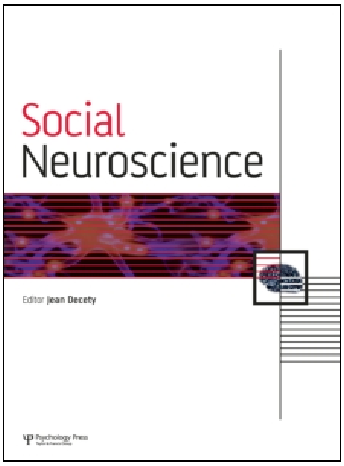

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Facing disapproval: Performance monitoring in a social context

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Facing disapproval: Performance monitoring in a social context

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Facial expressions are a potent source of information about how others evaluate our behavior. In the present study, we investigated how the internal performance-monitoring system, as reflected by error-related negativity (ERN), is affected by external cues of positive (happy faces) or negative evaluation (disgusted faces) of performance. We hypothesized that if the social context indeed impacts on how we evaluate our own performance, we would expect that the same performance error would result in larger ERN amplitudes in the context of negative evaluation than in a positive evaluation context. Our findings confirm our predictions: ERN amplitudes were largest when stimuli consisted of disgusted faces, compared to when stimuli consisted of happy faces. Importantly, ERN amplitudes in our control condition, in which sad faces were used as stimuli, were no different from the positive evaluation condition, ruling out the possibility that effects in the negative evaluation condition resulted from negative affect per se. We suggest that external social cues of approval or disapproval impact on how we evaluate our own performance at a very basic level: The brain processes errors that are associated with social disapproval as more motivationally salient, signaling the need for additional cognitive resources to prevent subsequent failures.

Keywords: Error-related negativity; Event-related potentials; Emotion; Affect.

Adequate evaluation of performance and monitoring of the environment for cues signaling potential aversive outcomes are among the most crucial prerequisites for adaptive, goal-directed behavior. To date, research has focused on how the brain accomplishes this task, and how potential sources of information regarding the efficacy of behavior, such as immediate behavioral outcomes or one's affective state, impact on the strength of neural performance monitoring signals. Crucially, the present research focused on the effects of external, social sources of information: the emotional facial expressions of other people.

Facial expressions are foremost emotional reactions to emotional events, but also serve an important social communicative function (Ruys & Stapel, 2008). It is clear that social context effects are ubiquitous (e.g., social facilitation; Zajonc, 1965). However, the effects of social cues on the very early (neural) stages of the performance-monitoring process remain largely uninvestigated. To address this important and intriguing issue, we examined the extent to which the presence of a social context of disapproval (disgusted facial expressions) or approval (happy expressions) influences early stages of performance monitoring.

Over the last 20 years, there has been a surge in research efforts investigating the neural correlates of these performance-monitoring processes. Measuring event-related potentials (ERPs),

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Falkenstein, Hohnsbein, Hoormann, and Blanke (1990) discovered a neural response to errors that is now called the error-related negativity (ERN) (see also Gehring, Coles, Meyer, & Donchin, 1990). The ERN consists of a large negative shift in the response-locked ERP occurring within 100 ms after subjects have made an erroneous response. Typically observed at frontocentral recording sites (FCz, Cz), the ERN has been shown to have its source in the anterior cingulate cortex (ACC) (DeHaene, Posner, & Tucker, 1994; Holroyd, Dien, & Coles, 1998). Indeed, many studies have shown that the ACC is involved in the processing of outcomes that deviate in a negative way from expectations (reward prediction errors; Amiez, Joseph, & Procyk, 2005; Matsumoto, Matsumoto, Abe, & Tanaka, 2007). The ACC responds with increased activation when experimental subjects make errors (Ullsperger, Nittono, & von Cramon, 2007), but also increases when performance feedback is provided that indicates that outcomes are below expectations (e.g., Nieuwenhuis, Schweizer, Mars, Botvinick, & Hajcak, 2007). It is these reward prediction errors, as signaled by the ACC, that are proposed to be reflected by the ERN (Holroyd & Coles, 2002).

In addition to signaling errors and low outcomes, the ERN has been proposed to reflect an affective evaluation of such negative outcomes (Bush, Luu, & Posner, 2000). For example, the ERN was found to be enlarged for subjects with high levels of negative affect (Luu, Collins, & Tucker, 2000; Hajcak, McDonald, & Simons, 2004), depression (Chiu & Deldin, 2007), anxiety (Hajcak, McDonald, & Simons, 2003), and behavioral inhibition (Tops & Boksem, 2011). Of particular relevance here may be the finding that for subjects high on punishment sensitivity the ERN was enlarged under conditions of potential punishment, while for subjects high on reward sensitivity the ERN was enlarged under conditions of potential reward (Boksem, Tops, Kostermans, & De Cremer, 2008), indicating that the subjective value of the (negative) outcome is particularly reflected in the ERN (see also Hajcak, Moser, Yeung, & Simons, 2005; Pailing & Segalowitz, 2004). These findings fit well with theories of ACC function as an interface between emotion and cognition (Bush et al., 2000), as well as with current theories regarding how emotions influence behavior: Emotions are proposed to provide an online evaluation (good or bad) of current performance. In this view, positive emotions associated with a certain behavioral outcome may promote repeating this behavior, while negative emotions would promote behavioral change to prevent this negative outcome in the future (Aarts, Custers, & Holland, 2007; Carver & Scheier, 1990; Weiner, 1985).

In addition to internally monitoring our own performance, we also monitor our (social) environment for cues of potential success or failure. Facial expressions are a potent source of information about how others evaluate our behavior (i.e., Ekman, 2003). Happy emotional expressions (i.e., smiling) communicate that others evaluate our behavior positively (Matthews & Wells, 1999), while negative (i.e., disapproving) facial expressions communicate that “something is wrong” and that we should probably change our behavior (Blair, 1995). This “social referencing” effect is fundamental to learning the do’s and don’ts that are appropriate in our social environment. For example, infants as young as 8 months will look toward the primary caregiver upon the discovery of a novel object. The infants’ behavior is then determined by the caregiver’s emotional expression: If the caregiver displays a positive expression (i.e., smiling) the infant will approach the object, while if the caregiver displays a negative expression such as disgust, the infant will avoid the object (Blair, 2003; Klinnert, Campos, & Source, 1983; Walker-Andrews, 1998).

Expressions of disgust are of particular relevance in the present context. Whereas expressions of anger may also communicate rivalry or aggression, an expression of disgust directed at the self exclusively implies a negative evaluation of one’s current behavior (Amir, Klumpp, Elias, Bedwell, Yanasak, & Miller, 2005; Rozin, Lowery, Imada, & Haidt, 1999), and may elicit emotions such as shame and guilt (Elison, 2005). In turn, these emotions serve as potent feedback that current behavior is not very well appreciated by others and that this behavior should be modified (Baumeister, Vohs, DeWall, & Zang, 2007). Indeed, shame is elicited particularly by the experience of negative social evaluation (Ayers, 2003) and shame has also been related to increased ERN amplitudes (Tops, Boksem, Wester, Lorist, & Meijman, 2006).

In the present study, we investigated how the internal performance-monitoring system, as reflected by the ERN, is affected by external cues of positive or negative evaluation of performance. Subjects performed a version of a Simon task (Simon, 1969) in which stimuli were either happy faces (inducing a positive evaluation context), or disgusted facial expressions (inducing a negative evaluation context). If the social context impacts on how we evaluate our own performance, we would expect that the same performance error would result in larger ERN amplitudes in the context of negative evaluation than in a context of positive evaluation. It is important to separate such effects on ERN amplitude from the effects of negative affect per se. Indeed, facial expressions of disgust can induce negative feelings, and also ERN amplitudes may be modulated by the experience of transient negative affect (Wiswede, Munte, Kramer, & Russeler, 2009). Therefore, we also included stimuli depicting sad facial expressions as a control condition.

Moreover, these error signals of negative social evaluation should provide a motivational cue to change behavior in such a way that performance will be more positively evaluated by others in the future. In the present task, this would involve changing behavior to minimize future errors. As most errors in this sort of tasks are so called "slips" caused by responding prematurely, slowing down after such a slip reduces the probability of making another error (i.e., post-error slowing) (Rabbitt, 1966). Because negative social evaluation, as induced by the disgusted faces and reflected in ERN amplitudes, should provide a potent cue to change behavior, we expect this behavioral adaptation to error commission to be especially prominent in a negative social evaluation context.

METHODS

Subjects

Fifty-four healthy participants (22 men), between 18 and 23 ($M = 20.1$, $SD = 1.5$) years of age, were recruited from the university population. There were no significant differences in either age or gender of subjects in the three experimental conditions. Participants received course credit for their participation and written informed consent was obtained prior to the study.

Task

We used a version of the Simon task (Simon, 1969). Stimuli consisted of pictures of male or female faces from the NimStim Face Stimulus set (MacArthur Foundation Research Network) that were presented either right or left of fixation (see Figure 1). Subjects were instructed to respond to pictures of male faces by pressing the button under their left index finger and to press the button under their right index finger when the stimulus was a picture of a female face. On congruent trials the stimulus appeared on the same side of the screen as the required response (i.e., a picture of a male on the left side of the screen or a picture of a female presented on the right side). On incongruent trials, the stimulus location differed from the response side (i.e., a picture of a male presented on the right side of the screen or a picture of a female presented on the left side of the screen).

The stimuli were presented on a 17-inch PC monitor. Pictures were grayscale against a black background, and each picture had a height of 10 cm and a width of 8 cm. Forty percent of the trials consisted of incongruent stimuli, and 60% consisted of congruent stimuli, presented in random order. Stimuli remained on screen for 1,000 ms. Following a 750-ms interval, feedback was presented for 500 ms. The intertrial interval was 750 ms, so that each trial had a total duration of 3 s. Participants completed 400 trials (20 min) in one of the three conditions that differed only in the types of pictures that were presented. In one condition, stimuli consisted of 10 different faces (5 male, 5 female faces) bearing a happy expression ($n = 18$). In a second condition, stimuli consisted of the faces of the same 10 people, but this time bearing a disgusted expression ($n = 17$). In the third condition, subjects viewed pictures of again the same 10 people, but this time bearing a sad expression to control for potential effects of negative affect ($n = 19$).

Figure 1. Examples of the stimuli used in the Simon task. Left: a congruent stimulus (pictures of males required a left-hand response) in the positive evaluation condition. Middle: an incongruent stimulus in the negative evaluation condition. Right: a congruent stimulus in the control condition.

Procedure

Before the start of the experiment, subjects were trained in performing the task, for 2.5 min (50 trials). Following the application of the electrodes, subjects were seated in a dimly lit, sound-attenuated, electrically shielded room at 1.20 m from a 17-inch PC monitor. Their index fingers rested on response buttons. Subjects were instructed to press the response button as quickly as possible when a target was presented, maintaining a high level of accuracy. Upon completion, subjects were debriefed and received their course credit.

Electrophysiological recording and data reduction

Electroencephalographic recordings (EEG) were made on 49 locations with active Ag–AgCl electrodes (Biosemi ActiveTwo, Amsterdam, The Netherlands) mounted in an elastic cap. Horizontal electrooculogram (EOGs) were recorded from two electrodes placed at the outer canthi of both eyes. Vertical EOGs were recorded from electrodes on the infraorbital and supraorbital regions of the right eye placed in line with the pupil. The EEG and EOG signals were sampled at a rate of 256 Hz, and offline re-referenced to an averaged mastoid reference.

All ERP analyses were performed with BrainVision Analyzer software (Brain Products GmbH, Germany). The data were resampled at 100 Hz and further filtered with a 0.53-Hz high-pass filter and a slope of 48 dB/oct and a 40-Hz, low-pass filter also with a slope of 48 dB/oct. Artifacts were rejected, and eye-movement artifacts were corrected by the Gratton, Coles, and Donchin (1983) method. A baseline voltage averaged over the 100-ms interval preceding events of interest was subtracted from the averages.

Data analysis

Performance

For the different stimulus conditions, mean reaction times (RTs) were calculated, and the percentage of hits, errors, and misses was also determined. Correct reactions occurring within a 100–1,000-ms interval after stimulus presentation were considered as hits. Because misses were very rare, we will focus here on hits and errors. To investigate strategic performance changes after error detection, we also analyzed RTs on trials following an error or a correct response (i.e., post-error slowing) (Rabbitt, 1966). As we found no difference in post-error slowing for congruent and incongruent trials, the reported data on post-error slowing include both incompatible and compatible $n-1$ trials.

ERPs

For error trials, mean ERN amplitude was calculated at FCz, where this component had its maximum. We quantified the ERN as the most negative peak occurring in the 100 ms following the erroneous response. For statistical analyses, we used the average amplitude of this peaks in a time window starting 20 ms before the peak until 20 ms after the peak. The same epochs were used for our analysis of the response-locked ERPs on correct trials (CRN). In addition, we also measured amplitudes of an ERP component following the ERN, the error positivity (Pe). The Pe was quantified as the average amplitude between 110 and 330 ms following the response, also at FCz.

Although feedback was presented following every trial, thus potentially allowing analysis of feedback-related ERPs, this feedback was not very informative because the task is so simple that subjects were well aware of making an error before feedback was presented. Therefore, feedback-related ERPs will not be presented.

RESULTS

Task performance

RTs and number of errors were calculated for the two trial types (congruent and incongruent) separately. For RTs, repeated-measures GLM (generalized linear model) with congruency as a within-subject factor and experimental condition (happy, disgusted, sad) as a between-subject factor indicated a significant main effect for trial type, $F(1, 51) = 56.24$, $p < .001$: Subjects responded slower in incongruent trials (562 ms) than in congruent trials (536 ms). This effect was not different for the three experimental conditions, $F(2, 51) = 0.15$, *ns*. Finally, there was no main effect of social context on RTs (disgusted: 547 ms; happy: 551 ms; sad: 550 ms; $F(2, 51) = 0.34$, *ns*).

The same analyses also revealed a main effect of trial type for accuracy, $F(1, 51) = 12.55$, $p < .001$: The number of errors made on incongruent trials (10.6%) was substantially larger than the number of errors made on congruent trials (7.7%). Again, we found no interaction between congruency and experimental condition, $F(2, 51) = 2.27$, *ns*, and no main effect of social context on error rates (disgusted: 7.4%, happy: 10.2%, sad: 9.7%; $F(2, 51) = 1.23$, *ns*).

On average, subjects responded slower to trials following an incorrect response (601 ms) than to trials following a correct response (548 ms), $F(1, 51) = 94.15$, $p < .001$. Although this post-error slowing effect tended to be largest in the disgusted condition (65 ms) and smallest in the happy condition (45 ms), with the sad condition somewhat in between (51 ms), this failed to reach significance, $F(2, 51) = 1.08$, *ns*.

ERPs[1]

A large negative deflection following an erroneous response (ERN) was observed that was significantly larger, $F(1, 51) = 137.43$, $p < .001$, than the deflection following a correct response (correct-related

[1] To control for potential contamination of response-locked ERPs by stimulus-evoked ERPs (most notably the P3), we also performed all ERP analyses with P3 amplitudes (measured 300–500 ms post-stimulus onset) included as a covariate. Results from these additional analyses were not different from those reported in the main text, indicating that our findings specifically reflect the impact of social context on performance evaluation.

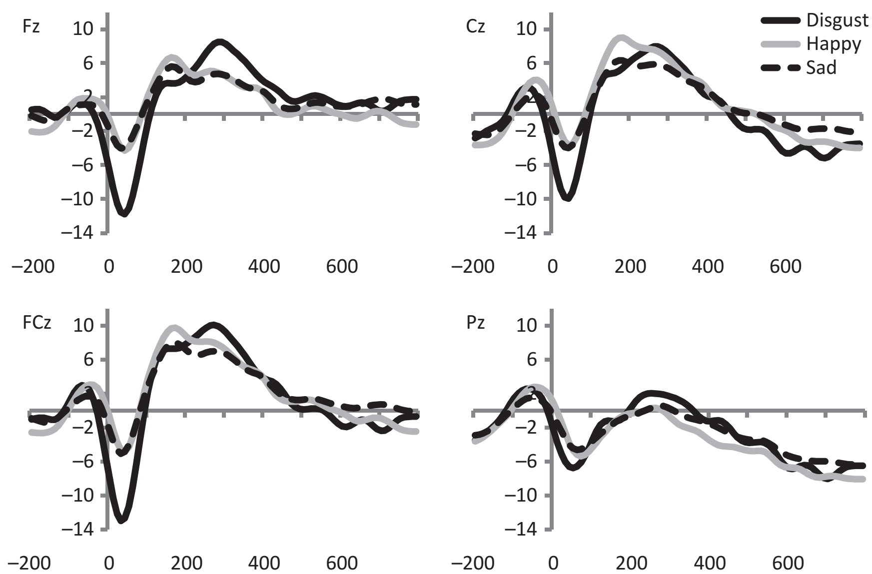

Figure 2. Response-locked ERPs at midline electrode sites for the negative evaluation condition (disgusted; $n = 17$), the positive evaluation condition (happy; $n = 18$), and the control condition (sad; $n = 19$).

negativity – CRN). This effect interacted with experimental condition, $F(2, 50) = 6.79$, $p < .005$. Follow-up *t*-tests showed that the ERN was larger in the disgusted condition than in the happy condition, $t(33) = -4.07$, $p < .001$, or the sad condition, $t(34) = -3.95$, $p < .001$, while the ERNs in the happy and the sad conditions were not significantly different, $t(35) = 0.68$, *ns* (Figure 2). Analysis of CRN amplitudes showed a different pattern of results: While both CRN amplitudes in the disgusted condition ($t(33) = -2.20$, $p < .05$) and in the sad condition, $t(35) = -2.24$, $p < .05$, were significantly more negative than in the happy condition, there was no significant difference in amplitudes between sad and disgusted conditions $t(34) = -0.86$, *ns*.

Contrasting the difference between ERN and CRN in the three conditions (i.e., the "difference wave" resulting from subtracting CRN from ERN) revealed an enhanced negativity following erroneous responses in the disgusted condition compared to both the happy condition, $t(33) = -2.34$, $p < .05$, and the sad condition, $t(35) = -3.62$, $p < .001$. This difference between ERN and CRN was not significantly different for the happy condition compared to the sad condition, $t(35) = 0.94$, *ns*.

Following these negative ERP components, we observed a large positive waveform (Pe) that was significantly more positive for ERPs elicited by erroneous responses than for ERPs elicited by a correct responses, $F(1, 50) = 97.03$, $p < .001$. Pe amplitudes were not different for the three conditions, $F(2, 50) = 1.79$, *ns*.

Finally, ERN amplitude was found to be related to post-error slowing: Subjects displaying the largest ERN amplitudes slowed down the most, $r(54) = 0.27$, $p < .01$. When we look at this correlation more closely for the three different conditions, we see that, only in the disgusted condition, post-error slowing was strongly related to ERN amplitudes, $r(17) = 0.54$, $p < .05$, while in the happy condition, $r(18) = 0.10$, *ns*, and in the sad condition, $r(19) = 0.24$, *ns*, ERN amplitudes and post-error slowing were unrelated. The Fisher *r*-to-*z* transformation was used to assess whether this correlation in the disgusted condition was significantly higher than the correlations in the other conditions. The results showed that these differences were marginally significant, $z < 1.36$, $p > .08$.

DISCUSSION

In the present study, we investigated how the internal performance-monitoring system, as reflected by the ERN, is affected by external cues of positive (happy faces) or negative evaluation (disgusted faces) of performance. We hypothesized that if the social context does indeed impact on how we evaluate our own performance, we would expect that the same performance error would result in larger ERN amplitudes in the context of negative evaluation than in a context of positive evaluation.

Our findings confirm our predictions: ERN amplitudes were largest when stimuli consisted of disgusted faces (negative evaluation context), compared to when stimuli consisted of happy faces (positive evaluation context). Importantly, ERN amplitudes in our control condition, in which sad faces were used as stimuli, were no different from the positive evaluation condition, ruling out the possibility that effects in the negative evaluation condition resulted from negative affect per se. Indeed, using a very similar task, it has previously been shown that happy, angry, and neutral facial expressions did not result in differences in ERN amplitude at all (Compton, Carp, Chaddock, Fineman, Quandt, & Ratliff, 2007). These findings suggest that external social cues of disapproval impact on how we evaluate our own performance at a very basic level: Within 100 ms of making a mistake, our brain responds more strongly to this mistake in the context of social cues signaling disapproval than when making the same mistake in a non-disapproving social context.

Interestingly, we found that particularly in the disgusted condition ERN amplitudes were related to corrective actions (i.e., slowing down after an erroneous response to prevent subsequent errors): Large ERN amplitudes were related to more post-error slowing. In addition, post-error slowing in absolute terms tended to be larger in this condition, although not significantly so. These observations fit well with the idea that the emotions subjects may experience in the context of negative evaluation (such as shame) serve the adaptive purpose of motivating behavior change, so that this negative emotion (and thus the behavior that caused it) will not recur in the future. Indeed, ERN amplitudes have been shown to be predictive of performance adjustments (Cohen & Ranganath, 2007; Frank, Woroch, & Curran, 2005) and have recently been shown to reflect a learning process guiding behavior away from repeating a previous mistake (Van der Helden, Boksem, & Blom, 2010). The present results suggest that social cues of negative evaluation may facilitate this process, although it should be noted that the observed differences between conditions in post-error slowing were only marginally significant, possibly due to small sample sizes. Therefore, these findings need to be interpreted with caution.

The present findings fit well with previous results showing that the subjective value of the (negative) outcome is particularly reflected in the ERN (e.g., Boksem et al., 2008; Hajcak et al., 2005; Pailing & Segalowitz, 2004), indicating that, in a context of negative social evaluation (induced by the disgusted facial expressions), errors are experienced as particularly aversive and salient. In contrast, we showed that this subjective value of negative outcomes did not affect Pe amplitudes. Measured at 110–330 ms post-response, this component can be considered an "early Pe" (e.g., Van Veen & Carter, 2002), which has been related to error-evaluation processes similar to the ERN and has also been related to affective/motivational processes by some authors (e.g., Boksem, Tops et al., 2006; Falkenstein et al., 2000; Hajcak et al., 2004). However, the current results indicate that, at least in the present experimental context, the Pe is largely unaffected by such processes, speaking to the observation that findings regarding the Pe are rather inconsistent and a clear functional interpretation of this component remains to be put forward (Overbeek, Nieuwenhuis, & Ridderinkhof, 2005).

Our findings add to a growing literature suggesting that social factors are involved in performance or outcome evaluation. For example, we recently reported that unfair outcomes elicited larger "feedback ERNs" (FRN) particularly for subjects who value fairness highly (Boksem & De Cremer, 2010). In addition, we found that FRN amplitudes elicited by experienced losses depend on the outcome experienced by others: FRN amplitudes were increased when subjects experienced a loss in the context of another subject experiencing a gain (Boksem, Kostermans, & De Cremer, 2010). FRN amplitudes were also shown to depend on one's social standing: For subjects at the bottom of the social hierarchy (who are more likely to experience negative evaluation and potential rejection), FRN amplitudes were larger than for those higher in the hierarchy (Boksem, Kostermans, Milivojevic, & De Cremer, in press). Importantly, the ACC (the putative source of the ERN) has also been shown to be involved in processing "error" signals from the social environment such as exclusion, rejection, and the experience of shame and guilt[2] (Eisenberger, Lieberman, & Williams, 2003; Kross, Egner, Ochsner, Hirsch, & Downey, 2007).

Additionally, our findings demonstrate the importance of other people's emotional reactions in how much effort we expend to achieve something. Previous research shows that, in a reward context, pairing neutral objects with angry facial expressions stimulated subjects to increase physical effort to obtain

[2]A neural structure that is consistently co-activated with the ACC in processing these "social error" signals is the anterior insula (AI) (Lamm & Singer, 2010). In addition, this neural structure is consistently activated by viewing disgusted faces, as in the present experiment (Philips, Endrass, Kathmann, Neumann, J., von Cramon, & Ullsperger, 1997), by becoming aware of having made a mistake (Klein et al., 2007), while the AI also has a necessary role in the normal occurrence of the ERN (Ullsperger & von Cramon, 2003). Indeed, it has been proposed that the role of the AI in these processes may reflect the processing of personally and motivationally important salient information, and the subsequent recruitment of cognitive effort (Ullsperger et al., 2010). This interpretation is very similar to our suggestions that ERN may reflect engagement (Tops & Boksem, 2010), emphasizing the role of both ACC and AI in this process.

these neutral objects (Aarts et al., 2010). The present research suggests that, in a performance context, disgusted facial expressions have a similar effect. By amplifying the error-related signal in the brain, other people's disgust may increase our effort to perform well on a task. An interesting subject for future research would be to investigate under what circumstances facial emotional expressions, such as sadness and fear, affect our willingness to invest increased effort.

A very influential form of the model stating that affect acts as an online feedback mechanism to guide goal-directed behavior has been developed by Carver and Scheier (1990, 1998). These authors proposed that positive affect signals that progress toward a valued goal is adequate or even above expectations, while negative affect signals that progress is not as good as desired. Hence, negative affect is a motivator to put in more effort, while positive affect may even signal opportunities to turn attention to something else, without jeopardizing long-term success (Carver, 2003). Although the present work highlights the importance of specific emotional reactions (e.g., disgust) rather than global positive or negative affect for guiding goal-directed behavior (see also Aarts et al., 2010), the basic idea that emotional reactions provide performance feedback fits well with current theories that suggest that ERN reflects a measure of engagement (Cavanagh & Allen, 2008; Luu et al., 2000; Tops & Boksem, 2010): Bored or fatigued subjects show reduced ERN amplitudes, while highly motivated subjects show increased ERN amplitudes (e.g., Boksem, Meijman, & Lorist, 2006; West & Travers, 2008). In line with Carver and Scheier's model, the perceived negative evaluation as induced by the disgusted faces may signal that progress is below expectation, in turn stimulating increased levels of effort and engagement.

In summary, we found that cues of negative social evaluation (faces bearing the emotional expression of disgust) influence how we evaluate our performance: A mistake that is made in such a context of negative social evaluation elicits a larger ERN than when a similar mistake is made in a non-rejecting social context. These findings suggest that external social cues of approval or disapproval impact on how we evaluate our own performance at a very basic level: The brain processes errors associated with social disapproval as more motivationally salient, signaling the need for additional cognitive resources to prevent subsequent mistakes and negative evaluation by others.

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REFERENCES

Aarts, H., Custers, R., & Holland, R. W. (2007). The nonconscious cessation of goal pursuit: When goals and negative affect are coactivated. *Journal of Personality and Social Psychology*, *92*(2), 165–178.

Aarts, H., Ruys, K. I., Veling, H., Renes, R. A., De Groot, J. H. B., Van Nunen, A. M., et al. (2010). The art of anger: Reward context turns avoidance responses to anger-related objects into approach. *Psychological Science*, *21*(10), 1406–1410.

Amiez, C., Joseph, J. P., & Procyk, E. (2005). Anterior cingulate error-related activity is modulated by predicted reward. *European Journal of Neuroscience*, *21*(12), 3447–3452.

Amir, N., Klumpp, H., Elias, J., Bedwell, J. S., Yanasak, N., & Miller, L. S. (2005). Increased activation of the anterior cingulate cortex during processing of disgust faces in individuals with social phobia. *Biological Psychiatry*, *57*(9), 975–981.

Ayers, M. (2003). *Mother–infant attachment and psychoanalysis: The eyes of shame*. New York, NY: Brunner-Routledge.

Baumeister, R. F., Vohs, K. D., DeWall, C. N., & Zhang, L. Q. (2007). How emotion shapes behavior: Feedback, anticipation, and reflection, rather than direct causation. *Personality and Social Psychology Review*, *11*(2), 167–203.

Blair, R. J. R. (1995). A cognitive developmental approach to morality: Investigating the psychopath. *Cognition*, *57*(1), 1–29.

Blair, R. J. R. (2003). Facial expressions, their communicatory functions and neuro-cognitive substrates. *Philosophical Transactions of the Royal Society of London – Series B:Biological Sciences*, *358*(1431), 561–572.

Boksem, M. A. S., & De Cremer, D. (2010). Fairness concerns predict medial frontal negativity amplitude in ultimatum bargaining. *Social Neuroscience*, *5*(1), 118–128.

Boksem, M. A. S., Kostermans, E., & de Cremer, D. (2010). Failing where others have succeeded: medial frontal negativity tracks failure in a social context. *Psychophysiology*. Advance online publication. doi: 10.1111/j.1469-8986.2010.01163.x

Boksem, M. A. S., Kostermans, E., Milivojevic, B., & De Cremer, D. (in press). Social status determines how we monitor and evaluate our performance. *Social, Cognitive and Affective Neuroscience*.

Boksem, M. A. S., Meijman, T. F., & Lorist, M. M. (2006). Mental fatigue, motivation and action monitoring. *Biological Psychology*, *72*(2), 123–132.

Boksem, M. A. S., Tops, M., Kostermans, E., & De Cremer, D. (2008). Sensitivity to punishment and reward omission: Evidence from error-related ERP components. *Biological Psychology*, *79*(2), 185–192.

Boksem, M. A. S., Tops, M., Wester, A. E., Meijman, T. F., & Lorist, M. M. (2006). Error-related ERP components and individual differences in punishment and reward sensitivity. *Brain Research*, *1101*, 92–101.

Bush, G., Luu, P., & Posner, M. I. (2000). Cognitive and emotional influences in anterior cingulate cortex. *Trends in Cognitive Sciences*, *4*(6), 215–222.

Carver, C. S. (2003). Pleasure as a sign you can attend to something else: Placing positive feelings within a general model of affect. *Cognition & Emotion*, *17*(2), 241–261.

Carver, C. S., & Scheier, M. F. (1990). Origins and functions of positive and negative affect – A control-process view. *Psychological Review*, *97*(1), 19–35.

Carver, C. S., & Scheier, M. F. (1998). *On the self-regulation of behavior*. New York, NY: Cambridge University Press.

Cavanagh, J. F., & Allen, J. J. B. (2008). Multiple aspects of the stress response under social evaluative threat: An electrophysiological investigation. *Psychoneuroendocrinology*, *33*(1), 41–53.

Chiu, P. H., & Deldin, P. J. (2007). Neural evidence for enhanced error detection in major depressive disorder. *American Journal of Psychiatry*, *164*(4), 608–616.

Cohen, M. X., & Ranganath, C. (2007). Reinforcement learning signals predict future decisions. *Journal of Neuroscience*, *27*(2), 371–378.

Compton, R. J., Carp, J., Chaddock, L., Fineman, S. L., Quandt, L. C., & Ratliff, J. B. (2007). Anxiety and error monitoring: Increased error sensitivity or altered expectations? *Brain and Cognition*, *64*(3), 247–256.

Dehaene, S., Posner, M. I., & Tucker, D. M. (1994). Localization of a neural system for error-detection and compensation. *Psychological Science*, *5*(5), 303–305.

Eisenberger, N. I., Lieberman, M. D., & Williams, K. D. (2003). Does rejection hurt? An fMRI study of social exclusion. *Science*, *302*(5643), 290–292.

Ekman, P. (2003). *Emotions revealed: Recognizing faces and feelings to improve communication and emotional life*. New York, NY: Times Books.

Elison, J. (2005). Shame and guilt: A hundred years of apples and oranges. *New Ideas in Psychology*, *23*(1), 5–32.

Falkenstein, M., Hohnsbein, J., Hoormann, J., & Blanke, L. (1990). Effects of errors in choice reaction tasks on the ERP under focussed and divided attention. In C. H. M. Brunia, A. W. K. Gaillard, & A. Kok (Eds.), *Psychophysiological brain research* (pp. 192–195). Tilburg, The Netherlands: Tilburg University Press.

Falkenstein, M., Hoormann, J., Christ, S., & Hohnsbein, J. (2000). ERP components on reaction errors and their functional significance: a tutorial. *Biological Psychology*, *51*(2–3), 87–107.

Frank, M. J., Woroch, B. S., & Curran, T. (2005). Error-related negativity predicts reinforcement learning and conflict biases. *Neuron*, *47*(4), 495–501.

Gehring, W. J., Coles, M. G. H., Meyer, D. E., & Donchin, E. (1990). The error-related negativity: an event-related brain potential accompanying errors. *Psychophysiology*, *27*, s34.

Gratton, G., Coles, M. G., & Donchin, E. (1983). A new method for off-line removal of ocular artifact. *Electroencephalography and Clinical Neurophysiology*, *55*, 468–484.

Hajcak, G., McDonald, N., & Simons, R. F. (2003). Anxiety and error-related brain activity. *Biological Psychology*, *64*(1–2), 77–90.

Hajcak, G., McDonald, N., & Simons, R. F. (2004). Error-related psychophysiology and negative affect. *Brain and Cognition*, *56*(2), 189–197.

Hajcak, G., Moser, J. S., Yeung, N., & Simons, R. F. (2005). On the ERN and the significance of errors. *Psychophysiology*, *42*(2), 151–160.

Holroyd, C. B., & Coles, M. G. H. (2002). The neural basis of human error processing: Reinforcement learning, dopamine, and the error-related negativity. *Psychological Review*, *109*(4), 679–709.

Holroyd, C. B., Dien, J., & Coles, M. G. H. (1998). Error-related scalp potentials elicited by hand and foot movements: Evidence for an output-independent error-processing system in humans. *Neuroscience Letters*, *242*(2), 65–68.

Klein, T. A., Endrass, T., Kathmann, N., Neumann, J., von Cramon, D. Y., & Ullsperger, M. (2007). Neural correlates of error awareness. *NeuroImage*, *34*(4), 1774–1781.

Klinnert, M. D., Campos, J. J., & Source, J. (1983). Emotions as behavior regulators: Social referencing in infancy. In R. Plutchik & H. Kellerman (Eds.), *Emotions in early development* (pp. 57–86). New York, NY: Academic Press.

Kross, E., Egner, T., Ochsner, K., Hirsch, J., & Downey, G. (2007). Neural dynamics of rejection sensitivity. *Journal of Cognitive Neuroscience*, *19*(6), 945–956.

Lamm, C., & Singer, T. (2010). The role of anterior insular cortex in social emotions. *Brain Structure & Function*, *214*(5–6), 579–591.

Luu, P., Collins, P., & Tucker, D. M. (2000). Mood, personality, and self-monitoring: Negative affect and emotionality in relation to frontal lobe mechanisms of error monitoring. *Journal of Experimental Psychology: General*, *129*(1), 43–60.

Matsumoto, M., Matsumoto, K., Abe, H., & Tanaka, K. (2007). Medial prefrontal cell activity signaling prediction errors of action values. *Nature Neuroscience*, *10*(5), 647–656.

Matthews, G., & Wells, A. (1999). The cognitive science of attention and emotion. In T. Dalgleish & M. J. Power (Eds.), *Handbook of cognition and emotion* (pp. 171–192). New York, NY: Wiley.

Nieuwenhuis, S., Schweizer, T. S., Mars, R. B., Botvinick, M. M., & Hajcak, G. (2007). Error-likelihood prediction in the medial frontal cortex: A critical evaluation. *Cerebral Cortex*, *17*(7), 1570–1581.

Overbeek, T. J. M., Nieuwenhuis, S., & Ridderinkhof, K. R. (2005). Dissociable components of error processing: On the functional significance of the Pe vis-à-vis the ERN/Ne. *Journal of Psychophysiology*, *19*(4), 319–329.

Pailing, P. E., & Segalowitz, S. J. (2004). The error-related negativity as a state and trait measure: Motivation, personality, and ERPs in response to errors. *Psychophysiology*, *41*(1), 84–95.

Phillips, M. L., Young, A. W., Senior, C., Brammer, M., Andrew, C., Calder, A. J., et al. (1997). A specific neural substrate for perceiving facial expressions of disgust. *Nature*, *389*(6650), 495–498.

Rabbit, P. M. A. (1966). Errors and error correction in choice reaction tasks. *Journal of Experimental Psychology*, *71*, 264–272.

Rozenkrants, B., & Polich, J. (2008). Affective ERP processing in a visual oddball task: Arousal, valence, and gender. *Clinical Neurophysiology*, *119*(10), 2260–2265.

Rozin, P., Lowery, L., Imada, S., & Haidt, J. (1999). The CAD triad hypothesis: A mapping between three moral emotions (contempt, anger, disgust) and three moral codes (community, autonomy, divinity). *Journal of Personality and Social Psychology*, *76*(4), 574–586.

Ruys, K. I., & Stapel, D. A. (2008). Emotion elicitor or emotion messenger? Subliminal priming reveals two faces of facial expressions. *Psychological Science*, *19*(6), 593–600.

Simon, J. R. (1969). Reactions towards the source of stimulation. *Journal of Experimental Psychology*, *81*, 174–176.

Tops, M., & Boksem, M. A. S. (2010). Absorbed in the task: Personality measures predict engagement during task performance as tracked by error negativity and asymmetrical frontal activity. *Cognitive, Affective and Behavioral Neuroscience*, *20*(4), 441–453.

Tops, M., & Boksem, M. A. S. (2011). Cortisol involvement in mechanisms of behavioural inhibition. *Psychophysiology*. DOI: 10.1111/j.1469-8986.2010.01131.x.

Tops, M., Boksem, M. A. S., Wester, A. E., Lorist, M. M., & Meijman, T. F. (2006). Task engagement and the relationships between the error-related negativity, agreeableness, behavioral shame proneness and cortisol. *Psychoneuroendocrinology*, *31*(7), 847–858.

Ullsperger, M., Harsay, H. A., Wessel, J. R., & Ridderinkhof, K. R. (2010). Conscious perception of errors and its relation to the anterior insula. *Brain Structure & Function*, *214*(5–6), 629–643.

Ullsperger, M., Nittono, H., & von Cramon, D. Y. (2007). When goals are missed: Dealing with self-generated and externally induced failure. *NeuroImage*, *35*(3), 1356–1364.

Ullsperger, M., & von Cramon, D. Y. (2003). Error monitoring using external feedback: Specific roles of the habenular complex, the reward system, and the cingulate motor area revealed by functional magnetic resonance imaging. *Journal of Neuroscience*, *23*(10), 4308–4314.

Ullsperger, M., von Cramon, D. Y., & Muller, N. G. (2002). Interactions of focal cortical lesions with error processing: Evidence from event-related brain potentials. *Neuropsychology*, *16*(4), 548–561.

Van der Helden, J., Boksem, M. A. S., & Blom, J. H. G. (2010). The importance of failure: Feedback related negativity predicts motor learning efficiency. *Cerebral Cortex*, *20*(7), 1596–1603.

Van Veen, V., & Carter, C. S. (2002). The timing of action-monitoring processes in the anterior cingulate cortex. *Journal of Cognitive Neuroscience*, *14*(4), 593–602.

Walker-Andrews, A. S. (1998). Emotions and social development: Infants' recognition of emotions in others. *Pediatrics*, *102*, 1268–1271.

Weiner, B. (1985). An attributional theory of achievement motivation and emotion. *Psychological Review*, *92*, 548–573.

West, R., & Travers, S. (2008). Tracking the temporal dynamics of updating cognitive control: An examination of error processing. *Cerebral Cortex*, *18*(5), 1112–1124.

Wiswede, D., Munte, T. F., Kramer, U. M., & Russeler, J. (2009). Embodied emotion modulates neural signature of performance monitoring. *Plos One*, *4*(6), e5754.

Zajonc, R. B. (1965). Social facilitation. *Science*, *149*, 269–274.