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Facing the enemy: Spontaneous facial reactions towards suffering opponents

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Abstract

The suffering of an opponent is an important social affective cue that modulates how aggressive interactions progress. To investigate the affective consequences of opponent suffering on a revenge seeking individual, two experiments (total $N = 82$) recorded facial muscle activity while participants observed the reaction of a provoking opponent to a (retaliatory) sound punishment in a laboratory aggression task. Opponents reacted via prerecorded videos either with facial displays of pain, sadness, or neutrality. Results indicate that participants enjoyed seeing the provocateur suffer: indexed by a coordinated muscle response featuring an increase in *zygomaticus major* (and *orbicularis oculi* muscle) activation accompanied by a decrease in *corrugator supercilii* activation. This positive facial reaction was only shown while a provoking opponent expressed pain. Expressions of sadness, and administration of sound blasts to nonprovoking opponents, did not modulate facial activity. Overall, the results suggest that revenge-seeking individuals enjoy observing the offender suffer, which could represent schadenfreude or satisfaction of having succeeded in the retaliation goal.

KEYWORDS

facial electromyography, facial expression, reactive aggression, revenge, suffering

1 | INTRODUCTION

Escalating aggressive interactions are often characterized by desires to take revenge and to punish the other person for a previous interpersonal offense (Jackson et al., 2019). While many studies investigated the antecedents of revenge seeking, only few published studies examined reactions to retaliatory actions that would satisfy the individual's need for vengeance. The present research investigated how the affective reactions of avengers are modulated by the target's reaction to a (retaliatory) sound punishment, as indexed by spontaneous muscle activations during the observation of the target's suffering.

Several behavioral and neuropsychological studies indicate that taking revenge can be rewarding for the aggressor (for a review, see Chester, 2017). In one study, for example, participants' brains were scanned using positron emission tomography (PET) during punishment of a defector in an economic exchange. The brain scans revealed increased activation of the *anterior dorsal striatum*—a region that is typically implicated in the anticipation of rewards (de Quervain, 2004). Another neuroimaging study measured BOLD responses during physical punishments of a provocateur in a behavioral aggression paradigm (Chester & DeWall, 2016). This study found greater activity in the *nucleus accumbens* (NAcc), which is a brain region critical for the subjective experience of hedonic reward. Evidence for a pleasant experience of revenge was also found in measurements of event-related potentials in scalp-recorded

EEG (Krämer et al., 2008). After feedback that they could punish the opponent in a behavioral aggression paradigm, participants with high trait aggressiveness showed an enhanced negativity at mediofrontal sites in the EEG relative to participants with low trait aggressiveness. This difference suggests that punishment of the opponent was rewarding for the high trait aggressive participants or less rewarding for low trait aggressive persons. In sum, several research findings point to the conclusion that taking revenge could be rewarding for the revenge seeking person.

In the studies reviewed above, however, participants could not see the target's reaction to the punitive action. Hence, they leave it unclear how specific reactions of the retaliation target affect revenge seeking. This question was examined in a study in which participants could observe the opponent's reaction to physical punishments in a laboratory aggression paradigm (Eder et al., 2020). In this study, participants played a competitive reaction time (RT) game against (fictitious) opponents who were supposedly connected via internet. The winner in the game could administer an annoying sound blast to the opponent, whose intensity from mild to severe was selected before each trial. Some opponents showed a very aggressive behavior during the game by consistent administrations of severe sound blasts to the participant, which provoked retaliatory sound punishments from the participant. Importantly, participants saw a video transmission of the opponent in winning trials, in which he expressed pain, anger, sadness, or no emotion in reaction to the sound punishment. A meta-analysis of four experiments showed that seeing the opponent in pain reduced intensities of subsequent noise punishments most strongly ($r = .39$, [.27, .51]), while displays of sadness ($r = .16$, [−.05, .36]) and anger ($r = .02$, [−.12, .16]) had no appeasing effects.

Several explanations can be proposed to understand why individuals reduced revenge-seeking in the study of Eder et al. (2020) after they have seen the provocateur suffer. One explanation is that provoked participants wanted to make the opponent pay for their prior provocation, and that seeing the provocateur suffer satisfied this need (Frijda, 1994). According to this *satisfaction hypothesis*, participants should be pleased about seeing the opponent suffer from a retaliatory punishment. Alternatively, it is also possible that participants were emotionally distressed by the observation that they have visibly harmed another person, for instance, by instigation of guilt feelings (Baumeister et al., 1994) or by empathetic concerns for the opponent (Young et al., 2017). According to this *empathetic-concern/guilt hypothesis*, the view of a suffering opponent should evoke an unpleasant experiential reaction in the observer. In sum, affective reactions of opposite valence can be hypothesized for seeing the provoking opponent hurt, which were examined in the present research using facial electromyography (fEMG).

1.1 | The present research

The present studies were designed to measure affective reactions towards revenge punishment outcomes in a structured competitive game. Participant and (fictitious) opponents interacted with each other via a competitive RT game similar to that used by Eder et al. (2020). During each game round, the participant was asked to press the mouse button as quickly as possible after the appearance of a visual cue. The main goal was to act faster as the opponent, because the loser would hear an aversive noise blast whose intensity was selected by the winner. At the start of each trial, the participant selected the intensity of the sound blast that would be delivered to the opponent after winning the RT game. Conversely, she received a sound blast that was allegedly selected by the opponent if she lost the game. Notably, the opponents' selections were controlled by the computer program: most computer opponents selected low intensities, but a few of them consistently selected high intensity sound blasts to provoke retaliatory punishments by the participants. In line with our pre-registered selection rule (https://osf.io/74gh5/), we included only those participants in our analyses who punished provoking opponents more strongly compared to non-provoking ones (i.e., who were provoked effectively).

Most important, participants could observe the (male) opponent during the sound punishment via an allegedly live video feed (without audio). In most of the trials, the fictitious opponent showed a calm (neutral) face to the sound punishment; however, in selected trials he reacted with a clear facial expression of suffering (pain). Participants' own facial activities during viewing were recorded via electrodes positioned on muscles in the face.

Facial EMG is a highly time sensitive and unobtrusive measurement procedure of muscle contractions. It can register even subtle shifts in muscle tone that are spontaneously produced during the viewing of emotional stimuli such as affective pictures or videos (Cacioppo et al., 1986; Larsen et al., 2003). Furthermore, fEMG allows for a measurement of affective reactions without interruption of the revenge act and drawing attention to the measurement of affective reactions. The latter could be important because there are strong normative rules in respect to inflicting pain on others which could distort self-reports (Vigil-Colet et al., 2012).

To differentiate between negative and positive affective reactions, we recorded muscle activations of the *corrugator supercilii* (CS, brow furrowing) and the *zygomaticus major* (ZM, lifting mouth corners, smiling) that index unpleasant and pleasant experiential reactions, respectively (Larsen et al., 2003). In addition, a coordinated increase in both ZM and CS activity during the observation of a pain expression could be interpreted as a simulation of pain via facial mimicry (Sun et al., 2015).

In Study 1, opponents reacted to a sound punishment either with expressions of pain or with no emotion (calm face). In Study 2, an additional condition was included in which opponents reacted with sadness. Sadness was included in Study 2 because it is an expression of a negative emotion that is not a specific reaction to physical pain. By comparison, it could hence be determined whether facial activities are specific to expressions of physical pain.

2 | STUDY 1

Study 1 investigated muscle contractions of CS and ZM during the observation of opponents that expressed pain or no emotion after a (retaliatory) sound punishment. According to the comparative-suffering hypothesis, seeing the opponent hurt by the retaliatory sound punishment should be appraised positively by the avenger, as indexed by an increased ZM activation. According to the empathetic-concern/guilt hypothesis, by contrast, seeing the opponent suffer from a sound punishment should increase CS activity, due to a personal distress reaction, or increase both, ZM and CS activities, in line with an empathic reaction involving pain mimicry.

2.1 | Method

Preregistration documents, materials, experiment files, and raw data can be accessed at https://osf.io/74gh5/.

2.1.1 | Participants

A total of 56 volunteers were recruited from the participant pool of the University of Würzburg. Six participants were excluded due to equipment failure and an additional four participants due to excessive movement artifacts. In line with our preregistered exclusion criteria, an additional six participants were excluded because they showed no retaliatory behavior (i.e., provoking opponents were not more punished than non-provoking opponents). The final sample consisted of 40 participants (5 male, M age = 23.55 years, SD = 3.69). A sensitivity analysis showed that this sample size had sufficient statistical power p = .80 for the detection of a ANOVA effect $f \geq .20$ of the opponent's emotional reaction on the participant's facial activity (correlation among measures: r = .20, nonsphericity correction = 1, performed with GPower 3.1.9.2). Males and females were recruited because gender differences are negligible after provocation (Bettencourt & Miller, 1996). All participants gave prior informed consent and they received 15 € for participation. The study was performed in agreement with the Declaration of Helsinki and approved by the ethics committee of the University of Wuerzburg (GZEK 2020-74).

2.1.2 | Materials

The opponent reaction videos were taken from Eder and colleagues (2020). The videos were 3,000-ms long and showed young males wearing headphones. Only young males were selected as targets of aggression to control for target effects and gender differences in the expression of pain (Wise et al., 2002).

Suffering was expressed with facial displays of pain involving brow furrowing, teeth clenching, and a rapid shutting of the eyes (see the video material at https://osf.io/ysnd3/). In the videos with no emotion expression, the opponent showed no visible reaction to the sound punishment. We included a total of 24 videos displaying pain reactions (two for each model). Emotional ratings of the video material by an independent sample (N = 289) are provided in the Supporting Information (Table S5). Additionally, we included 24 videos where the opponent displayed smiling reactions. These videos were only shown during noise punishments in a subset of trials in which the participant has lost the game and received a punishment by the opponent. Smiling responses were included to examine how the receipt of a noise punishment influences facial mimicry. Given that their analyses address another research question, they are not reported in this paper.

For noise punishment, a 3-s long white noise was used. Noise blasts were taken from the Inquisit database (Millisecond Software, Seattle, WA, USA). The loudest noise blast (5) was 75 dB and intensities were lowered in 5 dB steps corresponding with each noise level step (1 = 55 dB, 5 = 75 dB).

Participants also answered the German version of the Interpersonal Reactivity Index (IRI; Davis, 1980) the so-called SPF (Paulus, 2009), a self-report measure of dispositional empathy that is positively related to facial mimicry effects (Drimalla et al., 2019; Sonnby-Borgström et al., 2003). The SPF comprises four subscales (empathic concern, perspective taking, fantasy scale and personal distress) with 4 items each.

2.1.3 | Procedure

The skin was prepared using alcohol and an abrasive electrolyte solution before placing the Ag/AgCl surface electrodes (4 mm) on top of the ZM muscle, the CS muscle, and on the left mastoid serving as a reference (electrode distance: 1.5 cm). Electrode handling and placement were conducted in line with the guidelines for human electromyographic research (Fridlund & Cacioppo, 1986). EMG data were recorded with a 16-channel amplifier (V-Amp, Brain Products, Gilching Germany). The raw signal was stored on a separate computer.

Written instructions informed participants that they would play a competitive RT game (CRTT) against an opponent who would be visible via a live video feed. Participants were instructed that the one who reacts the slowest would be punished via an unpleasant noise blast. The task procedure was a modified Taylor aggression paradigm (Taylor, 1967). Before the CRTT began, the noise blasts were played in the highest and lowest setting to familiarize the participant with the sound levels. A cover story told participants that skin conductance levels would be measured with electrodes as an indicator of stress experienced during the task. Instructions also stated that their opponents would be students located at a different university in Germany and that they were supposedly assigned to a study condition in which they could observe the opponent via internet video transmissions, whereas the opponent could not see them. The task was run using E-Prime 3.0 software (Psychology Software Tools, Sharpsburg, PA, USA) on a computer with a 1,920 × 1,200 screen for stimulus presentation. Responses were collected via mouse clicks.

Figure 1 shows the sequence of events in a trial of the CRTT. Each trial began with the selection of the level of the noise blast (1–5) that would be administered to the opponent, if the participant won the trial. The selection was followed by the reaction time task, which showed a red circle as a preparatory signal that changed into green as a go signal for a rapid click of the left mouse button. The time window for a valid response was set to 1,000 ms. An error message appeared if the participants did not press the key during this time limit ("We could not detect your response inside the time window. Please repeat this trial."). After a valid response the participant was informed about the outcome of the reaction task (win/loss). In win trials, the following message was displayed for 3,000 ms: "You won. You chose volume [value]. You will now see your opponent as he hears the sound." After a 3,000-ms blank display, the opponent video was shown (3,000 ms). In loss trials, the participant received the message: "You lost. Your opponent chose volume [value]." They heard the noise blast of the indicated intensity, and after 3,000 ms blank they watched a video of the opponent. The opponent showed either a smile or no emotion when he won the game. Participants' facial activities during his reaction were recorded but not analyzed for this paper.

Overall, participants played 48 blocks, 16 in which the fictitious opponent provoked retaliatory punishments with administrations of very loud sound blasts (levels 4–5) and 32 blocks in which opponents did not provoke with selections of mild sound blasts (levels 1–3). Each block consisted of 5 CRTT trials. In 16 blocks with nonprovoking opponents, the outcome of the game (win/loss) was random. In the remaining 32 blocks, the outcome in the first trial was randomly determined, the second and third trials were lost (the participant received sound blasts from the opponent), and the fourth and fifth trials were won by the participant (administration of sound blasts to the opponent). When the provoking opponent lost the game in the fourth and fifth trials, he expressed pain in the fourth trial and no emotion in the fifth trial. In four of the 16 blocks, however, he expressed no emotion in both trials. The remaining 16 blocks with nonprovoking opponents had analogous win/loss streaks and opponents displayed analogous reactions to sound punishments. Each opponent was featured four times (total number of opponents = 12).

After each block, participants were asked to rate their feelings of anger towards the opponent on a 5-point Likert scale and feelings of dominance, arousal and pleasantness on self-assessment manikin scales (Bradley & Lang, 1994). After the CRTT, participants answered the SPF questionnaire and were debriefed. The debriefing made explicit that the opponents were fictitious; that their punishments were controlled by the experimental software; and that the opponents' reactions were prerecorded videos.

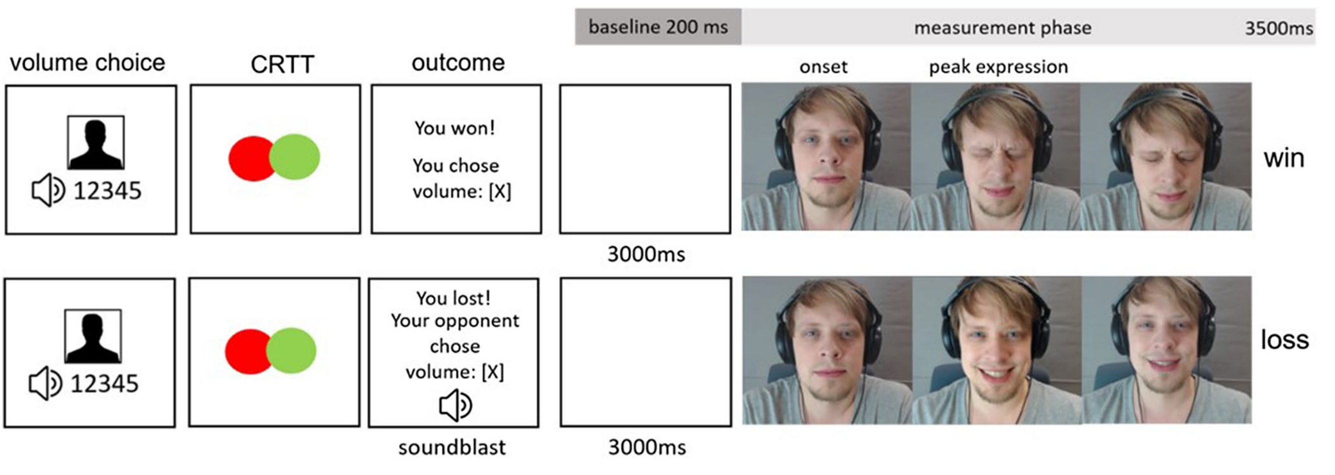

FIGURE 1 Example of a win and loss trial featuring video reactions

2.1.4 | Data preprocessing and analysis plan

EMG data were processed offline using the Brain Vision Analyzer 2.2 software (Brain Products, Gilching Germany). fEMG data were filtered (20 Hz low cutoff filter, 499-Hz high cutoff filter, 50-Hz notch), full wave rectified and segmented (−200 ms prior to stimulus onset to 3,500-ms post-stimulus onset). Prior to data analysis, trials were averaged for each condition and exported into 500-ms time bins. Data were additionally screened for low EMG activation (caused by technical failures such as loose or broken electrodes). Artefacts were semi automatically detected via a build in function of the brain vision analyzer using a gradient of maximum allowed voltage steps of 50 µV/ms and a maximum difference of 200 µV in each 200-ms interval. Additionally, data were visually inspected for movement artefacts (e.g., coughing) and all trials containing artefacts were removed. Difference scores were calculated using the 200 ms prior to video onset as baseline. The figures display standardized means (within-subject z transformed difference scores) for convenient interpretation of the results.

Deviating from our preregistered analysis, we ran a linear mixed model (LMM) analysis in JAMOVI (using the GAMLj module, version 1.0.7; The Jamovi Project, 2021). The original preregistered analysis based on repeated measurement ANOVAs is reported in the Supporting Information. We included baseline-corrected EMG responses for each muscle as the dependent variable and added fixed effects of *Provocation* (high/low), *Emotion* (neutral/pain), *Time* (500 ms intervals across 3,500 ms), as well as interactions thereof. We included participant as a random effect. Significance was calculated using the Satterthwaite's method to estimate degrees of freedom and generate *p* values. The model specification was as follows: MuscleResponse ~ 1 + Provocation + Emotion + T ime + Provocation: Emotion + Provocation:Time + Emotion: Time+(1 | Subject).

Follow-up tests of significant *Provocation* by *Emotion* interaction effects were simple effects analyses within each provocation condition. This approach allowed us to compare muscle responses between the negative emotion conditions (pain/sadness) with the neutral condition separately for each provocation condition. We further conducted simple effects analysis of time with emotion as a moderator, separately for each provocation condition. We will only report and discuss the results from each main effect, the interaction between provocation and emotion as well as our a priori planned comparisons of muscle responses based on opponent expressions within each provocation condition (simple effects for emotion and time, for each provocation condition separately). For a report on all fixed effects results including each possible interaction term, please see the Supporting Information.

2.2 | Results

2.2.1 | Ratings

As shown in Table 1, after provoking compared to nonprovoking blocks participants were more aroused, $t(39) = 4.28$, $p < .001$, $d_z = 0.68$, felt less dominant, $t(39) = 3.50$, $p = .001$, $d_z = 0.55$, and more unpleasant, $t(39) = 4.98$, $p < .001$, $d_z = 0.79$. Selected levels of noise punishments were significantly higher after provocation, $t(39) = 8.38$, $p < .001$, $d_z = 1.33$. Self-reported anger was also higher $t(39) = 9.13$, $p < .001$, $d_z = 1.44$.

2.2.2 | Punishment choices

Changes in revenge seeking (volume choices) were indexed by difference scores that compared volume choices in CRTT trials before and after having seen an opponent reaction. Difference scores were calculated via subtracting the chosen volume in Trial 4 (win CRRT trial with emotional opponent reaction) from the chosen volume in Trial 5 (after having observed the opponent video). Negative values indicate a reduction in the intensity of desired noise punishments. Results showed that provoked participants significantly reduced the volume punishment following pain displays ($M = -0.37$, $SD = 0.50$) compared to neutral displays ($M = -0.14$, $SD = 0.59$), $t(39) = -2.41$, $p = .021$, $d_z = 0.38$; in contrast, there was no significant effect without prior provocation, $t(39) = 1.40$, $p = .171$, $d_z = 0.22$.

TABLE 1 Means (with *SD*) for behavioral measurements in Study 1

	Noise level	Valence	Arousal	Dominance	Anger
Provocation	2.99	3.63	2.12	3.51	3.07
	(1.13)	(0.71)	(0.80)	(1.09)	(1.04)
No provocation	2.00	3.82	1.80	3.71	1.94
	(0.82)	(0.69)	(0.65)	(1.09)	(0.68)

Note: Ratings are based on 5-point scales with 1 indicating no/the least amount and 5 indicating the largest amount, except for valence which ranged from 1 negative to 5 positive.

2.2.3 | Electromyography

Zygomaticus major

Fixed effect omnibus tests of ZM muscle responses resulted in significant main effects of Provocation, $F(1, 1059) = 27.66$, $p < .001$ and Emotion, $F(1, 1059) = 12.79$, $p < .001$, and a significant Provocation × Emotion interaction, $F(1, 1059) = 16.53$, $p < .001$. The interaction effect indicates that participants' ZM muscle responses depended on the opponents' emotional expressions and prior provocation. Follow-up comparisons in high provocation trials revealed that ZM muscle reactions were significantly larger when seeing the (provoking) opponent in pain versus a neutral expression ($b = -31.55$, $SE = 5.84$), $t(1059) = -5.40$, $p < .001$. As shown in Figure 2, the ZM reaction started about 1,300 ms after video onset. ZM muscle reactions to opponent expressions were not different in the no provocation condition ($b = 2.02$, $SE = 5.84$), $t(1059) = 0.35$, $p = .729$. Analysis of simple effects of time within each emotion, separately for each provocation condition, did not result in any significant effects of time, all Fs ≤ 0.87, all ps $\geq .541$.

Corrugator supercilii

Fixed effect omnibus tests of CS muscle responses resulted in significant main effects of Provocation, $F(1, 1059) = 6.95$, $p = .009$, and a significant Provocation by Emotion interaction, $F(1, 1059) = 5.69$, $p = .017$. The main effect of Emotion was not significant, $F(1, 1059) = 0.27$, $p = .604$. Simple effects analysis within provocation blocks indicate lower CS responses during neutral expressions during provocation when compared to responses during pain expressions ($b = -33.4$, $SE = -16.2$), $t(1059) = 2.05$, $p = .040$. There was no difference in CS muscle reactions during the no provocation condition ($b = 21.4$, $SE = 16.2$), $t(1059) = 1.32$, $p = .187$. Analysis of simple effects of time within each emotion, separately for each provocation condition, did not result in significant effects, all Fs ≤ 1.08, all ps $\geq .374$.

2.3 | Discussion

Results show an increase in ZM muscle activation during observation of a pain response. Assuming that the ZM is responsive to positive affects (Brown & Schwartz, 1980), this increase indicates that avengers enjoyed seeing the opponent suffer from the noise punishment. The effect was only observed after punishments of provoking opponents, which suggests that revenge motivation played an important role in the appraisal of opponent reactions. Furthermore, ZM activity did not change after the punishment of provocateurs who did not express suffering. This result pattern suggests that participants were specifically pleased about having hurt the opponent.

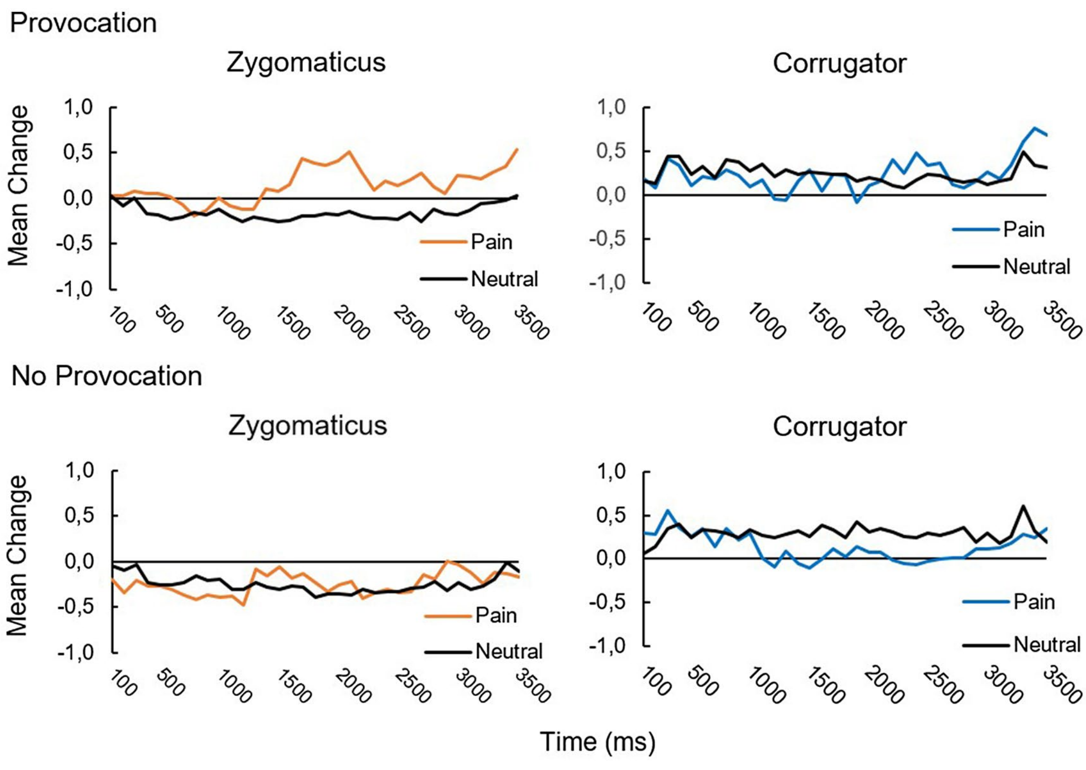

FIGURE 2 Time course of the normalized EMG response from stimulus onset to 3,500-ms post-stimulus onset during observation of suffering opponents in Study 1

Analyses of CS responses revealed more CS activity when seeing the provoking opponent suffer from a noise punishment. This reaction could index mimicry of the pain expression, which is characterized by simultaneous ZM and CS activities (Sun et al., 2015). Visual inspection of the time course however suggests that the ZM response peaked earlier than the CS response, which means that both responses were asynchronous. Furthermore, based on theory one would have expected larger pain mimicry responses when seeing the non-provoking opponent suffer (Zaki, 2014). Additionally, CS activity during pain and neutral expressions largely overlapped except for short time periods, which does not support a strong effect of the observed emotion on the CS response. In short, we viewed it unlikely that the CS response indexed a pain mimicry response; however, an additional experiment was needed that clarified the nature and robustness of this particular result.

3 | STUDY 2

Study 2 included an additional opponent reaction to sound punishments: sadness. Sadness expresses suffering that is not specific for physical pain (Horstmann, 2003). In the context of the competitive RT game, the expression could be also interpreted as a signal of defeat and/or submission (Tiedens, 2001). By comparing pain with an additional suffering display, we aimed to investigate whether the ZM and CS increases observed in Study 1 is specific for expressions of pain. In Study 2, we additionally measured activations of the *orbicularis oculi* (OO) muscle surrounding the eye. In combination with an increase in ZM activity, OO activity is a signifier of "genuine" smiling (the so-called Duchenne smile; Ekman & Friesen, 1982, see also Hess et al., 2017).

3.1 | Method

3.1.1 | Participants

Seventy-six students participated for a monetary payment of 12€. In line with our exclusion criteria, 18 datasets were excluded due to artefacts and technical errors (caused by broken electrodes and amplifier malfunction) and an additional 16 datasets due to ineffectiveness of the provocation treatment. The final sample consisted of 42 participants (7 males, mean age = 25.07 years, $SD = 4.43$). A sensitivity analysis showed that this sample size had sufficient statistical power $p = .80$ for the detection of a small ANOVA effect $f \geq 0.20$ of the opponent's emotional reaction on the participant's facial activity (correlation among measures: $r = .20$, nonsphericity correction = 1, performed with GPower 3.1.9.2). All participants gave prior informed consent.

3.1.2 | Materials

We selected 12 pain videos from Study 1 and added 12 sadness videos taken from Eder et al. (2020). Emotional ratings of the video materials are provided in the Supporting Information (Table S5). For the registration of prolonged or late facial reactions, a still image taken from the last video frame was appended to the video for a duration of 3 s. The still image depicted the negative emotional expression featured in the video and prolonged the expression unobtrusively.

3.1.3 | Procedure

To measure the *orbicularis oculi* muscle activation we placed two electrodes next to the outer corner of the left eye. All other EMG specific procedures were identical to those of Study 1. To account for later changes in muscle activation following the peak expression of each emotion, we prolonged the time window of the EMG measurement from 3 to 6 s.

The CRTT, self-assessment manikin scales, anger item and the SPF empathy questionnaire were identical to Study 1. Overall, there were 12 blocks: 6 with provoking and 6 with non-provoking (fictitious) opponents that appeared in random order. The number of trials per block was increased to 10 trials. The win/loss ratio was 5/5. Opponents' reactions were only shown during punishments in winning trials. In two out of five winning trials, the opponent displayed pain or sadness as a reaction to the sound punishment. In the other three out of five winning trials, the opponent expressed no emotion. Blocks always featured either a pain or a sadness expression twice, but never a combination of both. In total, this procedure yielded 6 pain and 6 sadness expressions by provoking and non-provoking opponents, respectively. Participants played two blocks against each opponent: in one block the opponent reacted with sadness, in the other block with pain. In contrast to Study 1, opponent videos were only shown during win trials.

3.1.4 | Data preprocessing and analysis plan

Data processing and artefact detection were identical to Study 1. Due to the longer recording period, we segmented data from 500 ms prior to stimulus onset to 6,000 ms post stimulus onset into 500 ms time intervals. Difference scores were calculated using the 500 ms time bin prior to stimulus onset as baseline. The data-analytic approach was the same as in Study 1, with the exception that the Emotion factor had 3 levels (neutral/pain/sadness). Figure 3 shows an overview of standardized muscle activations relative to baseline in each condition.

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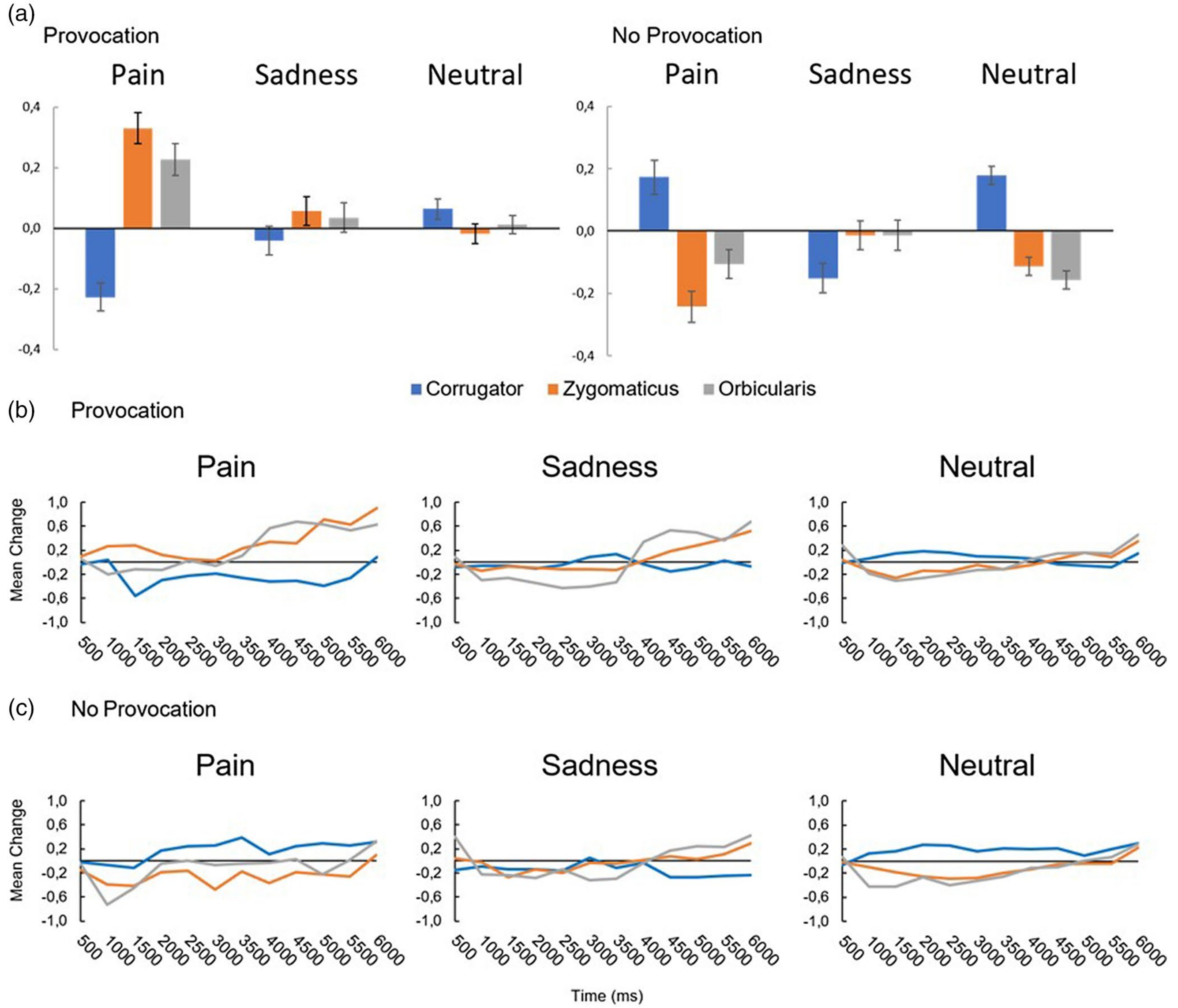

FIGURE 3 Panel (a) represents the z-standardized means of muscle activation over the full 6-s period for each emotion expression and muscle site (CS, ZM, and OO) separately. Panels (b) and (c) depict the time course of the z-transformed fEMG response from stimulus onset to 6,000-ms post-stimulus onset for each provocation and emotion condition

3.2 | Results

3.2.1 | Ratings

Table 2 provides a descriptive overview of the rating measures. In blocks with provoking opponents, participants felt more aroused, $t(41) = 5.05$, $p < .001$, $d_z = 0.75$, and less dominant, $t(41) = -3.16$, $p = .003$, $d_z = 0.43$; however, there was no significant difference in ratings of pleasantness, $t(41) = -1.19$, $p = .234$, $d_z = 0.18$. Participants were more angry about provoking compared to nonprovoking opponents, $t(41) = 9.51$, $p < .001$, $d_z = 1.46$. In line with the preregistered manipulation check of the provocation treatment, provoking opponents were punished more than nonprovoking ones, $t(41) = 8.21$, $p < .001$, $d_z = 1.27$.

3.2.2 | Punishment choices

Difference scores for the emotion condition were calculated by subtracting the noise level selected for the trial with an emotional opponent reaction from the noise level selected in the subsequent trial. Analyses of difference scores showed that provoked participants significantly reduced the volume of the noise punishment following pain displays ($M = -0.44$, $SD = 0.81$) compared to neutral displays ($M = -0.09$, $SD = 0.63$), $t(41) = -2.26$, $p = .029$, $d_z = 0.349$. Sadness displays did not result in a significant decrease in punishment volume compared to neutral displays ($M = -0.17$, $SD = 0.42$), $t(41) = -0.381$, $p = .705$, $d_z = 0.058$. Difference scores for neutral displays were calculated based on the last two neutral trials (before any

TABLE 2 Means (with *SD*) for measurements in Study 2

	Noise level	Valence	Arousal	Dominance	Anger
Provocation	3.04	3.83	2.13	3.54	2.82
	(0.98)	(0.63)	(0.74)	(0.97)	(0.91)
No provocation	1.89	3.86	1.67	3.80	1.43
	(0.87)	(0.55)	(0.70)	(0.87)	(0.58)

Note: Ratings are based on 5-point scales with 1 indicating no/the least amount and 5 indicating the largest amount, except for valence which ranged from "1" (negative) to "5" (positive).

emotional reaction occurred) for each block separately (pain/sadness). Analogous comparisons of difference scores in no provocation blocks produced no significant effects, all ts(41) ≤ 0.82, all ps ≥ .418.

3.2.3 | Electromyography

Zygomaticus major

Fixed effect omnibus tests of ZM muscle responses resulted in a significant main effect of Provocation, $F(1, 2933) = 41.20$, $p < .001$, a significant main effect of Emotion, $F(2, 2933) = 3.31$, $p = .037$, and a significant Provocation × Emotion interaction, $F(2, 2933) = 13.60$, $p < .001$. The latter effect indicated that ZM muscle reaction depended on the opponents' emotional expression, as well as on the level of provocation.

ZM activity after provocation

ZM activations during expressions of pain were significantly higher than ZM activations during neutral expressions ($b = 136.2$, $SE = 26.6$), $t(2933) = 5.13$, $p < .001$. Sadness expressions also resulted in a significantly higher activation of ZM when compared to neutral ($b = 71.6$, $SE = 26.6$), $t(2933) = 2.70$, $p = .007$. The analysis of time effects revealed a significant increase in ZM activity during pain during time bins 9–12 (all bs ≥ 148.18, all ps ≥ .05), as well a significant increase during sadness during time bins 10–12 (all bs ≥ 195.97, all ps ≥ .01).

ZM activity after no provocation

ZM activity during pain expressions was significantly lower compared to neutral ($b = −54.7$, $SE = 26.6$), $t(2933) = −2.06$, $p = .040$. Responses during sadness expressions did not differ from neutral ($b = 14.1$, $SE = 26.6$), $t(2933) = 0.531$, $p = .596$. The analysis of time effects revealed no significant effects of time, all Fs ≤ 0.92, all ps ≥ .518.

Orbicularis oculi

Fixed effect omnibus tests of the OO responses revealed a main effect of Provocation, $F(1, 2933) = 14.96$, $p < .001$, Emotion, $F(2, 2933) = 12.22$, $p < .001$, and a significant interaction between Provocation and Emotion, $F(2, 2933) = 5.20$, $p = .006$.

OO activity after provocation

OO activations during pain expressions were significantly larger compared to neutral ($b = 156.7$, $SE = 27.0$, $t(2933) = 5.03$, $p < .001$). OO activations during sadness expressions did not differ from neutral ($b = 24.9$, $SE = 31.1$), $t(2933) = 0.799$, $p = .425$. The time specific analysis revealed a significant increase in OO activity during time bins 7–12 during pain expressions (all bs ≥ 252.94, all ps ≤ .004). We also observed a significant decrease during sadness expressions during time bins 4–7 (all bs ≥ −201.87, all ps ≤ .022) followed by a significant increase during time bins 9, 10, and 12 (all bs ≥ 191.28, all ps ≤ .030). The initial decrease in OO activity was also present during neutral expressions during time bins 3–5 (all bs ≥ −191.39, all ps ≤ .030).

OO activity after no provocation

OO responses during pain expressions did not significantly differ from neutral ($b = 60.00$, $SE = 31.1$), $t(2933) = 1.92$, $p = .054$. Responses during sadness expressions were significantly higher compared to neutral ($b = 66.3$, $SE = 31.1$, $t(2933) = 2.131$, $p = .033$). We also observed an early significant decrease of OO activity during neutral expressions during time bins 2–4 (all bs ≥ −173.52, all ps ≤ .05), as well as during sadness expressions during time bins 2–4 and 6–7 (all bs ≥ −225.55, all ps ≤ .010). There was only a short significant decrease during time bin 2 ($b = −221.29$, $p = .012$) during pain expressions (all other bs ≥ 160.22, all ps ≥ .069).

Corrugator supercilii

Fixed effect omnibus tests of CS responses revealed no significant main effect of Provocation $F(1, 2933) = 2.01$, $p = .156$, but a significant effect of Emotion, $F(2, 2933) = 6.32$, $p = .002$, and a significant Provocation × Emotion interaction effect, $F(2, 2933) = 37.31$, $p < .001$.

CS activity after provocation

CS activity during pain expressions was significantly lower compared to neutral ($b = −213.2$, $SE = 40.2$), $t(2933) = 5.306$,

$p < .001$. We observed no significant difference between sadness and neutral ($b = 20.8$, $SE = 40.2$), $t(2933) = 0.517$, $p = .606$. We further observed no significant effects of time ($bs \geq 176.12$, all $ps \geq .120$).

CS activity after no provocation

Responses during pain expressions did not differ significantly from neutral ($b = 50.6$, $SE = 40.2$, $t(2933) = 1.26$, $p = .208$. Responses during sadness expressions were significantly lower compared to neutral ($b = -205.8$, $SE = 40.2$), $t(2933) = 5.12$, $p < .001$. We observed no significant effects of time (all $bs \geq 162.419$, all $ps \geq .153$).

3.3 | Discussion

Seeing the provoking opponent suffer from a (retaliatory) sound punishment increased smiling indexed by ZM and OO activity, while CS activity decreased, which—taken together—suggests a "genuine" smiling reaction. The smiling reaction was only evoked by displays of pain, whereas the opponent's expression of sadness had no analogous effect. This pattern suggests that the smiling reaction was specific for displays of pain as an expression of suffering.

Furthermore, the small ZM increase evoked by pain observation in Study 1 did not replicate in Study 2. In contrast, Study 2 revealed a decrease in CS activity when seeing the provoking opponent suffer. This CS decrease was present over a prolonged time period and matched the smiling reaction indexed by the ZM and OO activations. Therefore, we believe that the CS increase observed in Study 1 was a spurious finding that does not warrant a strong interpretation.

4 | GENERAL DISCUSSION

Two experiments recorded participants' facial muscle activities while they observed the emotional reaction of an opponent to a (retaliatory) sound punishment in a laboratory aggression task. The fEMG data revealed that participants enjoyed seeing the provoking opponent suffer from the noise punishment: there was a coordinated increase in ZM (and OO muscle in Study 2) activation that was accompanied by a decrease in CS activation in Study 2. The smiling reaction only occurred during observation of punishments of provoking opponents, and participants did not smile when the provoking opponent expressed no emotion or sadness. The smiling during the opponent's expression of pain, but not during expressions of sadness in Study 2, suggests that the enjoyment was specifically linked to the perception that the sound punishment has physically harmed the opponent.

Participants' smiling after having visibly hurt the provoking opponent could reflect satisfaction of having succeeded in the retaliation goal to inflict harm on this opponent. This would fit previous research that also found evidence for aggressive pleasure and rewarding effects of revenge taking (for a review see Chester, 2017).

Besides satisfaction, participants could also have experienced schadenfreude over the opponent's misfortune, which is known to produce a smiling reaction that is indistinguishable from joy (Boecker et al., 2015). Hence, several explanations are possible for why participants smiled during painful punishments of the provocateur, and more research is needed to distinguish between them. One difference between Schadenfreude and aggressive pleasure is agency. While Schadenfreude is associated with the misfortune of others, without any personal responsibility or agency, reward and pleasure stemming from reaching the retaliation goal should increase with agency. Future studies could vary the amount of subjective agency while administering the punishment and therefore differentiate between the affect evoked by carrying out the aggressive act itself and the affect evoked by the punishment outcome (for example, suffering).

Perception of the opponent's pain (or sadness) did not trigger mimicry and/or a compassionate facial reaction, as indexed by increased activity of the CS muscle. The absence of a compassionate response to the suffering of the provocateur is in line with reports that empathy for pain is markedly reduced for unfair and disliked persons (Likowski et al., 2008; Singer et al., 2006). However, participants also showed no compassionate reaction towards non-provoking opponents, who were presumably more liked in comparison. Research suggested that facial mimicry is generally decreased in competitive task settings (Weyers et al., 2009), which could explain the absence of a mimicry response.

The present data also do not indicate that participants experienced guilt due to having visibly harmed the opponent. For this discussion, however, it should be noted that participants were only included in the present analyses when the provocation of retaliatory aggression by opponents was effective. It is possible that participants who do not seek revenge show more compassion with targets of sound punishments, which could be an interesting avenue for future research.

Analyses of punishment choices replicated the results from a previous study that observed a reduction of punishment after observation of a suffering response (Eder et al., 2020). Like in Eder et al.'s study, noise punishments were significantly reduced after observation of pain but not after sadness and calm displays. The present study additionally showed that this effect critically depends on a prior provocation, which is a novel and original finding. (In Eder et al.'s study, only provoking opponents reacted emotionally to noise punishments). An interesting question for future research is whether the experience of positive affects (as indexed by ZM activities) is linked to a down regulation of punishment (indexed by a reduction of punishments intensities). The design of the present studies was not optimized to assess this relation. Future studies could investigate correlations between the magnitude of smiling after having harmed the opponent and subsequent revenge seeking, and whether the experience of positive affect is causally involved in revenge seeking.

Several limitations of the present study need to be mentioned. First, regarding the stimuli, full expression onsets and overall intensity of expressions varied slightly across the different opponents. This adds variance to existing individual variations in reaction onsets. Further, differences in the intensity of the portrayal of pain and sadness expressions can arouse observers in different degrees, which in turn could modulate facial activities (Fujimura et al., 2010).

Secondly, most participants were females playing against male opponents. Previous studies found gender differences in display rules as well as in the perception of pain cues displayed by men and women (Nayak et al., 2000; Yang et al., 2009). Studies of schadenfreude reported no gender differences in levels of experienced pleasure (Hareli & Weiner, 2002). To check for gender difference, we ran separate analyses of subgroups of females and male participants and found no differences in the pattern of results (for a report of these analyses see the Supporting Information). Note, however, that the male subgroup was most likely too small ($n = 13$) for a meaningful analysis. Therefore, additional research is needed that takes into consideration the gender of the opponent and that of the participant observing the expression.

Thirdly, not every participant showed a positive affective response towards opponents in pain. Although the majority of participants exhibited a smiling response, visual analysis of muscle activation patterns on individual levels also revealed a reversed pattern for some participants (exhibiting an increase in CS activity towards suffering opponents). The sample of participants showing this reversed reaction was too small for a meaningful analysis (Study 1: $n = 3$; Study 2: $n = 2$). Future studies should therefore also take personality traits into account that are known to influence the enjoyment of revenge taking and/or empathetic reactions (e.g., attitudes towards vengeance). Studies also found that victims of an interpersonal offense want offenders to know the reasons for a retaliatory punishment and that they feel most satisfied when the target signals "understanding" on the victim's intent to punish and a positive moral change in respect to the wrongdoing (Funk et al., 2014; Gollwitzer et al., 2011). Future research could employ a combination of facial displays and messages of understanding as a test for the impact of moral motivations that may also satisfy the avenger.

To summarize, this study demonstrates that avengers enjoy the punishment of offenders if the punishment has hurtful consequences. Further, avengers only adjust their punishment following directly observed hurtful consequences. These hurtful consequences were observed via displays of pain as a salient indicator of opponent suffering. Future studies are needed to distinguish between the different underlying sources of enjoyment, such as schadenfreude or satisfaction with having succeeded in the goal to take revenge.

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AUTHOR CONTRIBUTIONS

Vanessa Mitschke: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Software; Supervision; Validation; Visualization; Writing-original draft; Writing-review & editing. **Andreas B. Eder:** Funding acquisition; Methodology; Validation; Writing-review & editing.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the Supporting Information section.
Supplementary Material

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