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Shocking Action: Facilitative Effects of Punishing Electric Shocks on Action Control

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Four experiments examined motivational effects of response-contingent electric shocks on action initiation. Although the shock was unambiguously aversive for the individual in line with subjective and functional criteria, results showed that the shock-producing action was initiated faster relative to a response producing no shock. However, no facilitation effect was found when strong shocks were delivered, ruling out increased emotional arousal as an explanation. The action was initiated faster even when the response discontinued to generate a shock. Furthermore, a control experiment with affectively neutral vibrotactile stimulations at homologous sites showed an analogous response facilitation effect. Overall, the results contradict the widespread belief that a contingency with a punishing response effect is sufficient for a response suppression. Instead, the results suggest that punishing action effects can facilitate action initiation via anticipatory feedback processes. Implications for theories and applications of punishment are discussed.

Keywords: punishment, response contingent electric shock, response suppression, motivation, goal-directed action

Punishment is known as an effective procedure to suppress undesired behaviors. There are myriads of studies demonstrating the effectiveness of punishment procedures in laboratory and applied settings with humans and infrahuman organisms (Axelrod & Apsche, 1983; Azrin & Holz, 1966). Behavioral techniques involving punishment are routinely applied by laypeople and professionals in educational, clinical, and corrective settings (Kazdin, 2012; Lerman & Vorndran, 2002). It is noteworthy, however, that behavioral effects of punishments are grossly underresearched in comparison to effects of rewards, at least in modern science. This neglect may have to do with the bad reputation that punishment and aversive behavior techniques have gained in psychology and related behavioral sciences (Horner et al., 1990). Nevertheless, it is clear that a scientific study of punishment effects is indispensable for a deep understanding of the motivational controls of a behavior change.

The present research was conducted to take a new look at punishment effects on behavioral performance in a reaction time (RT) task. Most research studied effects of punishing action consequences on learning and motivation. For instance, Thorndike (1913) suggested in his *law of effect* that "when a modifiable connection between a situation and a response is made . . . and accompanied or followed by an annoying state of affairs, its strength is decreased" (p. 4). In line with this *suppression hypothesis*, many studies (most of them with rodents) obtained evidence that behavior is indeed suppressed after punishment (Azrin & Holz, 1966; Van Houten, 1983). Suppression was found to be greater at higher intensities and duration of punishment, and with continuous and immediate punishments of a behavioral response (Meindl & Casey, 2012). Furthermore, behaviors producing an electric shock (punishment) are more suppressed than behaviors uncorrelated with shocks, indicating that the contingency between a response and a punisher plays an important role (Church, Wooten, & Matthews, 1970).

Other studies, by contrast, observed facilitative effects of punishment on learning and performance (e.g., Stephens, 1934; for a review, see Fowler, 1971). In a classic study of Muenzinger (1934), rodents navigated faster through a maze when a correct turn was "reinforced" with a moderate electric shock. Tolman, Hall, and Bretnall, (1932) observed an analogous facilitative effect with college students who were shocked after providing a correct response ('shock-right effect'). They proposed a *law of emphasis*, which suggests that any emphasis on a correct response can facilitate learning in a trial-and-error situation even when the teaching signal is aversive. These and related findings led Thorndike to conclude that "there is no evidence that an annoyer takes away strength from the physiological basis of the connection in any way comparable to the

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way in which a satisfying after-effect adds strength to it." (1932, p. 313, as cited in Muenzinger, 1934).

Notably, facilitation of a punished behavior was not only reported for learning in trial-and-error tasks (indexed by faster learning/fewer errors) but also for response speed in behavior tasks. Guthrie (1935) argued that facilitative effects of punishment are expected when the conditioned reaction to a punisher is congruent with the intended behavior. In line with this *competing response hypothesis*, a rodent study showed that the elicitation of competing or facilitating responses affects running down an alley to food: rats that, upon arriving at the goal, were shocked in their fore paws slowed down their running, whereas rats that were shocked in their back paws speeded up (Fowler & Miller, 1963).

Research with humans suggests that a response-contingent shock also facilitates intended behavior that is unrelated to escape from shock. Kida (1983) trained adults to respond to the color of lights as quickly as possible with keypresses. After extensive training of the response task, a press of one response key reliably produced a moderately unpleasant electric shock. Now, the shocking response key was pressed faster relative to the foregoing period without a shock. The response facilitation effect was however observed only in the first trials after the introduction of the response contingent shock and when an alternative action (producing no shock) was available. In line with Tolman et al. (1932), Kida explained the facilitation by punishment with an attention shift to the shocking response and its associated cue after the introduction of the response contingent shock. It should be noted, however, that these experiments were conducted with as few as two to eight participants. Furthermore, the introduction of the shock slowed down the unpunished reaction relative to the corresponding baseline, suggesting that participants responded generally more cautiously after the introduction of the shock. Accordingly, a facilitation of an arbitrary response by a punishing effect is less clear than a facilitation of congruent escape responses.

The present research used a similar approach like Kida (1983) but this time with a thorough knowledge of the shock contingency prior to the response task. Participants learned in a first phase that a press of one response key produced an unpleasant electric shock, and a press of the other key had no effect. For a subsequent test phase, they were then instructed to categorize digits as quickly as possible using the same response keys with the same shock contingencies. We were interested in a strong test of the suppression hypothesis that claims a direct suppression of a response causing a punishing stimulus (shock). That means, the shocked action should be initiated slower because the association with or fear of a punishing consequence should suppress the initiation of the punished response. Alternatively, one can also expect facilitative effects of a response contingent shock for this task on the basis of the research literature reviewed above. However, an attention shift to the response contingent shock is less plausible after extensive experience of the shock contingency prior to the test phase.

An important challenge when conducting research on punishment is to establish an effective punishment. Two definitions of punishment are prominent in the modern psychological and behavior-analytic literature (Holth, 2005). One widespread definition, originally proposed by Azrin and Holz (1966), defines punishment as "a reduction of the future probability of a specific response as a result of the immediate delivery of a stimulus for that response" (p. 381). A second definition, espoused by Skinner (1953), defines punishment as a procedure in which responses are followed by either the removal of a positive reinforcer or the presentation of a negative reinforcer (or aversive stimulus). This definition requires that positive and negative reinforcers are identified prior to the punishment procedure. Importantly, we adhered to both definitions in the present research. Following a Skinnerian definition, the intensity of the delivered electric shocks was adjusted for each individual until it was rated by the individual to be an aversive (unpleasant or slightly painful) stimulus. Second, in line with a functional definition, a free-operant procedure was included that examined whether participants will avoid button presses producing a shock when they have an opportunity to do so. Thus, the response contingent electric shock was identified as being "punishing" according to both, experiential and functional definitions of punishment.

Nevertheless, one may still argue that the electric shocks were not punishing in the present research because they were instrumental in approaching a higher valued goal (e.g., a monetary compensation for doing well on the instructed response task). However, this objection in our opinion is misleading because most punishment situations involve incentives that motivated the appearance of a punished behavior in the first place (Dinsmoor, 2001). Even more important, a response suppression effect is also hypothesized for more complex motivations like those involving an approach-avoidance goal conflict. According to Gray's theory of a behavioral inhibition system (Gray & McNaughton, 2000), behavior is suppressed by a "behavioral inhibition system" after the detection of a conflict between approach and avoidance. Accordingly, suppressive effects of a response-contingent shock are also expected for the present experiments in which participants were in conflict between an approach tendency to comply with the experimenter's task instructions and a tendency to avoid the punishing consequence of an instructed action.

Overview of the Experiments

We conducted four experiments using the shock-punishment procedure described above and one control experiment with vibrotactile stimulations. In Experiment 1, a press of one button was followed by an unpleasant shock, and a press of the other button produced no shock. This experiment provided initial evidence for a facilitative effect of a response-contingent punishment. In Experiment 2 we implemented procedures that should have enhanced the severity or averseness of the electric shock for the participant. Experiment 3 examined whether punishments with mild and strong shocks affect response performance differently. Experiment 4 included an extinction condition with no presentations of response-contingent shocks during the test phase. Experiment 5 examined whether an analogous effect is obtained with affectively neutral vibrotactile stimulations as response effect. Overall, the results argue against a strong version of the suppression hypothesis that claims a direct suppression of the punished action.

Experiment 1

In a binary choice RT task, a press of one response key generated an unpleasant electric shock, and a press of the alternative key had no effect. The dependent variable of main interest was the RT to initiate keypresses producing a shock versus no shock. However, we also analyzed response accuracy to explore the possibility of a speed–accuracy trade-off. The intensity of the electrocutaneous stimulation was individually adjusted until the stimulation was clearly unpleasant for each participant. An additional free operant procedure was included to probe whether the participants had a motivation to avoid the response contingent shock.

Method

Participants. Thirty-one volunteers from the Würzburg area with a mean age of 26.3 years (range: 19–38) participated in exchange for payment. Only women were recruited to control for gender differences in pain perception (Paller, Campbell, Edwards, & Dobs, 2009). Participants were informed about the delivery of unpleasant electric shocks before participation and provided written consent. We planned with a minimum sample size of 20 participants but data collection continued depending on the availability of laboratory space. The experiments were approved by the ethics committee of the Faculty of Social Sciences, University of Jena (FSV 10/01), and by the research ethics board of the Department of Psychology, University of Würzburg (GZEK 2014–10). Raw data underlying the findings reported in this article can be accessed at *Harvard Dataverse* (http://dx.doi.org/10.7910/DVN/TSUPPX).

Apparatus and material. Participants were individually tested in a dimly lit room. Stimulus presentation and measurement of response latencies were controlled by a software timer with video synchronization (E-Prime 2.0 Professional; Psychology Software Tools, Inc.). Participants pressed the buttons of the computer mouse with the fingers of the dominant (right) hand.

Electric shocks were delivered by a constant current stimulator (Digitimer DS7A; Digitimer Ltd, Hertfordshire, U.K.) with an internal frequency of 50 Hz. A bar electrode was attached with an adhesive tape near to the elbow joint of the left forearm. The electric shock was a single 2-ms electric pulse with an individually adjusted intensity that received a rating of unpleasantness (see Procedure below). The skin area underneath the electrodes was cleaned with peeling gel and electrodes were filled with a conductive paste.

Procedure. A female research assistant conducted the experiment to minimize gender effects in the interaction with the experimenter (Wise, Price, Myers, Heft, & Robinson, 2002). The experiment consisted of four phases: (a) a shock adjustment phase; (b) a shock learning phase; (c) a test phase; and (d) a shock avoidance test.

Shock adjustment phase. The intensity of the electric shock was individually adjusted using a staircase procedure. After an announcement, the experimenter delivered an electric shock to the participant. Participants rated each shock sensation verbally on a 9-point rating scale with the anchors 1 (*not unpleasant at all*), 4 (*slightly unpleasant*), and 9 (*painful*). The research assistant entered the rating of the shock manually into a computer. Shock intensity started with 10 mA and was increased in steps of 1 mA until the participant's intensity rating reached the score 4 (slightly unpleasant). For the next calibration cycle, the shock intensity was first increased by an additional 1 mA and then stepwise decreased by 1 mA until the participant's intensity rating was below 4. Two additional calibration cycles followed with start values 1 mA below (calibration with increasing intensities) and above the last value (calibration with decreasing intensities), resulting in 3 uprising and 3 declining calibration cycles. Intensities with a rating score 4 were averaged and the mean intensity was used for electrocutaneous stimulation in the subsequent phase.

Shock learning phase. Instructions for this phase were to press the left and right mouse buttons. A press of one mouse button immediately produced an electric shock (shock key), and a press of the other button generated no shock (no-shock key). The assignment of the electric shock to the mouse buttons was counterbalanced across participants.

A free choice procedure was used to familiarize the participants with the response-shock contingencies. Two bars were presented at left and right locations on the computer screen. Participants were instructed to fill both bars with corresponding mouse button presses. A trial started with the presentation of a fixation cross for a random time interval between 1.5s and 2s. Then, a white box appeared at the center of the screen for 200 ms that marked the onset of a response window (1s) for a mouse button press. A press of the shock key immediately produced an electric shock. After a delay of 50 ms, two visual bars appeared at the left and right sides of the screen that indicated the distribution of left and right keypresses, respectively. Left and right mouse button presses added a visual chunk to the bar corresponding to the response location. When the number of allowed keypresses was reached (indexed by a full bar), a message instructed the use of the other mouse button. An error message appeared if no button was pressed or the button press was too fast (RT $<$200 ms). The learning phase was continued until each mouse button was pressed 20 times.

Test phase. Instructions for this phase were to categorize digits into smaller (1–4) and greater (6–9) than 5. A digit appeared inside the white box for a duration of 200 ms. Participants were to categorize the digit as quickly and as accurately as possible using the same mouse buttons as in the shock-learning phase. The assignment of the mouse buttons to the digits was counterbalanced across participants. Importantly, a press of the shock key continued to produce a shock during the test phase. The next trial was initiated after a random time interval between 1.5 and 2s. Participants completed 5 blocks with 8 trials (40 trials); each digit appeared once in a block in random order. Trials with errors (i.e., incorrect, omitted or anticipatory responses with RT $<$200 ms) were repeated in random order after the last block.

Shock avoidance test. In this phase, participants could press the mouse button of their own preference without response constraints. The procedure was the same as in the shock-learning phase but this time without filling up iconic bars. Instructions emphasized that exclusively pressing one button is acceptable. Participants performed 20 mouse button presses of their choice, and the shock key was still effective in producing a shock. A preference for the no-shock key over the shock key was used as an index of shock avoidance.

Results

The significance criterion was set to $p < .05$ for all analyses. Greenhouse-Geisser corrected p values are reported with uncorrected degrees of freedom. Standardized effect sizes (Cohen's d, partial eta-square) are reported when appropriate. The average shock intensity was 71 mA ($SD = 89$). As expected, participants selected the no-shock key more frequently in the shock avoidance test (M = 73%, SD = 19.2), $t(30) = 6.75$, $p < .001$ (dz = 2.46), confirming that the electrocutaneous stimulation was aversive.

Response performance during the test phase was analyzed. One participant with an extremely high number of incorrect responses (37%) was removed before analyses. Trials with errors and RT outliers identified with individual Tukey (1977) criterions were additionally removed for analyses of RTs (6.6% of the trials). A comparison of the mean RTs with a paired-samples t test showed faster presses of the shock key (M = 440 ms, SD = 52) relative to the no-shock key (M = 463 ms, SD = 53), $t(29) = 4.43$, $p < .001$, dz = 0.81.

Trends in the RT data were analyzed to control for possible effects of habituation and/or task practice (Kida, 1983). To this aim difference scores in blocks of eight trials were computed by subtracting the RT of the no-shock key from the RT of the shock key (without including trials repeated after the fifth block). In trend analyses of the difference scores, significance tests of linear, quadratic, and cubic trends were not significant (largest F = 1.09, ps > .30). The facilitative effect was however numerically largest in the first three trial blocks (for visual inspection see the left panel in Figure 1).

Participants made slightly more errors on trials requiring a press of the shock key (M = 4.6%, SD = 4.0) compared with trials requiring a press of the no-shock key (M = 4.0%, SD = 4.4), but this difference was not significant ($|t| < 1$). The correlation between the difference in the error rate (errors on trials requiring a press of the shock key minus errors on trials requiring a press of the no-shock key) and the facilitation effect in the RTs (RT shock key minus RT no-shock key) was $r = .30$, $p = .11$, arguing against a speed–accuracy trade-off in the response performance.

Discussion

The RT data showed that the response-contingent shock facilitated the production of the associated response. This finding rejects a strong version of the suppression hypothesis. However, a possible caveat is that a slightly unpleasant electric shock was too weak for a response suppression. For a second experiment, we therefore increased the averseness of the electric shock further.

Experiment 2

Research showed that increased duration of punishment affects response suppression similarly to increased intensity of punishment (Church, Raymond, & Beauchamp, 1967). For Experiment 2, we therefore increased the duration of the electrocutaneous stimulation delivered after a particular keypress. Furthermore, the intensity of the electric shock was calibrated to a "slightly painful" stimulation, and the intensity of the electric shock was increased by additional 30% after calibration. A behavioral avoidance test was additionally used to identify an aversive stimulation before the test phase using a functional criterion. The shock avoidance test was now presented immediately after the shock-adjustment phase, and the intensity of the stimulation was increased until the participant consistently avoided a press of the shock key. In combination, these procedures should ensure that the electrocutaneous stimulation was aversive to each individual.

Method

Participants. Participants were 25 women (M = 24.6 years, range: 19–38) from the Würzburg area. They were informed about the delivery of slightly painful electric shocks and provided written consent before participation. One data set was removed because the participant was tested with a very low shock intensity (0.13 mA) due to an experimenter error.

Apparatus, stimuli, and procedure. Apparatus, stimuli, and procedures were the same as in Experiment 1 except for the following changes: a train of 10 square-wave 2-ms pulses (5 ms interpulse interval) was used for electric stimulation. Participants rated the stimulation in a shock-adjustment phase on a 9-point rating scale with the anchors 1 (*sensation*), 4 (*slightly painful*), and 9 (*maximally tolerable pain*). Shock intensity started with 0 mA (no shock) and was calibrated in steps of 0.5 mA. The intensity of the shock was increased by additional 30% after averaging but could not exceed 5 mA for ethical reasons (following a guideline of Crosbie, 1998). The minimum intensity was set to 1 mA.

The shock-learning phase started with two instructed presses of each mouse button that were used to familiarize participants with

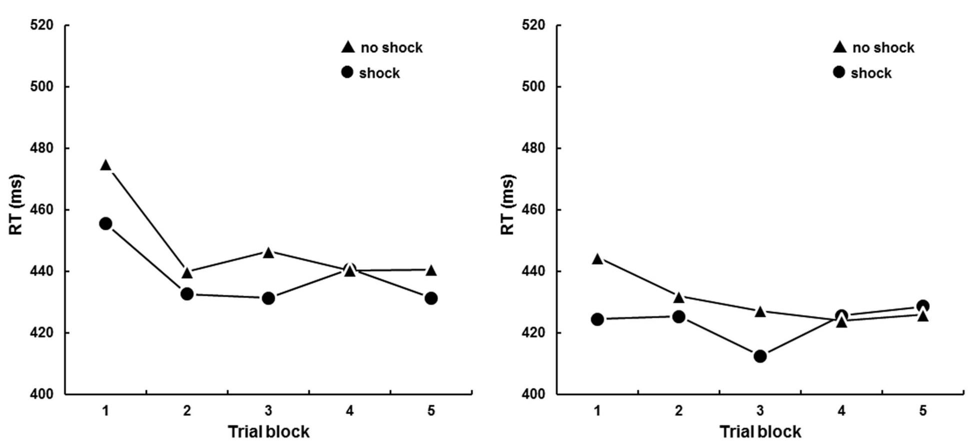

Figure 1. Reaction time as a function of the contingency with an electrocutaneous stimulation and trial block in Experiment 1 (left) and Experiment 2 (right). A trial block contained 8 trials. Trials repeated after the fifth block are not plotted.

the response-shock contingencies. Then, a shock avoidance test followed similar to the one presented in Experiment 1, for which presses of exclusively one response key was acceptable (free response choice). Importantly, the response decision of the participant was used to adjust the intensity of the shock until she exhibited a clear aversion against the shock key. Participants completed trial blocks with 4 response decisions. If the shock key was pressed in a block, then the experimenter increased the intensity of the shock by 0.5 mA (maximum value: 5 mA). Trial blocks were repeated until the participant exclusively selected the no-shock key in two consecutive blocks (8 keypresses) or until a maximum of 10 blocks was reached. Then, the shock-learning task followed with instructions to fill visual bars on the screen with corresponding mouse button presses. For this task, however, more presses of the shock key were necessary to fill the assigned bar. The unequal response distribution in this phase was used to balance out the frequencies of keypresses across both tasks (i.e., the shock avoidance test with more presses of the no-shock key and the shock-learning task with more presses of the shock key). After the shock-learning task, the intensity of the shock was again rated on the intensity scale of the shock-adjustment phase. The test phase was identical with Experiment 1.

Results

The mean shock intensity was 2.9 mA ($SD = 1.4$, range: 1–5 mA). Trials with errors and RT outliers according to Tukey (1977) were removed before RT analyses (8.2% of the trials). A paired-samples t test of the RTs in the test phase revealed faster presses of the shock key ($M = 423$ ms, $SD = 55$) compared with the no-shock key ($M = 441$ ms, $SD = 51$), $t(23) = 2.71$, $p < .05$, $dz = 0.55$. In trend analyses of the difference scores in the trial blocks, the significance tests for linear, quadratic, and cubic trends were not significant (largest $F = 1.94$, ps $> .17$); however, a numeric facilitation effect was again absent in the last two trial blocks (for visual inspection see the right panel in Figure 1).

Errors on trials requiring a press of the shock key were more frequent ($M = 4.2\%$, $SD = 4.7$) relative to errors on trials requiring a press of the no-shock key ($M = 3.5\%$, $SD = 4.3$), but this difference was again far from significance (with $|t| < 1$). There was no correlation between the difference in the error rate (errors on trials requiring a press of the shock key minus errors on trials requiring a press of the no-shock key) and the facilitation effect in the RTs (RT shock key minus RT no-shock key), $r = -.03$, $p = .87$.

Discussion

Results replicate the findings of Experiment 1, again showing a facilitation of the action producing an electric shock. Given our experiential and functional averseness checks, it is not plausible that the electrocutaneous stimulation was not aversive to the participant. Rather, the results suggest that an aversive action effect is not sufficient for a suppression of the associated behavior.

Experiment 3

The experiments described so far consistently found a facilitative effect of response contingent shocks. Several explanations exist for this effect. One explanation, first advocated by Tolman and colleagues (1932) and followed up by Kida (1983), views attentional processes responsible for the response facilitation. With the introduction of a salient response effect, the participants' attention is directed toward the response set producing a shock. Note, however, that a response contingency with an electric shock was introduced a long time before the digit categorization task in the present experiments. Therefore, it is unclear whether an explanation with an attention-shift is plausible for the present setup.

A second explanation is a response facilitation due to increased arousal. Many studies have shown that fear of punishment can have an energizing effect on behavior, increasing response strength or reducing the latency of a response (Neiss, 1988). Although this effect is most plausible for avoidance behaviors, there is also evidence that (emotional) arousal can strengthen any behavior that is dominant in a particular situation (Coombes, Cauraugh, & Janelle, 2007; Hackley, 2009). Arousal induced by the fearful anticipation of an electric shock may hence have facilitated the initiation and/or execution of the (dominant) instructed response.

A third explanation relates the facilitation effect to cybernetic regulations that use the response contingent shock as a feedback signal for action control. Electrocutaneous stimulations involve tactile stimulations of the affected skin area that are perceived in addition to the interoception of an affective signal (Fernandez & Turk, 1992). The sensory component of a response contingent shock may hence have facilitated response selection by providing an accessory signal that could be used to differentiate between both responses. In fact, animal studies have shown that electric shocks facilitate the speed of learning when they provide feedback on correct actions (shock-right effect; Fago & Fowler, 1972) or when they are discriminative cues for different types of avoidance responses (differential outcomes effect; Overmier, Bull, & Trapold, 1971). Furthermore, affective sensations, once learned as a response effect, could also have directive effects on response selection via anticipatory processes (Eder, Rothermund, De Houwer, & Hommel, 2015). In short, feedback effects could explain why a response generating an electric shock was selected and executed faster than a response producing no effect.

It should be noted that the processes described above are not exclusive and could operate in parallel. Experiment 3 therefore attempted to disentangle their possible contributions with a variation of the shock intensity: the response contingent shock was mild in one task block and intense in another task block (counterbalanced order). A strong shock should be feared more and should evoke more arousal (indexed by greater changes in the skin conductance level) in comparison to a mild shock. Accordingly, response facilitation should be larger in the task block with strong shocks according to the arousal-hypothesis. A similar prediction is derived from the attention-hypothesis, because a strong shock should be more salient and attract more attention (Eccleston & Crombez, 1999). The cybernetic explanation, by contrast, expects no difference in the size of the facilitation effects, because a response feedback with mild and strong shocks transmits the same information.

Method

Participants. A minimum of 20 participants for each counterbalanced condition was planned ($n = 40$); however, data collection continued depending on the availability of laboratory space. Participants were 65 women from the Würzburg area with an age between 19 and 34 years (M = 23.5). They were informed about the delivery of electrics shocks and signed a written informed consent before participation. Two participants were removed because they reached the maximum shock intensity (5 mA) after the shock acquisition phase.

Apparatus, stimuli, and procedure. The procedures of Experiment 2 were used with the major change that the duration of the electric shock was varied in two task blocks. For one task block, the duration of the shock was increased from 10 to 20 electric pulses, and for a second task block the duration was decreased from 10 to 6 electric pulses (both with a 5 ms interpulse interval). The order of the task blocks was counterbalanced across participants. Instructions for the upcoming task block were explicit about the intensity of the shock. Furthermore, a shock-learning phase preceded each task block.

Participants rated the intensity of the shock after each shock learning phase on a visual analogue scale (0–100) with the anchors *barely painful* on the left and *very painful* on the right. Electrodes were attached to the palmar sites of the left hand to measure skin conductance responses (SCR) in each task block. Furthermore, a detection test of the electrocutaneous stimulation was included after each task block. Participants had to indicate in each trial whether the experimenter had delivered a shock (press of the key *J* for YES) or not (press of the key *N* for NO). They worked through 10 trials in randomized order, with a shock being presented in half of the trials. This test was included to probe for differences in the detectability of mild and strong shocks.

The raw skin conductance data was down-sampled to 50 Hz and further analyzed using the Continuous Decomposition Analysis of the Matlab based software Ledalab V3.4.3. The signal was decomposed into a tonic and a phasic (SCR) driver component (Benedek & Kaernbach, 2010a, 2010b). Thus, the phasic driver is less biased by slow and stimulus-unrelated changes of tonic skin conductance, and served as SCR within a time window of 1–5 s after the onset the shock, resp. the omission of the shock. To adjust for the left-skewed distribution of SCRs, the data were logarithmized using the function ln-(SCR + 1). Finally, values were z-standardized to adjust for interindividual differences in reactivity.

Results. The mean shock intensity was 2.1 mA (SD = 0.9), with the minimum and maximum intensities being set by the experimenter to 1 mA and 5 mA. A comparison of the subjective pain ratings confirmed that the mild shock (M = 31, SD = 20) was less painful than the strong shock (M = 47, SD = 18), $t(62) = 10.11$, $p < .001$, $dz = 1.27$. Furthermore, participants' SCRs to strong shocks relative to no shock were more intense than those to a mild shock relative to no shock, $t(61) = 2.52$, $p < .05$ (dz = 0.32; one data set was lost due to a technical failure). The difference in the SCRs was correlated with the difference in the subjective pain ratings, $r = .27$, $p < .05$. Participants excelled in the shock detection test (M = 99%, SD = 0.3) and there was no performance difference in the detection of mild and strong shocks ($|t| < 1$). Overall, these results confirm that the manipulation of the shock intensity was effective and that participants clearly perceived the mild shocks.

For RT analyses, trials with errors and RT outliers according to Tukey (1977) were removed (4.2% of the trials). A mixed analysis of variance (ANOVA) of the mean RTs in the test phase with shock intensity (mild vs. strong) and response key (shock key vs. no-shock key) as within-subjects factor and order of task blocks (mild vs. strong shock first) as between-subjects factor showed no effects of the order of the task block and shock intensity (Fs < 1). The main effect of response key was significant, indexing faster presses of the shock key (M = 472, SD = 72) compared with the no-shock key (M = 487, SD = 74), $F(1, 61) = 11.51$, $p < .001$, $\eta_p^2 = .16$. This effect was qualified by a significant interaction with shock intensity, $F(1, 61) = 4.03$, $p < .05$, $\eta_p^2 = .062$. Follow-up comparisons showed a clear facilitation effect when the shock key produced mild shocks ($\Delta M = -21$ ms), $t(62) = 4.60$, $p < .001$ (dz = 0.58), and there was no significant facilitation when the keypress produced a strong shock ($\Delta M = -9$ ms), $t(62) = 1.54$, $p > .10$ (dz = 0.19).

In trend analyses of the absolute effect sizes (RT shock key minus RT no-shock key) with trial block (1–5) and shock intensity (mild vs. strong) as factors, the linear trend of shock intensity did not reach significance, with $F(1, 60) = 3.75$, $p = .058$, $\eta_p^2 = .059$. The linear and quadratic trends of trial block were significant, $F(1, 60) = 6.10$, $p < .05$, $\eta_p^2 = .092$, and $F(1, 60) = 4.54$, $p < .05$, $\eta_p^2 = .070$. As shown in Figure 2, the magnitude of the facilitation effect increased with trial block, with no facilitation of the shock key in the first trial block (irrespective of the intensity of the shock). Other effects were not significant (largest $F = 2.19$, $ps > .14$).

In an ANOVA of the error rates the interaction between shock intensity and order of the task block was significant, $F(1, 61) = 5.65$, $p < .05$, $\eta_p^2 = .085$. Other effects were not significant (largest $F = 2.61$, $ps > .10$). There was no correlation between the difference in the error rate (errors on trials requiring a press of the shock key minus errors on trials requiring a press of the no-shock key) and the facilitation effect in the RTs (RT shock key minus RT no-shock key) in either condition, with $r = -.05$, $p = .70$, in the mild-shock and $r = -.01$, $p = .96$, in the strong-shock condition.

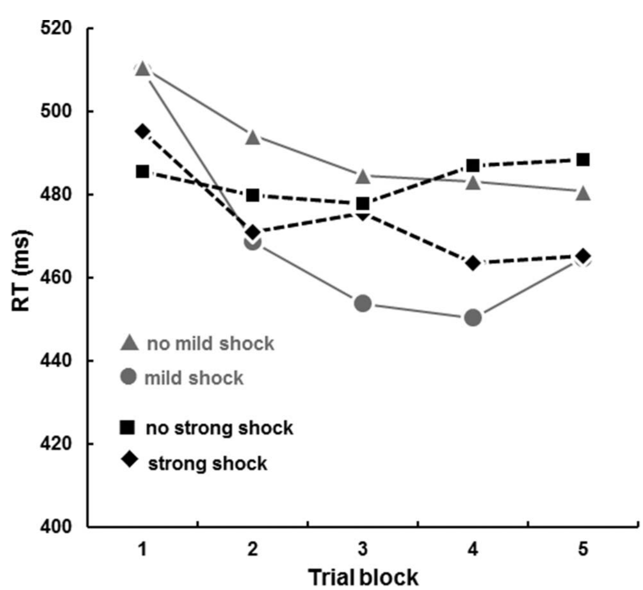

Figure 2. Reaction time as a function of the contingency with a mild and strong electrocutaneous stimulation in Experiment 3. A trial block contained 8 trials. Trials repeated after the fifth block are not plotted.

Discussion

The results argue against the arousal hypothesis. Participants were more aroused by and fearful of the strong shock relative to the mild shock. Nevertheless, the enhanced arousal did not facilitate the production of the shocking response. The results are also inconsistent with the attention hypothesis that expected stronger facilitation effects after the introduction of a strong electric shock. Furthermore, an absent response facilitation effect in the condition with strong shock was also unexpected by the cybernetic account that expected facilitation effects with both shock intensities. In short, the results argue strongly against an explanation with emotional arousal and they are inconclusive in respect to the attention and cybernetic accounts.

Experiment 4

A possible emotional explanation of the observed facilitation effect is reduction of fear (Mowrer, 1939). Fear can be assumed to be maximal during the expectation of a shock, which might have motivated the participant to end fear with a quickened keypress producing the shock. Studies in line with this explanation showed that fear-reducing behaviors are negatively reinforced even when a shock or punishment is unavoidable (e.g., Hineline, 1970). Note, in addition, that a motivation by fear reduction was not ruled out by Experiment 3 because participants in this experiment could arguably have feared both, mild and strong shocks.

A stronger test of the fear-reduction explanation is an extinction condition without fear of shock. Shock electrodes were removed from the participant's skin after shock learning in one condition of Experiment 4. Response performance in the test phase was then compared with the performance in a control condition for which response-contingent shocks were still delivered during the test. According to the fear-reduction hypothesis, there should be no response facilitation in the extinction condition without fear of shock. The cybernetic account, by contrast, still expects feedback-guidance by a memorized response effect. In fact, studies on action-effect learning showed a remarkable stability of action-effect memories after acquisition in a free-choice learning phase (Elsner & Hommel, 2001). Accordingly, this account expects a facilitation of the punished action even for the extinction phase.

Method

Participants. Participants were 75 volunteers (49 women, $M = 25.4$ years, range: 18–48) from the Würzburg area that were randomly assigned to the extinction and control condition. They were informed about the delivery of slightly painful electric shocks and provided written consent before participation. Two participants experienced a technical malfunction of the equipment. Data of additional five participants were removed because they were tested with a very low shock intensity (<1 mA) and/or rated the shock intensity with zero ('no pain') on a visual analogue scale (0–100). One additional participant was removed because his categorization performance in the test phase was at chance. After removal there were 33 participants in the extinction condition and 34 subjects in the control condition.

Apparatus, stimuli, and procedure. The experiment was identical to Experiment 2 with the exception that the shock electrodes were removed from the participants' skin in one condition after the shock-learning phase. Furthermore, participants rated the intensity of the shock after the shock-learning phase on a visual analogue scale (0–100) with the anchor *no pain* on the left and *maximally tolerable pain* on the right.

Results

The intensity of the shock was set to $M = 3.8$ mA ($SD = 1.3$, range: 1–5 mA) and the subjective pain rating was $M = 47$ ($SD = 24$). There were no significant differences between the conditions on these numbers (with $|ts| < 1$).

Trials with errors and/or RT outliers were removed for RT analyses (7.6% of the trials). A mixed ANOVA of the RTs in the test phase with condition as between-subjects factor (extinction vs. control) and response key as within-subjects factor (shock key vs. no-shock key) yielded a significant main effect of response key, $F(1, 65) = 11.61$, $p < .001$, $\eta_p^2 = .15$. The main effect of condition, $F(1, 65) = 1.64$, $p = .23$, and more important, the interaction between condition and response key were not significant (F < 1). A planned comparison replicated the facilitation effect in the control condition with faster presses of the shock key ($M = 446$, $SD = 73$) relative to the no-shock key ($M = 459$, $SD = 62$), $t(33) = 1.82$, $p < .05$ (one-tailed). Most notably, the formerly shock-producing response key ($M = 425$, $SD = 58$) was pressed faster relative to the alternative key ($M = 443$, $SD = 69$) in the extinction condition too, $t(32) = 3.16$, $p < .01$.

In trend analyses of the absolute effect sizes (RT shock key minus RT no-shock key) with trial block (1–5) and condition (extinction vs. control) as factors, the linear trend of trial block was not significant ($F < 1$). The linear trend of the interaction effect between trial block and condition however approached significance, $F(1, 63) = 3.28$, $p = .075$, $\eta_p^2 = .049$. As shown in Figure 3, effect sizes in the extinction condition tended to decrease with trial block, and the opposite tendency was observed for the control condition. Note that two data sets were not included in this analysis due to missing data.

Corresponding analyses of the error rates produced no significant main effects (with both Fs < 1) but a significant interaction between condition and response key, $F(1, 65) = 4.16$, $p < .05$, $\eta_p^2 = .06$. A follow-up comparison in the control condition revealed less errors on trials requiring a press of the shock key ($M = 1.5\%$, $SD = 2.7$) relative to trials requiring a press of the no-shock key ($M = 3.0$, $SD = 3.5$), $t(33) = 1.95$, $p < .05$ (one-tailed). In contrast, errors in the extinction condition were numerically larger on trials requiring a press of the formerly shock-producing key ($M = 3.2\%$, $SD = 4.8$) relative to the other key ($M = 2.4\%$, $SD = 3.5$; \t\ < 1). Errors were too few for a meaningful trend analysis.

Discussion

The most important finding of Experiment 4 is the facilitation of a previously punished keypress in the extinction condition. This finding is at odds by a motivation-by-fear-reduction explanation of the response facilitation effect. With the shock electrodes visibly removed from the participant's skin, it was obvious to the participant that a press of the response key does not generate a shock. Accordingly, there should have been no fear of shock that could have expedited the keypress during the test phase. The results are

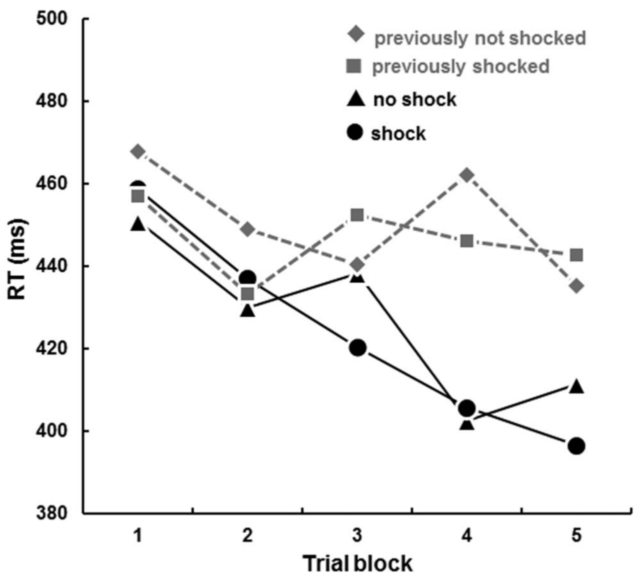

Figure 3. Reaction time as a function of the contingency with an electrocutaneous stimulation in the extinction and control conditions of Experiment 4. A trial block contained 8 trials. Trials repeated after the fifth block are not plotted.

also challenging for the attention hypothesis. After the removal of the salient response effect (shock), attention should have shifted have away from the response set that produced a shock in the shock-learning phase. However, no difference was observed in comparison to a control condition with a salient response-effect (shock), suggesting that attention to the response effect was not responsible for the response facilitation.

The cybernetic account can account for the present results with the assumption that knowledge of action-effect contingencies, once acquired, can guide action selection by memory retrieval in the absence actual action effects. In line with this assumption, studies showed that memories of sensory action effects are fairly robust in extinction tests (Elsner & Hommel, 2001, 2004). Thus, the memory of the response-contingent cutaneous stimulation might have supported action selection without inducing fear.

Experiment 5

According to the cybernetic account, any perceived event that is contingent upon a response should facilitate selection of that particular response if it helps to discriminate between the instructed responses. Experiment 5 tested this prediction with vibrotactile instead of electrocutaneous stimulations. The stimulation was again strong in one task block and mild in another task block. According to the cybernetic account, response contingent vibrations should facilitate the production of the response producing the vibration. Furthermore, the account expects no difference in the magnitude of response facilitation by strong and mild vibrations.

Method

Participants. Data collection was matched to the sample size of Experiment 3. The sample included 68 adults from the Würzburg area (mean age = 23.8 years, range: 18–33). Participants were informed about the vibrotactile stimulation applied to a finger and signed a written informed consent before participation. Data of three participants were removed because they indicated that they had not perceived a vibration.

Apparatus, stimuli, and procedure. The procedures were adapted to vibrotactile stimulations. A vibrating mini motor (12000 rpm, 10 mm diameter) was attached with an adhesive tape to the ring finger of the left hand. After some pretesting with research assistants, a fixed duration of 50 ms was selected for weak and 150 ms for strong stimulations. The weak vibration was presented in one task block and the strong vibration in a second task block (counterbalanced order). Before each task block, participants learned to associate a particular keypress with a vibration effect using the procedure of the shock learning phase. The intensity of the vibration was rated after each learning phase on a visual analogue scale (0–100) with the anchors *barely perceptible* on the left and *very intense* on the right. A detection test of the vibrotactile stimulation was presented after each task using the procedure of the shock detection test in Experiment 3.

Results

In a mixed ANOVA with intensity of the vibration as within-subjects and order of the task blocks as between-subjects factors, the strong vibration received a higher intensity rating ($M = 47$, $SD = 19$) than the weak vibration ($M = 18$, $SD = 12$), $F(1, 63) = 285.96$, $p < .001$, $\eta_p^2 = .819$. The intensity rating was generally higher when the mild vibration was rated first, $F(1, 63) = 9.99$, $p < .05$, $\eta_p^2 = .137$. The interaction between order of the task blocks and vibration intensity was however not significant ($F < 1$). Mean performance in the detection test was 99% ($SD = 2.7$), and to our surprise, detection of the mild vibration was slightly better ($M = 99.7\%$) than that of the strong vibration ($M = 98.3$), $F(1, 63) = 5.41$, $p < .05$, $\eta_p^2 = .079$. Other effects were not significant (largest $F = 1.86$, $ps > .17$).

Trials with errors and RT outliers were removed before RT analyses (4.8% of the trials). In a mixed ANOVA of the mean RTs in the test phase with vibration intensity (mild vs. strong) and response key (vibration key vs. no-vibration key) as within-subjects factors and order of the task blocks (mild vs. strong vibration first) as between-subjects factor, only the main effect of response key reached significance, $F(1, 63) = 4.31$, $p < .05$, $\eta_p^2 = .064$. The vibrating key was pressed faster ($M = 436$ ms, $SD = 56$) than the nonvibrating key ($M = 443$ ms, $SD = 55$), irrespective of the intensity of the vibration ($F < 1$). Other effects were not significant (largest $F = 2.02$, $ps > .15$). In trend analyses of the absolute effect sizes (RT vibration—RT no vibration) with order of the task blocks as between-subjects factor, no trend reached significance (largest $F = 3.09$, $ps > .08$). As shown in Figure 4, the response facilitation effect was numerically larger in subsequent trial blocks, but this trend was not statistically significant (linear: $F = 2.23$, $p = .14$; quadratic: $F = 1.13$, $p = .29$).

In an analogous ANOVA of the error rates in the test phase, the interaction between intensity of the vibration and order of the task blocks was significant, $F(1, 63) = 9.22$, $p < .01$, $\eta_p^2 = .128$, indicating more errors in the first task block. Other effects were not significant (Fs < 1). There was no correlation between the difference in the error rate (errors on trials requiring a press of the shock

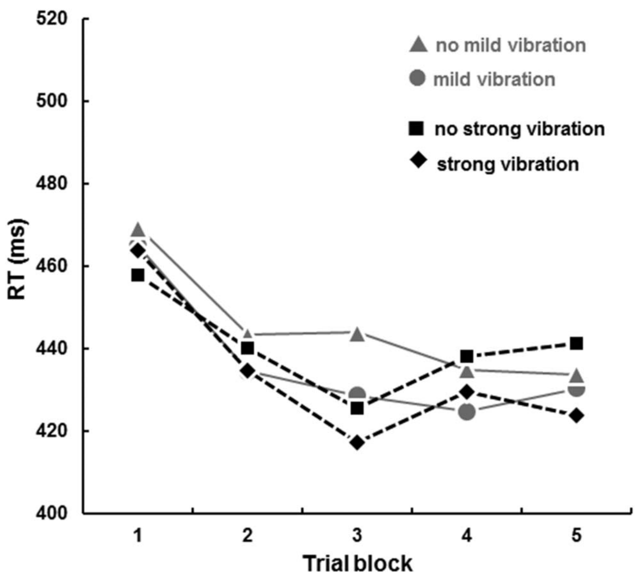

Figure 4. Reaction time as a function of the contingency with a mild and strong vibrotactile stimulation in Experiment 5. A trial block contained 8 trials. Trials repeated after the fifth block are not plotted.

key minus errors on trials requiring a press of the no-shock key) and the facilitation effect (RT shock key minus RT no-shock key) in the condition with a mild vibration, $r = .01$, $p = .96$, and in the condition with a strong vibration effect, $r = .04$, $p = .77$.

Discussion

The results suggest an important role of feedback-related processes for the response facilitation effect. The key generating a vibration was pressed faster than the key without a vibration effect. According to the cybernetic explanation, a response contingent event can help to discriminate between the responses, facilitating the selection of the response causing a response effect. This directive effect is presumably independent of the affective value or pleasantness of a response effect, given that both aversive and nonaversive action consequences were found to facilitate the associated response (Eder et al., 2015). Note, however, that RT was generally slower in Experiment 3 that used shocks as response effects compared with the control experiment with vibrotactile stimulations (Ms = 464 vs. 439 ms), $F(1, 124) = 4.31$, $p < .05$, $\eta_p^2 = .064$, as revealed by a mixed ANOVA of the RTs with experiment and order of the task blocks as between-factors. Furthermore, no facilitation effect was observed when the shock was intense, and a high versus low intensity of the vibration made no difference. These differences suggest that actions were generated with more caution with presentations of aversive action consequences.

The attention-hypothesis, in contrast, was again not supported by the results. The facilitation effect tended to be larger in later trial blocks, which is difficult to explain with an attention shift. Furthermore, strong vibrations should have attracted more attention (Johansen-Berg & Lloyd, 2000), but no difference in the magnitude of response facilitation was observed. In short, an attention shift to the response effect, if triggered by different stimulus intensities, had no facilitative effect on action selection.

General Discussion

A nearly universally accepted law in psychology is that punishments suppress the behavior causing the punishment. For many psychologists, a response suppression is even the defining feature of punishment, with punishment being the presentation of an event contingent upon a response that reduces the probability of that response (Azrin & Holz, 1966). However, as the present experiments and other research findings show, the effects of punishments on the producing action are much more varied and complex as it is commonly believed. Electric shocks that were unambiguously identified to be aversive for the individual facilitated, rather than suppressed, the action producing the shock. This result is surprising given the widespread belief that a punishing aversive consequence should directly inhibit the action producing the consequence. It is however less surprising given the extant research literature that observed analogous facilitative effects of punishment in learning and discrimination tasks (for reviews see Church, 1963; Fowler, 1971).

We consider the response-contingent electric shock in the present research as "punishing" in the sense that it caused discomfort to the individual, as verbally expressed by the participant, and triggered behavioral avoidance in an appropriate task setting. That means, a punishing property of the electric shock was established in line with subjective and functional definitions of punishment. Furthermore, conditions were arguably good for suppression by a response contingent shock:

- The intensity of the electric shock was adjusted to each individual using experiential and behavioral criteria. Although the maximum intensity was capped for obvious ethical reasons, it is clear that the electrocutaneous stimulation was unpleasant and aversive for each individual. It is also unlikely that participants had a prior social history that established electric shock as a discriminative stimulus for reinforcement (Van Houten, 1983).
- The electric shock was delivered after every action (continuous punishment schedule), which is known to increase the effectiveness of punishment procedures (Azrin & Holz, 1966).
- It was not possible for the participant to escape or minimize the punishment by means of some unauthorized behavior. Strategic response omissions and/or incorrect responding were not effective because participants knew that trials with errors will be repeated. The only way to avoid the electric shock was to abort participation in the experiment completely.

Given the conditions described above, and the consistent finding of a facilitative effect, one can thus conclude that the delivery of a punishing consequence is not sufficient for a behavioral suppression effect. Instead, additional conditions seem to be necessary for a suppression by punishment. For example, Guthrie (1935) argued that "punishment achieves its effects . . . by forcing the animal or the child to do something different" (p. 158, as cited in Church, 1963). According to this account, a punished action is suppressed only when the punishment triggers a reaction that is incompatible with the punished action. However, it is difficult to identify an incompatible reaction for the present research. With the shock electrodes being attached to the arm of the nonresponding hand, there should have been no motor interference in respect to the effectors used for the keypress. Thus, (in-) congruent reactions evoked by the anticipation of a punishment are not plausible for the present setup.

Another possibility is that the electric shock was too mild to evoke fear in the participant. Estes (1944) argued that fear of punishment triggers a conditioned emotional reaction that interferes with ongoing instrumental responding (conditioned suppression). A related emotional account views negative reinforcement as the main underlying cause of a response suppression by punishment (Dinsmoor, 2001). For example, Mowrer (1947) wrote:

> The performance of any given act normally produces kinesthetic (and often visual, auditory, and tactual) stimuli which are perceptible to the performer of the act. If these stimuli are followed a few times by a noxious ('unconditioned') stimulus, they will soon acquire the capacity to produce the emotion of fear. When, therefore, on subsequent occasions the subject starts to perform the previously punished act, the resulting self-stimulation will arouse fear; and the most effective way of eliminating this fear is for the subject to stop the activity which is producing the fear-producing stimuli. (p. 136; as cited in Church, 1963)

Importantly, both accounts expect that the magnitude of the behavioral suppression is positively related to the severity of the punishment (Appel & Peterson, 1965; Church et al., 1967), which was only moderate in the present experiments due to ethical restrictions. Thus, one could argue that the shock punishment was too weak for a suppressive effect in the present research. Furthermore, it is tempting to interpret the absence of a response facilitation effect with strong shocks in this direction. However, one must be careful with this interpretation. First, the absence of a facilitation effect does not imply a suppression of the behavior, because responding could be slowed down for reasons independent of a response inhibition. As a matter of fact, the mean RT of the punished action was not slower than that of the unpunished action in this particular condition of Experiment 3. Second, the key producing a strong shock was pressed slower than the other key only in the first trial block of the categorization task (Ms = 494 vs. 482 ms, $t(62) = 1.29$, $p = .20$), and there was no response suppression in subsequent trials (see Figure 2). It is noteworthy that a similar initial response slowing was observed in the condition with intense vibrotactile stimulations (Ms = 463 vs. 457 ms, $t < 1$; see Figure 4). This pattern suggests that participants responded generally with more caution after the announcement of an intense stimulation—which is a response strategy that is different from a direct response inhibition claimed by the suppression hypothesis.

Although the present experiments are inconclusive with respect to the conditions that are necessary for a response suppression by punishment, they are conclusive with respect to the underlying processes of a response facilitation. The results of the present experiments clearly argue against an explanation with increased (emotional) arousal. Strong shocks evoked more arousal (as indexed by a change in the SCR) in Experiment 3, but there was no facilitation of the arousing response. Furthermore, responses were also facilitated by vibrotactile stimulations that were not (emotionally) arousing. A facilitation of the (instructed) dominant response by arousal hence received no support.

Results of the present experiments do also not support an explanation with motivation by fear reduction (Mowrer, 1939). It is plausible that fear of shock was maximal during the anticipation of a shock, and that participants were motivated to end fear with a quickened keypress. In contradiction to this explanation, however, a response facilitation was also observed in an extinction condition without fear of shock (Experiment 4) and with nonthreatening vibrotactile stimulations (Experiment 5). Thus, if escape from fear was motivating the punished action, it could not have done so in these experiments.

Another motivational explanation that we have not mentioned before, is "motivation from control." Research suggests that the mere agency of producing an effect can have a motivational effect on action selection. In support of this theory, studies showed that a key was pressed faster when the action produced an immediate visual effect (relative to no or lagged effects), although the produced effect was affectively neutral and unrelated to the task at hand (Karsh & Eitam, 2015; Karsh, Eitam, Mark, & Higgins, 2016). Motivation from control could explain why participants pressed faster a response key that generated affectively neutral vibrations on the skin (Experiment 5). However, the account is less plausible for a facilitation of punished actions. First, it should be noted that our participants quickly avoided the delivery of an electric shock when they had an opportunity to do so (shock avoidance test), showing that the intentional production of unpleasant electric shocks was not "rewarding" and/or "reinforcing" for them. Second, a response facilitation effect was also obtained in the absence of an action effect that could be controlled (extinction condition of Experiment 4). Accordingly, a motivation by merely "having an action effect" is an incomplete account of the present results.

A nonmotivational explanation, originally espoused by Tolman and colleagues (1932), proposes an attention shift to the shocking response effect that renders the response set associated with the shock more salient for the participant. Although an attention shift to the shocking response effect is plausible, there is no evidence that differences in attention were causally involved in the response facilitation effect. First, an attention shift to the response effect, if triggered by different stimulus intensities, had no effect on the response speed. Second, enhanced attention to a response effect could not explain a response facilitation effect in the extinction condition with no presentation of a response effect. Third, the salience of the response effect, and with it the magnitude of the response facilitation, should have decreased with familiarization of the task, as observed by Kida (1983). However, trend analyses of the effect size as a function of trial blocks revealed no particular tendency. Facilitation effects tended to become smaller in the first two experiments but larger in the subsequent experiments. Moreover, the response contingency with a shock was introduced a long time before the RT task, that means, participants had experienced the response-contingent shocks many times before the test phase. This is an important procedural difference to Kida who introduced a response contingent shock only after extensive task practice without a shock.

The explanation that in our opinion fits best with the data is a cybernetic account. After having learned that a particular sensation (an electric shock) is produced by a particular keypress, participants can use the effect knowledge to select, initiate, and monitor the responsible action producing the effect. This notion of an inverse action control mode is well documented in movement science (Wolpert & Ghahramani, 2000), and it corresponds with the cybernetic idea that a behavior is displayed to produce intended perceptions in the environment (Hommel, Müsseler, Aschersleben, & Prinz, 2001; Powers, 1973). The intriguing implication is that even punishing stimuli, such as unpleasant electric shocks, can become a target sensation for anticipatory action control processes. Beckers, De Houwer, and Eelen (2002) found that a movement producing a shock is initiated faster in response to negative stimuli relative to positive stimuli. The negative stimulus presumably resembled the anticipated response effect (shock) more than a positive stimulus, facilitating movement initiation. Another study suggests that feelings of unpleasantness (or the cognitive representation thereof) can become a target sensation as well (Eder et al., 2015). Affective and nonaffective sensations could hence have become a target of anticipatory processes in the present experiment. By guidance of a sensory effect the keypress was initiated faster than without such guidance.

The facilitation of a previously punished response in the extinction condition of Experiment 4 suggests that action-effect memories underlying feedback-related processes are fairly resistant against extinction. This finding fits with previous studies on action-effect learning that analogously found that knowledge of auditory action effects, once acquired, is remarkably persistent (Elsner & Hommel, 2001, 2004). In contrast, Eder and colleagues (2015) observed a rapid extinction of pleasant and unpleasant feelings as action effects. This difference could suggest that feedback-guidance in the extinction condition was driven more by the sensory/haptic component of the electrocutaneous stimulation, and less by its affective component. However, more research is necessary to explore whether sensory and affective components of action effects are differently robust against extinction treatments.

Overall, the present findings highlight the flexibility of the human action system in dealing with aversive events that are contingent upon own actions. As mentioned in the introduction, most punishment situations involve not only aversive motivation but also conflicting appetitive motivations that motivated the punished action in the first place (Dinsmoor, 2001). This analysis in terms of an approach-avoidance goal conflict is also appropriate for the present research in which participants had an appetitive motivation to please the experimenter and/or to earn a monetary compensation for study participation. From this perspective, it is meaningful to ask questions about the relative dominance of a motivation and what capacity is needed to resolve an approach-avoidance conflict. According to Gray's theory of a behavioral inhibition system (Gray & McNaughton, 2000), for instance, there exist important interindividual differences in respect to a sensitivity to rewards and punishments that should affect the strength of a particular motivational impulse (e.g., Braem, Duthoo, & Notebaert, 2013; Sheynin, Moustafa, Beck, Servatius, & Myers, 2015). Furthermore, the magnitude of behavioral inhibition in conflict situations is influenced by cognitive inferences on the statistics of a situation, such as estimations of the costs and utilities of an inhibited action (Bach, 2017). These studies suggest that behavior inhibition in a punishment situation is not direct but mediated by a host of cognitive and affective variables that must be integrated in a theory of punishment effects.

To conclude, the present research shows that punishing action effects can have facilitative effects on the initiation and/or execution of the punished action. This is not only important for theories of punishment but also for the practical use of punishment procedures. With additional guidance by a sensory component, positive punishment procedures provide a cocktail of facilitative and suppressive effects that likely diminish the effectiveness of positive punishment as a "behavior decelerator" (Mazur, 2013). A facilitative effect of punishing stimuli (resulting in an "ironic" tendency to carry out the punished action) is most plausible for punishment situations with weak punishment, with suboptimal guidance of alternative actions, and/or under mental load or stress (Wegner, 2009). Sensory guidance by punishing stimuli is however minimized in negative punishment procedures that aim at the removal or omission of a reward. Thus, negative punishment procedures often may not only be more ethical but also more effective in the slowing and reduction of an unwanted behavior.

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