = 30$ per emotion category) was presented once in random order for 550 ms and immediately followed by a blank screen (1000 ms). In total, six words (two words of each emotion category) out of 90 were repeated and had to be overtly detected. The appearances of these six immediate repetitions in the word list were alternated across participants.

Analyses of Behavioral Data

Go/No-go task. Accuracy and RTs were analyzed separately using repeated-measures analyses of variance (ANOVAs) with the type of action (FA and fast hit) as within-subject factor. All data were analyzed using SPSS (version 20).

Evaluative categorization task. Accuracy and RTs (for correct responses) were analyzed using ANOVAs as a function of (a) the valence of the target word (either positive or negative) and (b) the type of action (FA and Fast Hit) preceding word presentation. We did not include in these analyses trials corresponding with slow hits because this action type did not lead to any significant and consistent evaluative priming effect in our previous study (Aarts et al., 2012). Separate analyses of slow hit responses also did not reveal any priming effect in this study, $t < 1$.This may be due to that the putative valence of slow hits (unlike either fast hits or FAs) was somehow ambivalent in the sense that a slow hit was a correct response but performed too slowly (hence, probably carrying also a negative connotation). Also, correct inhibitions were not included in the analysis because no overt action was performed in this condition. Separate statistical analyses performed on these trials showed that, also in the current study, the evaluative categorization was not significantly influenced by these correct inhibitions. More specifically, following a correct inhibition, the speed to categorize negative words was similar to that needed to categorize positive words ($t < 1$).

Word repetition detection task (localizer). Accuracy was analyzed using a repeated-measures ANOVA with the type of emotion word (negative, neutral, positive) as within-subject factor.

EEG Acquisition and Preprocessing

Go/No-go task. Continuous EEG was acquired at 512 Hz using a 128-channel (pin-type) Biosemi Active Two system (http://www.biosemi.com) referenced to the CMS-DRL ground. ERPs of interest were computed offline following a standard sequence of data transformations (Picton et al., 2000): (a) $-500/+1000$ ms segmentation around the motor response; (b) preresponse interval baseline correction (from -500 ms to 0 ms); (c) vertical ocular correction for blinks (Gratton, Coles, & Donchin, 1983), using the difference amplitude of two electrodes attached above and below the left eye; (d) artifact rejection, $M = -75/+75$, $SEM = 2.71$ amplitude scale (μV) across participants; (e) averaging of trials for each of the two main conditions separately (FA vs. fast hit); and (f) 30 Hz low-pass digital filtering of the individual average data.

Evaluative categorization task. The sequence of data transformations was similar to the one used for the go/no-go task with the notable exception that the baseline correction was not performed using the entire prestimulus interval (500 ms preceding word onset), but using the $-50/+50$ ms around word stimulus onset to minimize as far as possible residual effects of the preceding response-related ERPs (e.g., ERN/Ne and Pe components following the commission of a FA).[1] Four different ERP averages were computed for each participant: negative words following FAs; positive words following FAs; negative words following fast hits; positive words following fast hits.

[1] When using a different baseline correction interval (i.e., from -800 ms to -300 ms relative to the onset of the word), we found no significant difference between incorrect and correct actions, and between negative and positive words at the right occipital electrodes—EPN effect: accuracy, $F <$ 1; valence, $F < 1$—or right frontal electrodes—LPP effect: accuracy, $F <$ 1; valence, $F(1, 14) = 2.10$, $p > .10$.

Word repetition task (localizer). The sequence of data transformations was similar to the one used for the go/no-go task, and three individual ERP averages corresponding to the three main emotion word conditions were eventually computed. The deviant immediate repetitions of words ($n = 6$) requiring overt detection were not included in these averages.

ERP Data Analyses

Go/No-go task. We primarily focused on two well-documented error-related ERP components following incorrect response onset (Falkenstein et al., 2000; i.e., the ERN/Ne), with a maximum negative amplitude over frontocentral electrodes along the midline (electrode FCz) early on following motor execution (~0–100 ms postresponse onset), immediately followed by the Pe component (~150–300 ms postresponse onset), with a maximum positive amplitude over more posterior and central electrode locations along the midline (electrode Cz). For each ERP component and each condition separately (FA vs. fast hit), we calculated the area under the curve, during the 0–60 ms interval postresponse onset at electrode FCz for the ERN/Ne amplitude and during the 170–210 ms interval postresponse onset at electrode Cz for the Pe component (see Aarts & Pourtois, 2012, for a similar data analysis). The selection of these two specific scalp locations (and time windows) was based on the topographic properties of the present dataset, as well as based on converging results obtained in previous ERP studies using the same task (Aarts & Pourtois, 2010).

Statistical analyses were performed on the mean amplitude of each area using a paired *t* test (FA vs. fast hit). We also performed brain-behavior correlation analyses using the amplitude of the ERN/Ne (or CRN in the case of fast hits) and RTs for the evaluative categorization task. We sought to assess whether the error-related brain reactions occurring during the go/no-go task might somehow predict the size of the RT facilitation for the immediate orthogonal emotion word categorization task. More specifically, we assessed whether the ERN/Ne-CRN amplitude difference (reflecting roughly the sensitivity to the perceived accuracy) might be related to the RT facilitation for congruent trials (FA-negative word and fast hit-positive word) compared with incongruent trials (FA-positive word and fast hit-negative word). We therefore computed a compound measure of evaluative priming corresponding to the subtraction of congruent trials from incongruent trials and evaluated, using a Pearson coefficient correlation, whether this measure of priming might be related to amplitude changes occurring at the level of the ERN/Ne–CRN component. We also assessed whether the evaluative priming effect may be predicted by amplitude changes occurring at the level of the Pe component, and accordingly, we computed a similar amplitude difference between FAs and fast hits for this later deflection.

Word repetition task (localizer). To formally characterize the electrophysiological time-course of evaluative word processing, we submitted the ERP data of the localizer to a standard topographical mapping analysis. The rationale and basic principles of this analysis have been extensively described elsewhere (Michel, Seeck, & Landis, 1999; Murray, Brunet, & Michel, 2008; Pourtois, Delplanque, Michel, & Vuilleumier, 2008).The topographical analysis was run on the ERP data from stimulus onset until 500 ms after emotion word stimulus onset (i.e., 256 consecutive time frames at 512 Hz sampling rate), using a standard clustering (or spatiotemporal segmentation) method (K-means; Pascual-Marqui, Michel, & Lehmann, 1995). Following standard practice, the dominant scalp topographies (identified in the group-averaged data) that were found to discriminate between neutral and evaluative words (with a focus on the EPN and LPP components) were then fitted to the ERPs of each individual subject by using spatial-fitting procedures to quantitatively determine their representation across subjects and conditions. For each time interval (either EPN or LPP), the resulting global explained variance (GEV) values were finally compared across conditions (evaluative vs. neutral words) by using paired *t* tests. These analyses were carried out using CARTOOL software (Version 3.34; developed by D. Brunet, Functional Brain Mapping Laboratory, Geneva, Switzerland).

Evaluative categorization task. The previous analysis enabled us to identify two nonoverlapping time intervals following evaluative word onset (corresponding with the EPN and LPP), during which the processing of either positive or negative words differed from neutral words. These specific time intervals were then used as seeds during the main evaluative categorization task to assess whether the accuracy of the preceding action influenced emotion word processing or not. In a first step, we ran paired *t* tests (negative vs. positive words; alpha level set to .01) for all 128 electrodes concurrently, separately for FAs and fast hits, on the amplitude of the ERP signal during these two specific emotion sensitive time intervals (EPN and LPP). Given the obvious distortion of the ERP signal induced by the preceding action, we had to perform this first analysis comparing positive to negative words separately for FAs and fast hits. This first-pass statistical analysis allowed us to reveal clusters of electrodes where a reliable difference occurred between the processing of negative versus positive words, separately for FAs and fast hits. In a second step, we verified, using repeated-measures ANOVAs whether the amplitude of the ERP signal at these preselected clusters and during these two specific time-intervals was reliably influenced by the type of action (FA vs. fast hit) as well as the valence of the word (negative vs. positive).

Results

Behavioral Results

Outliers. Trials with RTs shorter than 150 ms (FAs, $M = 2.58$, $SEM = 0.87$; fast hits, $M = 4.47$, $SEM = 1.76$) or longer than 500 ms (FAs, $M = 0.90$, $SEM = 0.39$) during the go/no-go task were discarded, as were trials of the evaluative categorization task for which the RT exceeded 2.5 *SD* above or below the mean RT computed per condition (negative, $M = 2.29\%$, $SEM = 0.16$; positive, $M = 2.16\%$, $SEM = 0.22$).

Go/No-go task. Participants made less FAs than fast hits, $t(17) = -2.09$, $p = .05$, and RTs for FAs were longer than RTs for fast hits, $t(17) = 3.78$, $p < .01$ (see Table 2). These results were compatible with previous findings obtained with the same go/no-go task (Aarts & Pourtois, 2010, 2012).

Evaluative Categorization Task.

Speed. The ANOVA performed on the mean RTs for correct responses revealed a significant interaction effect between action type and word type, $F(1, 17) = 18.59$, $p < .001$. More specifically, RTs for negative words following FAs were shorter compared with

Table 2
Mean Number of Actions and Speed (Ms) During the Go/No-Go Task

	Number		Speed (ms)	
Variable	*M*	*SEM*	*M*	*SEM*
FAs	60.61	4.95	223.27	2.49
Fast hits	83.22	10.14	206.19	5.14

Note. FAs = false alarms.

RTs for positive words following FAs, $t(17) = -3.67$, $p < .01$. Participants also showed a tendency to categorize positive words slightly faster compared with negative words when they followed fast hits, although this effect did not reach significance, $t(17) = 1.66$, $p = .11$. The main effect of word type was also significant, $F(1, 17) = 7.00$, $p < .05$. Moreover, the ANOVA revealed a significant main effect of action type, $F(1, 17) = 32.87$, $p < .001$, reflecting overall longer RTs for words following FAs compared to words following fast hits, an effect in line with a systematic posterror slowing (Danielmeier & Ullsperger, 2011; Rabbitt, 1966; see Figure 2A).

Accuracy. The ANOVA performed on accuracy data (i.e., percentage of correct responses) revealed a significant interaction effect between action type (FA vs. fast hit) and word type (negative vs. positive), $F(1, 17) = 11.27$, $p < .01$. This interaction indicated that participants were less accurate to categorize words as positive following FAs, compared with negative words following FAs, $t(17) = 3.36$, $p < .01$. Accuracy was similar for categorizing positive versus negative words following fast hits. Furthermore, the main effect of action type reached significance, $F(1, 17) = 8.56$, $p < .01$, indicating higher accuracy following fast hits compared with FAs. Finally, the main effect of word type was also significant, $F(1, 17) = 9.37$, $p < .01$ (see Figure 2B).

ERP Results

Go/No-go task. When participants committed FAs, there was a clear sharp negative deflection that peaked roughly ~30-ms postresponse onset, with a maximum amplitude at frontocentral electrodes along the midline, including FCz. These electrophysiological properties were consistent with the ERN/Ne. Consistent with previous ERP studies (Falkenstein et al., 1991; Gehring et al., 1993), the amplitude of the ERN/Ne was reliably larger for FAs (i.e., response errors), relative to fast hits (i.e., correct responses), where a smaller negative component (CRN) was also clearly visible though, $t(17) = -2.66$, $p < .05$ (see Figure 3A).

This early negative component was immediately followed by a large positive potential, with maximum amplitude over more posterior scalp positions, including Cz. This error-related positive component was strongly attenuated for fast hits, $t(17) = 6.70$, $p < .001$ (see Figure 3A). These electrophysiological properties were compatible with the generation of a genuine error-related Pe component (Falkenstein et al., 2000; Ridderinkhof, Ramautar, & Wijnen, 2009).

Remarkably, we found that across participants the evaluative priming effect, that is, the RT difference between incongruent (FA-positive word and fast hit-negative word) and congruent trials (FA-negative word and fast hit-positive word), was actually related to the difference between the ERN/Ne and CRN component, $r = -.55$, $p < .05$ (see Figure 3A). This result was important because it suggested that the more the early frontocentral negative deflection following response onset differentiated between incorrect and correct actions, the larger the evaluative priming effect, (i.e., RT facilitation for categorizing the valence of a word that was presumably compatible or shared with the inferred value of the preceding action). These results confirmed that this early action-monitoring component was not only responsible for coding rapidly the accuracy value of the action (correct vs. incorrect) but also probably its concurrent emotional or motivational significance (good for fast hits vs. bad for FAs). Separate analyses for the two action types revealed an almost significant correlation between the size of the ERN/Ne and the RT difference between negative and positive words following FAs, $r = -.42$, $p = .09$ (see Figure 3B). This correlation showed that participants with a larger ERN/Ne component had subsequently a larger RT facilitation for categorizing negative relative to positive words. Symmetrically, we also observed a trend for an association between the CRN generated for fast hits and the subsequent RT facilitation to categorize positive relative to negative words following these correct actions, $r = .46$, $p = .06$ (see Figure 3C). This result suggested that a smaller CRN amplitude might be related to a larger RT facilitation for positive

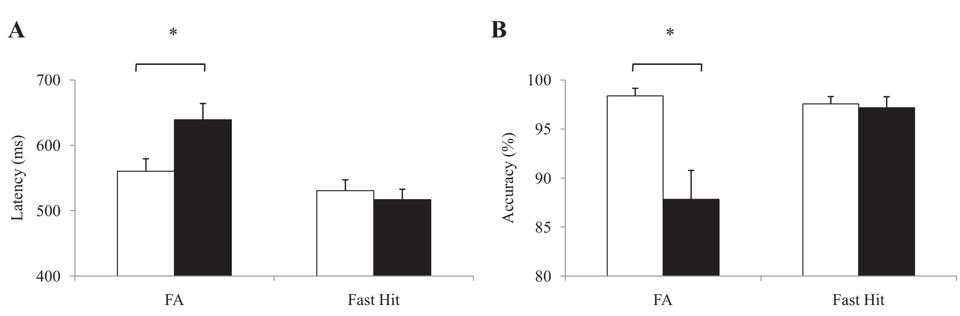

Figure 2. (A) Mean RTs (+1 *SE* of the mean – *SEM* for bars) for correct evaluative categorizations as a function of prime type (FA or fast hit) and word type (negative or positive words). (B) Mean accuracy in percentages (+1 *SEM* for bars) for correct evaluative categorizations as a function of prime type (FA or fast hit) and word type (negative or positive words).

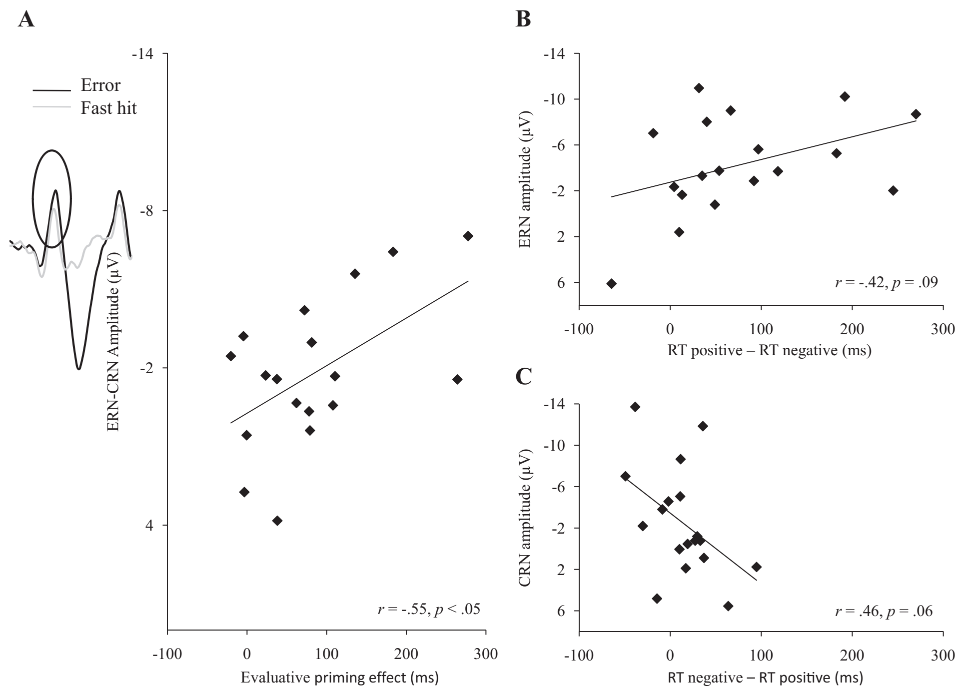

Figure 3. ERP results during the speeded go/no-go task. (A) A significant negative correlation was found between the evaluative priming effect (i.e., RT difference between incongruent, FA-positive word and fast hit-negative word, and congruent trials, FA-negative word and fast hit-positive word) and the amplitude difference between the ERN/Ne and CRN component. (B) A negative correlation was found between the ERN/Ne amplitude and the RT difference between positive and negative words. (C) By contrast, a positive correlation was found between the CRN amplitude and the RT difference between negative and positive words. Note that the second negative peak visible (left panel) corresponds with the early sensory-related effect following word onset (most probably this deflection is the negative dipolar counterpart of the occipital P1 component following word onset, peaking at frontocentral electrodes, like the ERN component).

compared to negative words. Such significant brain-behavior relationships were not found when using accuracy measures for the evaluative word categorization task (instead of RT speed); all *p*s $>$ .10. We did also not find any similar correlation between the Pe component and the evaluative priming effect, $r = -.16$, $p > .10$.

Word repetition detection task (localizer). Using the topographical analysis, we found that the ERP signal was reliably influenced by the evaluative content (positive and negative, relative to neutral) of the word during two nonoverlapping time intervals. The analysis for the first time interval accounted for 90% of the variance whereas the analysis for the second time interval accounted for 93% of the variance. The first interval was 176–215 ms postword onset, whereas the second spanned 326–391 ms postword onset. These latencies were compatible with an EPN and LPP effect, respectively (see Figure 4AB). Consistent with a sensitivity of these two ERP components to the emotional or arousal value conveyed by the written words, statistical analyses performed on the GEV values extracted for these two topographical components confirmed that the EPN topography explained more variance for evaluative compared with neutral words, $t(17) = -2.19$, $p < .05$ (see Figure 4C), and the LPP topography alike, $t(17) = -2.80$, $p < .05$ (see Figure 4D).

Evaluative categorization task. Action type (either FAs or fast hits) had a major influence on the expression and overall morphology of the visual ERPs time locked to the onset of the word. However, results obtained from the localizer session allowed us to pinpoint two time intervals following word onset where the processing of emotional words differed from neutral words (i.e., EPN and LPP effects). Hence, we used these two specific time intervals to interrogate whether the EPN, LPP, or both components might vary depending on the putative value of the preceding action.

A first statistical analysis based on running *t* tests (see Method section) showed that following FAs, a significant difference occurred between positive and negative words during the time interval corresponding with the EPN at right occipital (A30, B11; all *t*s $>$ 2.5, all *p*s $<$ .05) and left frontal electrodes (C25, D2, D11, D12, D19, D20, D28; all *t*s < -2.8, all *p*s $<$ .05). At these electrodes, the amplitude of the ERP signal was reliably larger for incongruent (positive words) compared with congruent (negative words) trials following FAs. By contrast, following fast hits, a reliable difference emerged between positive and negative words during the time interval corresponding with the LPP component, mainly at right frontal electrodes (B30-B32, C1-C6, C11, and C23; all *t*s < -2.7, all *p*s $<$ .05), as well as at some additional scalp positions (B19, C29, D22; all *t*s < -2.71, all *p*s $<$ .05). At all these electrode locations, the LPP signal was larger for incongru-

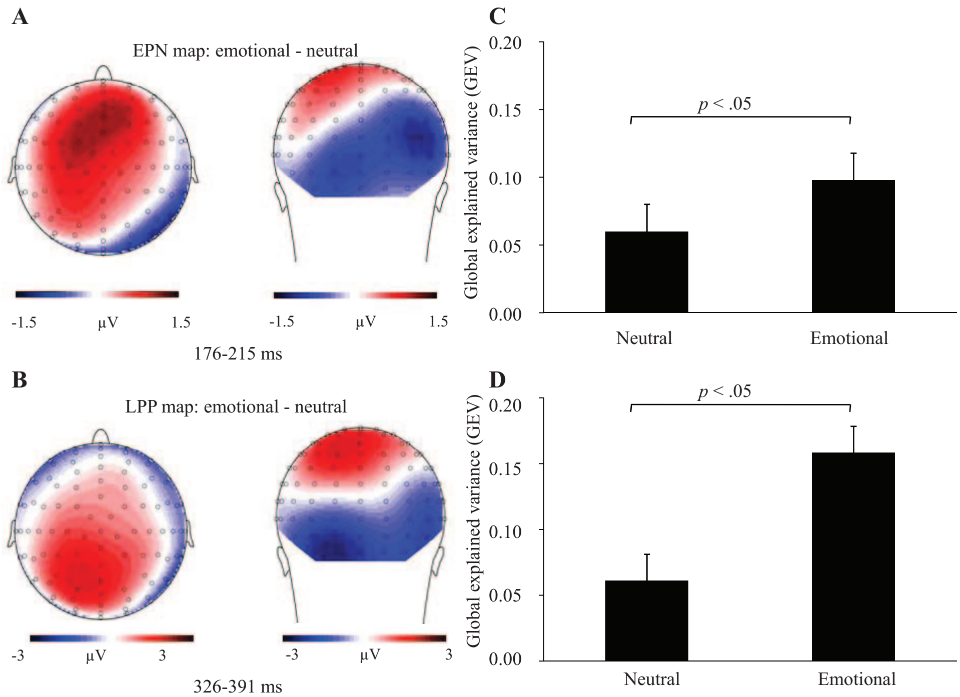

Figure 4. ERP results obtained for the localizer experiment. (A) The voltage map (horizontal and back views) of the EPN (184–210 ms postword onset) for emotional versus neutral words was characterized by a negative activity mainly at right occipital electrodes. (B) The voltage map (horizontal and back views) of the LPP (326–393 ms postword onset) for emotional versus neutral words showed a broad positive activity over centroparietal electrode positions. (C) The EPN topographical component explained more variance for emotional compared to neutral words (see results section for exact numerical values). (D) Likewise, the LPP topographical component explained more variance for emotional compared to neutral words (see results section for exact numerical values).

ent (negative words) compared with congruent (positive words) trials alike.

In a second step, we ran two separate repeated-measures ANOVAs on the mean amplitude of the ERP signal extracted during these two nonoverlapping time intervals. A first repeated-measures ANOVA was performed on the mean amplitude of the EPN component (i.e., 176–215 ms), whereas a second one was run during the later (i.e., 326–391 ms) LPP interval. For these two intervals separately, we verified next whether the amplitude of the component (EPN vs. LPP) was reliably influenced by the valence of the word (positive vs. negative). Accordingly, using these analyses, we could assess whether this valence discrimination happened earlier (i.e., during the EPN interval) following FAs than following fast hits or not. On the basis of the previous *t* tests, we found that fast hits happened to influence the word-related ERP signal during a later time interval (i.e., during the LPP interval) than FAs. The ANOVA performed on the ERP signal during the EPN interval with the within-subject factors electrode (n = 18:A26-A32, B3-B13 corresponding with the right occipital cortex), action type (FA vs. fast hit), and word valence (negative vs. positive) revealed a significant interaction between action type and word valence, $F(1, 289) = 4.81$, $p < .05$. More specifically, smaller EPN amplitudes for negative words following FAs were observed compared with positive words, $F(1, 289) = 7.23$, $p < .05$, whereas no such differential effect was observed following fast hits, $F < 1$. (see Figure 5AB). The main effect of accuracy was not significant, $F(1, 289) = 1.78$, $p > .10$. The main effect of valence was not significant either, $F < 1$. We also examined whether word valence influenced the amplitude of the EPN component for the same electrode positions (right occipital cortex) during the localizer run or not. However, this auxiliary analysis failed to reveal such a significant effect, $F < 1$. Note that this observation is not odd but in line with the results of the localizer run, showing that the topography of the electric field (rather than local amplitude changes at a few electrode positions) actually accounted for the valence-related EPN (as well as LPP) effect.

By contrast, for the LPP component, the repeated-measures ANOVA with the within-subjects factors electrode (n:16; B27-B32, C1-C7, C11, C22, and C23 corresponding to right frontal cortex), action type (FA vs. fast hit), and word valence (negative vs. positive) showed no significant interaction between action type and word valence, $F(1, 255) = 1.18$, $p > .10$. Instead, a main effect of valence was observed, $F(1, 255) = 22.15$, $p < .001$, indicating larger LPP amplitudes for negative compared with positive words. However, post hoc *t* tests showed that this differentiation between positive and negative words was significant following fast hits, $F(1, 255) = 46.20$, $p < .001$, whereas it was much smaller following FAs, $F(1, 255) = 3.56$, $p = .08$ (see

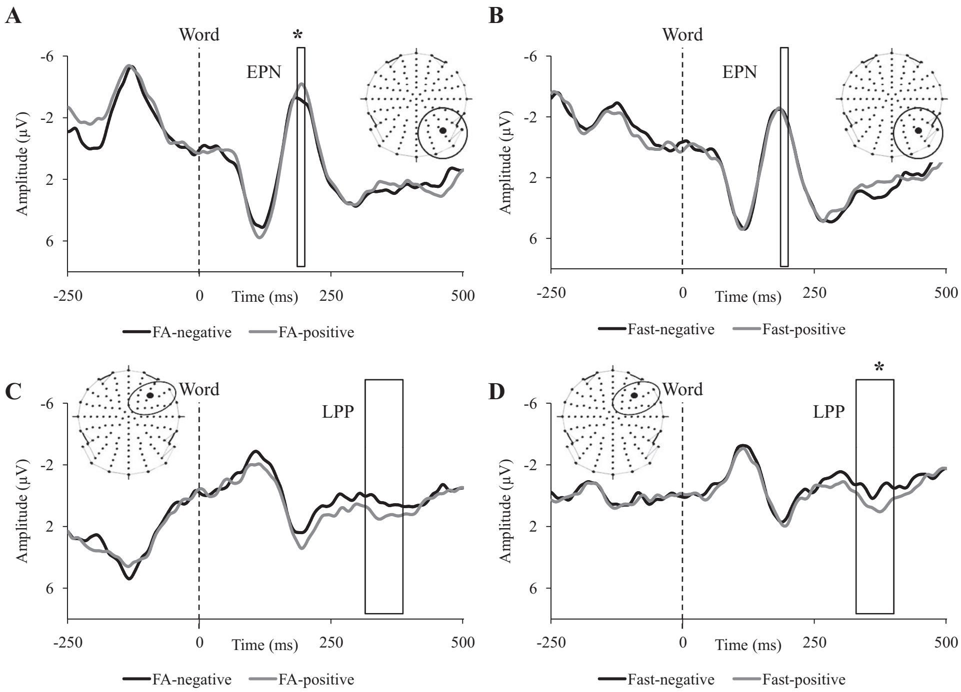

Figure 5. Main ERP results during the evaluative categorization task. (A) Grand average ERP waveforms (for a representative right occipital electrode, B6), separately for positive and negative words following FAs. The amplitude of the EPN was larger for positive compared to negative words. (B) No similar differential effect was seen (same electrode B6) for positive versus negative words following fast hits. (C) Grand average ERP waveforms (for a representative right frontocentral electrode – C4), separately for positive and negative words following FAs. A significant LPP difference was seen between these two conditions. (D) The amplitude of the LPP (same electrode C4) was also enhanced for negative compared to positive words following fast hits. Asterisks indicate $p < .05$.

Figure 5CD). When using the exact same electrode positions (right frontal cluster) and evaluating whether word valence influenced the amplitude of the LPP component during the localizer run, the analysis failed to do so, $F < 1$.

Discussion

The goal of the present ERP study was twofold. (a) First, we wanted to establish whether the magnitude of the ERN/Ne-CRN component generated early on following action execution might actually be related to the subsequent categorization of evaluative words as either positive or negative, that is, to the magnitude of the evaluative priming effect induced by these actions (see Aarts et al., 2012). (b) Second, we aimed at clarifying the actual electrophysiological manifestations of this evaluative priming effect, by focusing on standard visual ERPs generated in response to these evaluative words (and more specifically the emotion-sensitive EPN and LPP ERP components). Critically, these new ERP results unequivocally suggest the involvement of the ERN/Ne-CRN component in the processing of the affective valence of actions. More specifically, our results show that the evaluative priming effect was related to the ERN/Ne-CRN difference, that is, to the size of this early response-related component taking place 300 ms prior to word onset and generated in response to go/no-go actions.

Moreover, our new ERP findings allowed us to clarify what are the actual electrophysiological correlates of this evaluative priming effect. More specifically, we found that during the EPN time interval following evaluative word onset (as identified using an independent ERP data set obtained in the same participants), a significant ERP difference arose between positive versus negative words. This difference was only observed after FAs, but not after fast hits, indicated by a larger ERP signal for incongruent, compared with congruent action-word pairs. Such a valence-related ERP difference was also found for fast hits, but during a later and nonoverlapping LPP time period. During this second time period, negative words clearly elicited a larger ERP signal than positive words following fast hits, while this effect was attenuated following FAs. These ERP results suggest therefore that the evaluative priming effect may be associated with an enhanced emotional–arousal reaction during the sensory processing of evaluative words (when the valence of the word and the action mismatched), appearing earlier for evaluative words following FAs than fast hits. We discuss the implications of these new results below.

Online Automatic Processing of the Inferred Valence of Actions at the Level of the ERN/Ne-CRN

Whereas earlier studies already showed that unwanted response errors unlocked different psychophysiological emotional reactions compared to hits, which were consistent with the detection and processing of aversive events (Hajcak & Foti, 2008), as well as differential brain responses in the amygdala (Pourtois et al., 2010), the evidence linking response errors to a negative valence (presumably being different–opposite compared with hits) was primarily indirect or correlational in nature. Moreover, the accumulating neurophysiological evidence linking enhanced ERN/Ne-CRN amplitudes to elevated levels of negative affect and internalized psychopathology, including anxiety and depression (Olvet & Hajcak, 2008; Vaidyanathan, Nelson, & Patrick, 2012), does not enable to draw strong conclusions regarding an altered affective evaluation of actions (response errors vs. correct actions) in anxious, depressed, or both, participants. In all these ERP studies, no significant change in behavior, that is, the number of incorrect and correct actions, or emotional reactions following errors versus correct actions was seen or reported between high versus low anxious, or between depressed patients versus healthy controls. Accordingly, our new behavioral and ERP results are important because they suggest for the first time that actions performed during a standard go/no-go task are rapidly appraised along a genuine valence dimension (FAs were evaluated as more negative compared with fast hits; see behavioral results).

This evaluative priming effect was related to interindividual variations at the level of the magnitude of the response-locked ERN/Ne-CRN component, suggesting a link between this early action-monitoring ERP component and the automatic affective evaluation of actions (Aarts & Pourtois, 2010; Hajcak & Foti, 2008; Luu et al., 2000). This effect might operate via specific meta cognitive control systems working on the byproduct of an internal representation of motor actions, given the extremely rapid time-course and unfolding of these ERN/Ne-CRN brain effects presumably taking place in ACC (Fernandez-Duque et al., 2000; Winkielman et al., 2003) and likely reflecting the backdoor of rapid changes in midbrain dopaminergic brain structures (Fiorillo, Tobler, & Schultz, 2003; Holroyd & Coles, 2002). Our novel results show that across participants, the ones who showed a large difference between the ERN/Ne and CRN had a larger RT facilitation for processing the valence of the subsequent evaluative word when it was actually shared with that of the actions (i.e., congruent vs. incongruent action-word pairs), compared with participants showing a smaller ERN/Ne-CRN differentiation. These new results may, thus, help interpret the functional meaning of the ERN/Ne-CRN component and its systematic amplitude variations depending on specific state or trait factors. Future ERP studies are needed, however, to confirm the assumption that amplitude variations at the level of the ERN/CRN component translate the online evaluation of the valence of the action, as opposed to another process or variable, such as conflict monitoring (Botvinick et al., 2001; Carter et al., 1998; Yeung, Botvinick, & Cohen, 2004). Moreover, besides the ACC, it is likely that other brain regions (including the inferior frontal gyrus) might actually contribute to the emotional processing or regulation of simple responses (see Brown et al., 2012) and as such either directly or indirectly participate to the evaluative priming effect here reported. Therefore, imaging studies combining hemodynamic (fMRI) and neurophysiological (EEG) measurements of brain activity might help elucidate the actual spatiotemporal dynamic and specific contribution of nonoverlapping brain regions during the internal affective monitoring of actions (see Debener, Ullsperger, Fiehler, von Cramon, & Engel, 2005).

It is interesting that our correlation analysis also showed that when using the mean ERN/Ne amplitude alone (instead of the ERN/Ne-CRN amplitude difference), interindividual changes in the size of this error-related component show a trend toward predicting the subsequent RT facilitation for negative compared with positive words following the onset of these adverse events. This trend is in line with earlier psychophysiological results showing an enhanced startle response following errors compared with correct responses during a flanker task (Hajcak & Foti, 2008). In this earlier study alike, interindividual variations at the level of this automatic defensive response (Shi & Davis, 2001) were actually predicted by the magnitude of the ERN/Ne component. Similarly, the correlation between the CRN amplitude and the subsequent categorization of positive versus negative words was also almost significant alike.

Our new results suggest that at the behavioral level, response errors clearly prime negative affect whereas symmetrically correct actions (fast hits) did not prime positive affect so evidently (an observation qualified by an Action Type × Word Valence interaction effect at the statistical level). A few elements are here noteworthy to account for this asymmetry between response errors and fast hits in their propensity to activate opposite affective–motivational systems. First, whereas we did not find evidence for evaluative priming following fast hits in the present ERP study, we actually already did so in our previous behavioral study (Aarts et al., 2012, see results of Experiments 2–3). Furthermore, in light of the main new brain–behavior correlation reported in our study (see Figure 3A), we can conclude that online ERP measurements (e.g., ERN/CRN component) may be more sensitive than standard behavioral measures (e.g., RT speed) to capture an evaluative priming effect, including following fast hits. Finally, our results are overall compatible with the assumption that usually negative affect (defensive system) can be more easily or strongly activated than positive affect (appetitive system; Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001). Therefore, a main contribution of our study is to show that this asymmetry holds true, including for self-generated actions (as opposed to external stimuli or learned associations).

Altogether, these new ERP results suggest that these two early response-related ERP components (ERN and CRN) likely reflect the activity of a shared neural system (Roger et al., 2010), whose strength of activation may provide critical information regarding the emotional or motivational values of actions.

Action Valence Influences Early Stages of Emotional Word Processing

A second major finding of our ERP study concerns the actual electrophysiological time-course and manifestations of this evaluative priming effect. Early on following word onset (180–200 ms poststimulus onset; EPN effect), we found that positive words led to a larger EPN signal than negative words, following FAs. No such modulation was seen after fast hits, however. Later on, 320–390 ms postword onset (LPP effect) negative words led to a larger LPP signal than positive words, following fast hits but not following FAs. Our new ERP results therefore suggest that FAs led to an earlier influence during the sensory processing of evaluative words than did fast hits.

The occipital EPN component has mainly been related to a motivated attentional capture effect depending on arousal and possibly depending on direct feedback effects from deeper limbic structures (Sabatinelli, Bradley, Fitzsimmons, & Lang, 2005; Sabatinelli, Flaisch, Bradley, Fitzsimmons, & Lang, 2004), that is, a larger EPN is typically found for more arousing compared with less arousing pictures or words (Herbert et al., 2008; Kissler et al., 2007, 2009; Schacht & Sommer, 2009a, 2009b). Accordingly, the results of this study suggest that an incongruency between the valence of the word and the accuracy of the action (i.e., FA-positive word), led to an enhanced-arousal reaction 180–200 ms postword onset, relative to congruent FA-negative words pairs. Response errors are usually deviant events that "automatically" call for a change in the behavior and are accompanied by defensive emotional (Hajcak & Foti, 2008) or attentional orienting reactions (Notebaert et al., 2009). Thus, their potential influence on the subsequent evaluative word processing could possibly take place earlier than the concurrent and symmetrical priming effect triggered by fast hits–correct responses. However, additional work is needed to corroborate the link between error commission and an automatic enhanced-arousal reaction during subsequent evaluative word categorization. This could be achieved by including individuals showing hyperactive error-monitoring systems, like high anxious (subclinical) participants (Aarts & Pourtois, 2010; Hajcak et al., 2003a). Presumably, these individuals might show a larger EPN effect following FAs than low anxious individuals. Moreover, the question whether the present EPN effect actually resulted from a sensory facilitation for negative words sharing the same intrinsic valence than the preceding actions (i.e., FAs; see Grill-Spector, Henson, & Martin, 2006), or alternatively, from an interference effect created by the perceived mismatch for the association of positive words with FAs, also requires empirical validation. In this regard, the inclusion of a condition with neutral words or visual stimuli devoid of emotion might provide a valuable baseline to tease these two opposite accounts apart.

On the other hand, the LPP component has generally been associated in previous ERP studies with top-down frontoparietal (endogenous) attention selection mechanisms (Schupp et al., 2000) and was usually larger for high compared with low arousing stimuli alike (Olofsson, Nordin, Sequeira, & Polich, 2008; Schupp, Flaisch, Stockburger, & Junghöfer, 2006). Accordingly, the presentation of negative (compared to positive) words following fast hits as well as FAs might unlock an enhanced endogenous orienting reaction. However, this effect seems to be enhanced when the negative word was incongruent with the inferred valence of the action (i.e., fast hit), whereas no similar effect of congruency was found when the positive word was incongruent with the inferred valence of the action (i.e., FA). Unlike the early (perhaps automatic) EPN effect found following FAs during evaluative word processing, this later LPP effect could likely translate an attention-dependent change in the perceived emotional arousal of the words. Here too, additional work is needed, however, to link more directly changes in endogenous attention control systems with variations at the level of the LPP (Sabatinelli, Lang, Keil, & Bradley, 2007), including during action-word evaluative priming settings.

In sum, our new ERP findings show that the earliest action-monitoring brain effect (i.e., ERN/Ne-CRN component generated for the responses performed during the go/no-go task) predicted the subsequent RT facilitation during evaluative word processing, suggesting that this former ERP deflection is involved in a rapid evaluation of the emotional significance of actions. Moreover, we also found that whereas FAs automatically influenced the early sensory processing of the subsequent evaluative word (EPN effect), correct responses mainly influenced the processing of the evaluative word alike, but during a later and nonoverlapping time interval (LPP effect), suggesting asymmetries in the manifestation of the evaluative priming effect triggered by actions, depending on their actual valence.

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