Fear and Anger Prime Effects on Cognitive Performance: The Role of Prime Visibility

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ABSTRACT

Based on the Implicit-Affect-Primes-Effort (IAPE) model (Gendolla, 2012, 2015), the present experiment investigated the role of prime visibility as a moderator of fear and anger primes' effect on cognitive performance. Previous research has revealed inconsistent effects. Participants worked on a d2 mental concentration task with integrated pictures of fearful vs. angry faces, which were presented either masked (25 ms) or clearly visible (775 ms). Cognitive performance was assessed in terms of response accuracy and reaction times. Prime visibility significantly moderated the affect primes' effect on response accuracy: When the primes were visible, fear expressions resulted in significantly lower response accuracy than anger primes. The opposite pattern occurred when the affect primes were masked. Additionally, visible primes led to slower responses in general, suggesting controlled prime processing. The observed performance effects corroborate recent findings on physiological measures of resource mobilization in the context of the IAPE model.

HIGHLIGHTS

Participants were presented with masked (25 ms) vs. clearly visible (775 ms) primes of anger or fear during a mental concentration task.

The visibility of the primes significantly moderated the effect of affect primes on response accuracy.

When the primes were visible, fear primes resulted in significantly lower response accuracy than anger primes. The opposite pattern occurred when the affect primes were masked.

The performance results corroborate recent physiological findings related to the IAPE model.

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INTRODUCTION

Recent research revealed that emotions do not need to be consciously experienced to impact behavior. Rather, the mere activation of their mental representations is sufficient to induce behavior change and changes in underlying physiological activity (see Gendolla 2012, 2015; Silvestrini & Gendolla, 2019; van der Ploeg et al., 2017; Winkielman et al., 2005 for reviews). Specifically, implicitly processed fear and sadness primes have been found to increase cardiovascular responses during cognitive performance—reflecting effort, the mobilization of resources—more than anger or happiness primes (e.g., Chatelain & Gendolla, 2015; Chatelain et al., 2016; Freydefont et al., 2012; Gendolla & Silvestrini, 2011; Silvestrini & Gendolla, 2011a, 2011b). These studies were based on the Implicit-Affect-Primes-Effort (IAPE) model (Gendolla, 2012). According to that theory, information about performance ease and difficulty are features of individuals' mental representations of affective states, because people have learned that performance is easier in some affective states than in others (see Lasauskaite et al., 2017): sadness and fear are both associated with low coping potential and thus difficulty, while happiness and anger are both related to high coping potential and thus ease. Affect primes, like briefly flashed facial expressions of emotions that are implicitly processed during task performance, can make these ease and difficulty concepts accessible, influence subjective task demand, and thus determine effort in accordance with the principles of motivation intensity theory (Brehm & Self 1989): effort rises proportionally with subjective demand as long as success is possible and the necessary effort is justified.

Further research specified that affect primes' effect on behavior has some boundaries and is thus context-dependent (e.g., Framorando & Gendolla, 2018a, 2018b, 2019a, 2019b; Lasauskaite Schüpbach et al., 2014). Especially, the primed person's unawareness of the priming procedure appears to be essential for yielding priming effects (e.g., Loersch & Payne, 2012; Lombardi et al., 1987; Murphy et al., 1995; Verwijmeren et al., 2013). That is, priming procedures can only be effective if people misattribute their prime-related mental content to their own thoughts (Loersch & Payne, 2011). This becomes difficult when people become aware of a priming procedure (e.g., Oikawa et al., 2011). Based on the idea that people should prefer autonomy (Ryan & Deci, 2000) and believe to act in accordance with their own thoughts and decisions (Loersch & Payne, 2011), Gendolla (2015) suggested that people should dislike being manipulated and react to the perceived external influences with behavior correction (Brehm, 1966). Indeed, the effects of happiness, anger, and sadness primes on effort disappeared, or were even reversed, when people were able to see the primes or when they were warned about their occurrence. However, while the moderator effect of prime awareness is well documented for the influence of happiness, anger, and sadness primes (e.g., Framorando & Gendolla, 2018a, 2018b, 2019a; Lasauskaite Schüpbach et al., 2014), evidence for fear primes is still lacking. The present experiment aimed at filling this gap.

Beside multiple empirical demonstrations of affect primes' effect on physiological adjustment reflecting mental effort, some studies found evidence for corresponding effects on cognitive performance (e.g., Framorando & Gendolla, 2018a; Gendolla & Silvestrini, 2011; Lasauskaite et al., 2013). However, this was not systematically observed and the role of prime visibility was only investigated in the study by Framorando and Gendolla (2018a). Moreover, the studies that found performance effects administered primes of happiness, anger (both increased performance), and sadness (decreased performance), but to date we have not found evidence for fear prime effects on performance. The present experiment contributed to fill also this gap and tested fear vs. anger primes' effect on response speed and accuracy in an attention task.

FEAR AND ANGER EFFECTS ON COGNITIVE PERFORMANCE

Beside the lack of demonstrations of fear prime effects on cognitive performance, also the evidence for effects of consciously experienced fear and anger is ambiguous. On the one hand, experienced fear is frequently associated with impaired performance—as shown, for example, by detrimental effects of anxiety on creativity (Byron & Khazanchi, 2011), arithmetic (Ashcraft & Faust, 1994), and academic achievements (Cassady & Johnson, 2002). One reason for these detrimental effects seems to be that conscious feelings of fear and anxiety tax working memory capacity (Eysenck & Calvo, 1992; Pessoa, 2009). On the other hand, there is also evidence that anxiety can increase performance (see Robinson et al., 2013). Likewise, experienced anger has been found to narrow attentional scope (e.g., Gable et al., 2015) and to enhance selective attention (Finucane, 2011). But anger has also been related to superficial cognitive processing (e.g., Bodenhausen et al., 1994; Litvak et al., 2010; Tiedens & Linton, 2001). Summing up, the effects of experienced fear and anger on cognitive performance are equivocal. With this in mind, the present research also contributed to a better understanding of the roles of fear and anger in cognitive performance in general.

THE PRESENT EXPERIMENT

Participants worked on an adapted version of the d2 mental concentration task (Brickenkamp, 1981) with integrated fear vs. anger primes that were either briefly flashed and masked (suboptimal; 25 ms) or clearly visible (optimal; 783 ms). Originally, this study aimed at investigating affect prime effects on both effort-related cardiac responses and cognitive performance. Unfortunately, due to technical problems, cardiac pre-ejection period—the main variable mirroring effort in our previous research—could not be analyzed. But it was possible to analyze the effects of fear and anger primes on cognitive performance in terms of response accuracy and reaction times.

Based on the IAPE model (Gendolla, 2012) and the evidence supporting it, we expected that suboptimally presented fear primes should lead to the mobilization of higher cognitive resources than suboptimally presented anger primes (e.g., Chatelain & Gendolla, 2015; Gendolla & Silvestrini, 2011). Based on the IAPE model reasoning about the moderating role of prime awareness (Gendolla, 2015) and the evidence for it, this effect should be corrected and either disappear or be reversed when the affect primes are clearly visible (e.g., Framorando & Gendolla, 2018a, 2018b; Lasauskaite Schüpbach et al., 2014). In both cases, the result should be an affect prime x prime visibility interaction effect, which was our operational hypothesis for the mobilization of mental resources. Considering the evidence that affect primes' impact of effort mobilization was at least sometimes accompanied by corresponding effects on cognitive performance (e.g., Framorando & Gendolla, 2018a; Gendolla & Silvestrini, 2011; Lasauskaite et al., 2013), we tested the interaction effect hypothesis on cognitive performance in terms of response accuracy and reaction times.

METHOD

PARTICIPANTS AND DESIGN

N = 85 university psychology students were randomly assigned to a 2 (Prime: fear vs. anger) × 2 (Visibility: suboptimal vs. optimal) between-persons design. The sample size was determined a priori using a numerical guideline to collect at least 20 participants per condition (Simmons et al., 2011). This sample size provided enough power to detect significant effects of medium size in our other studies assessing cardiac measures of effort—which was originally also intended for this study but not possible because of technical problems. Two participants were removed from the analysis due to very low response accuracy in the d2 task (< 60% of correct response) suggesting that they did not comply with the task instructions. This left a final sample of *N* = 83 (55 women, 28 men, average age = 21 years). A sensitivity analysis run with G*power (Faul et al., 2007) revealed that this sample size was sufficient to detect a significant Prime × Visibility two-way interaction effect of a medium size ($\eta^2 = 0.09$) with 80% power.

AFFECT PRIMES

Pictures from the Averaged Karolinska Directed Emotional Faces (AKDEF) database (Lundqvist & Litton, 1998) with averaged neutral (MNES and FNES), fear (MAFS and FAFS), and anger (MANS and FANS), front perspective faces were used as affect primes for this study. The pictures were in grey scale. Half of them were averaged female faces and half were averaged male faces.

PROCEDURE

The local ethics committee had approved the present experiment. Participants were seated in a comfortable chair in front of a 120 Hz computer screen, gave signed consent, and were equipped with physiological sensors (see Supplemental Material). After starting the experimental program (E-Prime, Psychology Software Tools, Pittsburgh, PA) the experimenter went to an adjacent control room. After answering biographical questions (age, sex etc.), participants rated their affective states (2 fear items: frightened, anxious; 2 anger items: angry, irritated) on 7-point scales (1—*not at all*, 7—*very much*). To prevent suspicion, these affect measures were introduced as standard assessment, because people enter the laboratory in different feeling states. The questions were followed by a hedonically neutral documentary film about Portugal (8 min) while we assessed blood pressure and impedance cardiography (ICG) signals (see Online Supplemental Material).

Next, participants completed a version of the Brickenkamp (1981) d2 mental concentration task (5 min). Participants were asked to respond correctly and as fast as possible. The main task comprised 36 trials, which started with a fixation cross (1000 ms), followed by a face picture (affect prime) that centrally appeared for 25 ms (suboptimal condition) vs. 775 ms (optimal condition), a grey random dot picture mask (133 ms), and a second fixation cross (1000 ms). Next, participants had to indicate within 1500 ms whether a presented stimulus was the letter "d" accompanied by exactly two apostrophes by pressing a "yes" or a "no" key on the keyboard with their index or middle fingers of their dominant hand. Distractor stimuli were the letter "d" with 1, 3, or 4 apostrophes and the letter "p" with 1, 2, 3, or 4 apostrophes. The affect primes (fear vs. anger) appeared in only 1/3 of the trials (neutral faces were presented in the other trials) to prevent prime-habituation effects (Silvestrini & Gendolla, 2011a). After responding, participants received the message "response entered" or—in case of no response within 1500 ms "please answer more quickly". In the latter case, the message appeared for 4 s minus the participants' response time and the affect prime presentation time (25 ms or 750 ms depending on the condition). This assured the same duration of all trials in all conditions. To avoid possible affective reactions that could interfere with the effect of the affect primes, no correctness feedback was given during the task (Kreibig et al., 2012). The inter-trial interval randomly varied between 1750 and 3000 ms. As specified in the Supplemental Material, ICG signals and blood pressure were assessed during task-performance.

Prior to the main task, participants performed 12 practice trials to familiarize with the task. In the practice trials, only neutral facial expressions were used as primes (presented for 25 ms) and participants received response correctness feedback. After the task, participants rated subjective task difficulty ("How difficult did you find the task?"), success importance ("How important was it for you to succeed on the task?"), the same affect items as at the procedure's onset (1—*not at all;* 7—*very much*), and indicated possible medication and their cardiovascular health status. Finally, they were asked in a funnel debriefing to guess the purpose of the study and to describe a trial of the mental concentration task. Participants who reported having seen flickers were asked to describe their content.

RESULTS

All data used in the analyses and the data coding are publicly available on Yareta—the open access data archiving server of the University of Geneva: https://doi.org/10.26037/yareta:dikvp3mjx5a33pmlpyvepouute.

Due to technical problems, cardiac PEP and HR could not be analyzed. Analyses of SBP and DBP baseline values and reactivity scores, which did not reveal any significant effects ($ps \geq .089$), are reported in the Online Supplemental Material.

TASK PERFORMANCE

We analyzed response accuracy (% of correct responses) and average reaction times (in ms) of correct responses. Both measures had skewed distributions. According to K-S tests, log-transformation led to normally distributed residuals for the response times (p = .200), but not for response accuracy (p < .001). However, ANOVAs have been found to be robust against violations of normal distributions (e.g., Schmider et al., 2010). Thus, we report the effects for log-transformed performance measures and present, for an easier interpretation, the descriptive statistics of the non-transformed data.

Two preliminary 2 (Prime) × 2 (Visibility) ANCOVAs were conducted for both response accuracy and reaction times, using the response accuracy and reaction times of the practice trials, respectively, as covariates. Both response accuracy and reaction times showed strong associations between the task and the practice trials, $Fs(1,78) > 44.72$, $ps < .001$, $\eta^2 > .36$. Consequently, we adjusted both measures with regard to their respective practice scores to control for individual differences in response speed and accuracy in our between-persons design.[1]

Response Accuracy

The 2 × 2 ANCOVA of response accuracy revealed a significant Prime x Visibility interaction with a medium effect size, $F(1,78) = 7.88$, $p = .006$, $\eta^2 = 0.09$, 95% CI [0.021, 0.126], in absence of significant main effects (ps > .436). As depicted in Figure 1, fear primes led to higher response accuracy than anger primes in the suboptimal condition. This pattern was reversed in the optimal prime presentation condition—here, anger primes led to higher response accuracy than fear primes. This supports the interaction effect hypothesis.

Additional focused cell contrasts revealed that participants in the optimal presentation condition who were primed with anger showed significantly higher response accuracy (M = 97.40%, SE = 1.23) than those who were primed with fear, (M = 92.97%, SE = 1.20), $t(78) = 2.46$, p = .016, $\eta^2 = .07$, 95% CI [0.009; 0.085]. Conversely, in the suboptimal-presentation condition, fear primes (M = 97.06%, SE = 1.14) led to higher accuracy than anger primes (M = 94.63%, SE = 1.15). However, the cell difference was not significant (p = .146), 95% CI [-0.009; 0.062].[2]

Reaction Times

The 2 × 2 ANCOVA of the reaction times for correct responses revealed a significant prime visibility main effect, $F(1,78) = 10.88$, $p = .001$, $\eta^2 = .12$, 95% CI [0.033, 0.130], reflecting faster responses in the suboptimal (M = 636.72, SE = 11.55) than in the optimal-prime-presentation condition (M = 690.91, SE = 12.27).[3] The prime main effect and the prime x visibility interaction were both non-significant ($ps \geq .355$).

VERBAL MEASURES

We created mean fear and anger rating scores by averaging the respective single item ratings for the pre-task ($rs > .62$, $ps < .001$) and post-task ($rs > .82$, $ps < .001$) affect measures. The affect primes had no significant effects on the affect ratings. A 2 (Prime) x 2 (Visibility) x 2 (Time) mixed-model ANOVA of rated fear only revealed a significant time effect, $F(1,79) = 4.34$, $p = .041$, $\eta^2 = .05$, 95% CI [0.017; 0.755], reflecting slightly higher ratings at the beginning of the procedure (M = 3.77, SE = 0.25 vs. M = 3.37, SE = 0.26). The visibility main effect only approached significance, $F(1,79) = 3.31$, $p = .073$, η^2 = .04, 95% CI [0.158; 3.510], due to higher scores in the optimal presentation condition (M = 4.02, SE = 0.34 vs. M = 3.18, SE = 0.32), (other $ps \geq .145$). No significant effects emerged on the anger ratings ($ps \geq .089$, average M = 2.82, SE = 0.18). The same was true for the task difficulty ($ps \geq .386$, average M = 1.96, SE = 0.12) and importance of success ratings ($ps \geq .935$, average M = 5.04, SE = 0.16).

FUNNEL DEBRIEFING

Of the 83 participants, only one vaguely guessed the purpose of the study ("investigating the effect of

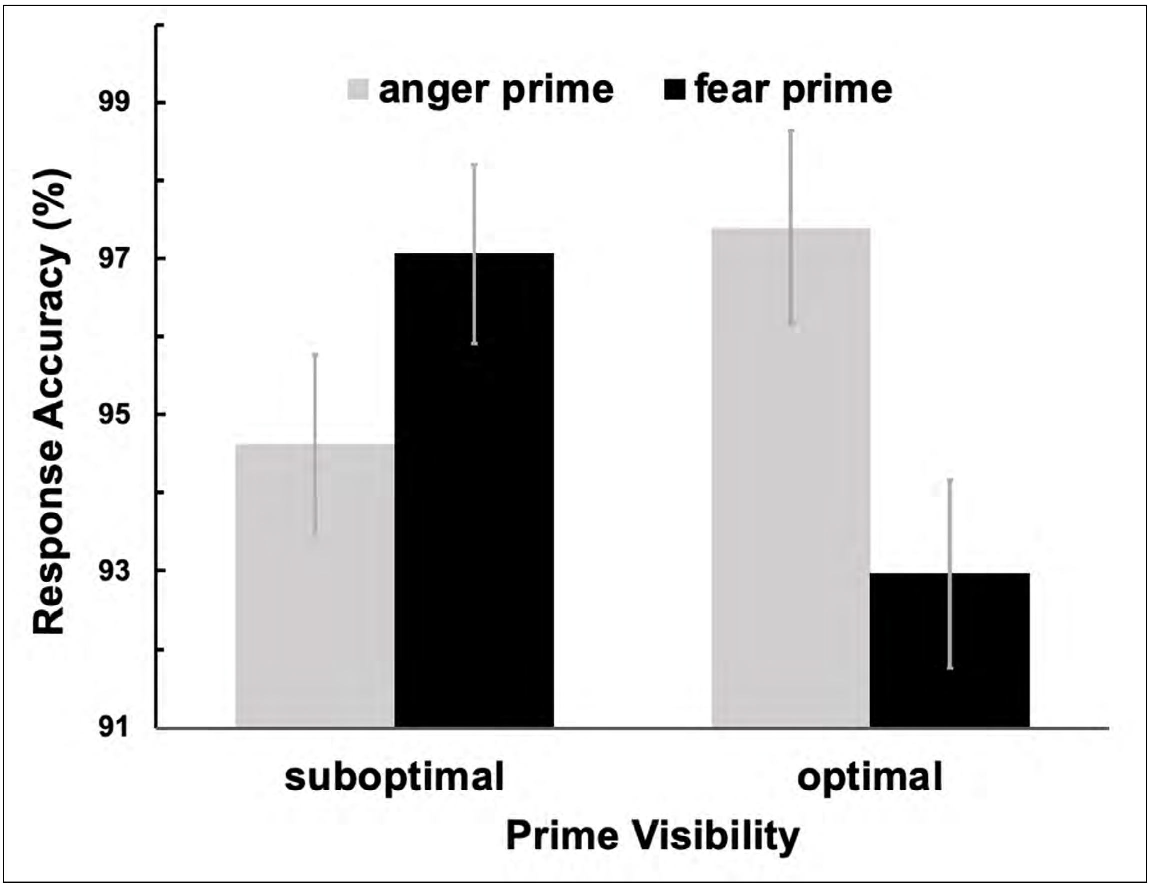

Figure 1 Cell means ±1 standard errors underlying the Prime × Visibility interaction effect on response Accuracy (in %) during task performance.

emotion primes"). When asked to describe a trial, only 9 participants (20.50%) reported to have seen emotional faces in the suboptimal-prime-presentation condition, whereas 35 participants (89.74%) did so in the optimal condition. The difference was highly significant, χ^2 (1, N = 83) = 39.85, $p < .001$, Cramer's V = .69, 95% CI [1.062; 1.704].

DISCUSSION

Prime visibility moderated the effect of fear and anger primes on cognitive performance: We found a significant Prime x Visibility interaction effect on response accuracy in absence of significant main effects. In the suboptimal prime presentation condition, fear primes led to higher response accuracy than anger primes—although the focused cell comparison was not significant. Most relevant, when the affect primes were clearly visible in the optimal prime presentation condition, the affect prime effect was reversed. Here, fear primes resulted in significantly lower response accuracy than anger primes. That is, clearly visible fear primes decreased response accuracy. The significant Prime x Visibility interaction effect was of medium size and the sensitivity analysis had revealed that our sample was big enough for detecting significant effects of that size. However, we also acknowledge that our main result—though conclusive—provides *first* evidence that calls for replications in future studies, ideally with higher powered studies.

Besides providing evidence that prime awareness moderated the effect of fear and anger primes on cognitive performance in terms of response accuracy in an attention task, we see our main result as an interesting point in the discussion about automaticity in general. Priming research has been criticized because of replicability problems and mixed findings (see Chivers, 2019). Our present findings conceptually replicate previous affect prime effects, discussed below, and lend further support to the idea that prime awareness is an important moderator of prime effects. This directly concerns, of course, only automaticity effects in our experimental affect priming paradigm. However, in a larger perspective, identifying moderator variables that have a systematic and thus predictable impact on priming effects can help to understand when, why, and how automaticity functions (see Dijksterhuis et al., 2014; Locke 2015). That is, besides providing insight into how implicit affect primes influence cognitive performance in our experimental procedure, the present study also highlights elements to consider for better understanding automaticity in general.

Most relevant, our present findings contribute to the emerging literature on affect primes' effects on cognitive performance. The present effects on response accuracy are compatible with other experiments that were run in the context of the IAPE model (Gendolla, 2012). In those studies (e.g., Framorando & Gendolla, 2018a; Gendolla & Silvestrini, 2011; Lasauskaite et al., 2013) briefly flashed happiness and anger primes that were processed during cognitive tasks decreased performance compared to briefly flashed sadness primes. Those studies revealed corresponding effects on cardiovascular measures of effort mobilization, especially cardiac PEP. Effort apparently brought return in these studies. However, this correspondence between resource mobilization and cognitive performance did only occur in some of our studies that all found predicted effort effects (see Gendolla, 2012, 2015). However, one recent experiment by Framorando and Gendolla (2018a) found evidence for a moderating effect of prime visibility on both effort and performance: suboptimally presented sadness primes led to both stronger cardiac PEP responses and higher response accuracy in a Sternberg-type short term memory task than suboptimally presented anger primes. This pattern tended to be reversed when the primes were clearly visible. The present effects on response accuracy resemble these findings and provide additional evidence for the joint effect of fear primes and prime visibility on cognitive performance—although we could not analyze the effects on cardiac PEP. However, it is of note that other researchers consider speed and accuracy as indicators of effort (e.g., Bijleveld et al., 2010; Roets et al., 2008).

In a larger perspective, it is interesting that other studies found effects of experienced fear and anger that are compatible with the present effects of visible fear and anger primes—although there was no evidence that our affect primes elicited conscious feelings, which is in line with our intention to manipulate implicit affect rather than affective experiences. However, in those other studies, experienced fear was related to impaired performance (Ashcraft & Faust, 1994; Byron et al., 2010; Cassady & Johnson, 2002) whereas anger was connected with increased performance (Davis et al., 2010; Rathschlag & Memmert, 2013; Robazza & Bortoli, 2007; Terry & Slade, 1995; Woodman et al., 2009). In our present study, implicitly processed fear and anger primes tended to produce the opposite pattern, which makes sense if one assumes that the implicitly processed fear primes should have led to higher effort than the implicitly processed anger primes.

CONCLUSION

In summary, the present experiment provides evidence for the combined effect of affect primes and prime visibility on cognitive performance. Importantly, the effect of fear and anger primes was moderated by prime visibility. The additional prime visibility main effect on response times suggests attention-taxing controlled prime processing in the optimal prime presentation condition (see Bijleveld et al., 2012): visible primes slowed participants' responses down. This lends support to our basic idea that prime visibility indeed resulted in behavior correction, which relies on attention and controlled cognitive processing (Posner & Snyder, 1975).

DATA AVAILABILITY STATEMENT

All data used in the analyses and the data coding are publicly available on Yareta – the open access data archiving server of the University of Geneva https://doi.org/10.26037/yareta:dikvp3mjx5a33pmlpyvepouute.

NOTES

1 Also ANOVAs without covariate adjustment revealed a significant interaction effect on accuracy, $F(1,79) = 4.76$, $p = .032$, $\eta^2 = .06$, and a significant prime visibility main effect on the reaction times, $F(1,79) = 6.39$, $p = .013$, $\eta^2 = .08$, in absence of other significant effects, $Fs(1,79) = 2.03$, $ps > .159$.

2 Given the above-reported non-normal distribution of the accuracy residuals, we ran an additional confirmatory non-parametric version of the ANCOVA with rank-transformed accuracy scores of the task and practice trials (Conover, 2012). Results corresponded to those reported above. The covariate, $F(1,78) = 8.63$, $p = .004$, $\eta^2 =. 10$, and the Prime x Visibility interaction effects, $F(1,78) = 4.80$, $p = .031$, $\eta^2 = .06$, were both significant, while the main effects were not ($ps \geq .928$). The effect size for the interaction effect on the rank-transformed data was a bit lower than that of our primary analysis. However, effect sizes of non-parametric tests should be interpreted with caution. The power of interaction tests of rank-order transformed data can be considerably lower than that of usual ANOVA *F* tests of not rank-transformed data (Clifford Blair et al., 1987; Sawilowsky et al., 1989).

3 *M*s and *SE*s were: suboptimal/fear-prime ($M = 652.49$, $SE = 16.33$), suboptimal/anger-prime ($M = 620.96$, $SE = 16.33$), optimal/fear-prime ($M = 693.27$, $SE = 17.21$), optimal/anger-prime ($M = 688.54$, $SE = 17.69$).

ADDITIONAL FILE

The additional file for this article can be found as follows:

- **Supplemental Methods.** Apparatus and Physiological Measures. DOI: https://doi.org/10.5334/spo.33.s1

TRANSPARENCY STATEMENT

We reported how we determined the sample size and the stopping criterion. We reported all experimental conditions and variables. We report all data exclusion criteria and whether these were determined before or during the data analysis. We report all outlier criteria and whether these were determined before or during data analysis.

Pre-registration statement: No parts of the study were pre-registered prior to the research being conducted.

ETHICS AND CONSENT

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent was obtained from all individual participants included in the study.

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

G.H.E.G. received the funding, provided the idea for the study, analyzed the data, and wrote the paper. D.F. contributed to developing the procedure, programmed the experiment, collected the data, analyzed the data, and wrote the paper.

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