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Susanne Augst, Thomas Kleinsorge & Wilfried Kunde

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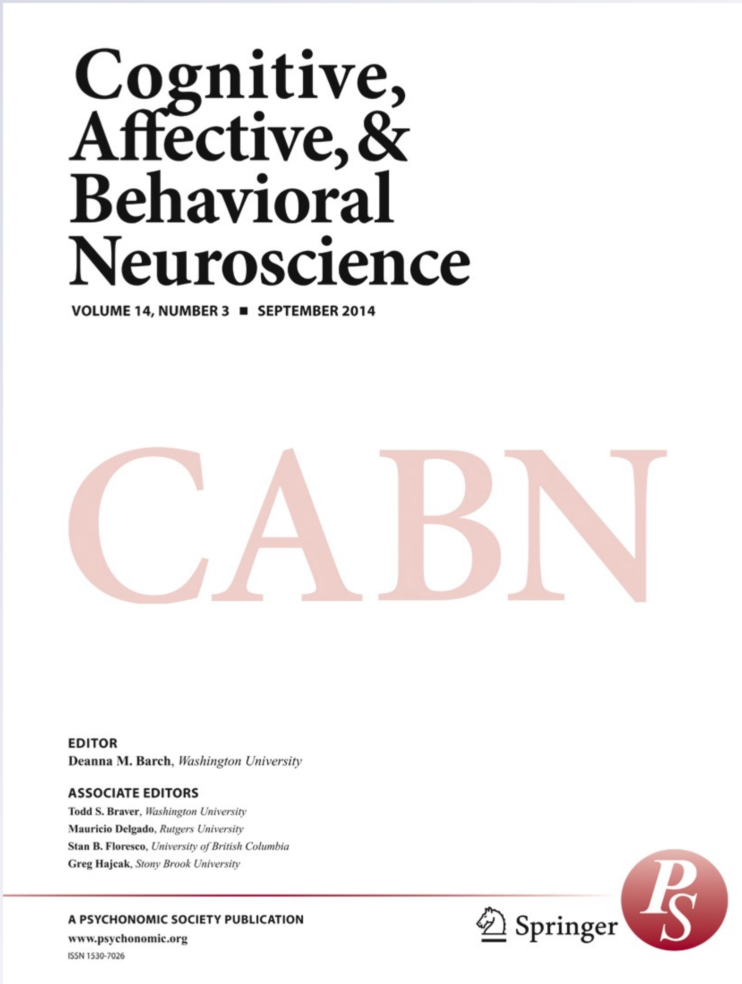

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Can we shield ourselves from task disturbance by emotion-laden stimulation?

Susanne Augst · Thomas Kleinsorge · Wilfried Kunde

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Abstract Emotion-laden stimuli can disturb information processing in an unrelated cognitive task. We investigated the possibilities and limitations for shielding from such disturbance. Participants performed a simple categorization task while being simultaneously exposed to negative, neutral, and positive pictures. Performance dropped with negative pictures, relative to positive and neutral stimuli. Unlike Stroop or Simon interference effects, this negativity-based disturbance did not reduce as a function of previous experience of disturbance (Exp. 1) or of announcement of such disturbance on a trial-by-trial basis (Exps. 2 and 3). We found hints of a reduction of negativity-based disturbance, however, when negative stimulation occurred with high list-wide probability (Exp. 4). These observations suggest that the control of negativity-based task disturbance might be possible in a sustained manner, but that it is severely limited when operating in a transient, moment-to-moment manner.

Keywords Cognitive control · Affective processing · Adaptation

Adaptive goal-directed behavior demands focusing on information that is relevant for a given task and ignoring information that is irrelevant. For example, while driving a car we should monitor the traffic attentively. Commercial banners are irrelevant for goal achievement, and should therefore be ignored. Usually, we can do so to a sufficient degree, but on closer look it becomes evident that irrelevant information penetrates behavior, nevertheless. This is almost always the case when the irrelevant information overlaps perceptually or conceptually with relevant information that needs to be processed (Kornblum, Hasbroucq & Osman, 1990). Classical experimental tasks in which such overlap exists are the Stroop (1935), Simon (1969), and Eriksen flanker (Eriksen & Eriksen, 1974) tasks. In all of these tasks, performance drops when irrelevant information suggests a different response than the relevant information. Such task disturbance from a mismatch of irrelevant and relevant stimuli (or responses) can be called *interference.*

However, in some cases specific types of information have the potential to impair information processing, despite being entirely unrelated to the task. This applies to the observers' own name (e.g., Pfister, Pohl, Kiesel & Kunde, 2012), to very salient events, such as feature singletons or abrupt visual onsets (e.g., Cosman & Vecera, 2009, 2010; Schreij, Owens & Theeuwes, 2008; Yantis & Jonides, 1984) and to highly valent information—that is, either positive or negative. The present study is concerned with the latter type of information, hence, impairments by valence-laden stimulation. This kind of impairment, which occurs even without overlap or similarity of task-irrelevant and task-relevant information, can be called *interruption.*

Valent stimuli have been shown to unintentionally capture attention (e.g., Luo, Holroyd, Majestic, Cheng, Schechter & Blair, 2010; Pessoa, 2005; Reeck & Egner, 2011) and to impair ongoing cognitive processes in a variety of domains (e.g., Bertels, Kolinsky & Morais, 2010; Cohen, Henik & Moyal, 2012; De Houwer & Tibboel, 2010; Gupta & Raymond, 2012; Melcher, Born & Gruber, 2011; Pereira, Volchan, de Souza, Oliveira, Campagnoli, Pinheiro & Pessoa, 2006; Verbruggen & De Houwer, 2007). A typical

S. Augst · W. Kunde
Department of Psychology, Julius Maximilians University Würzburg, Würzburg, Germany

T. Kleinsorge
Leibniz Research Centre for Working Environment and Human Factors, Dortmund, Germany

S. Augst (✉)
Department of Psychology III, Julius Maximilians University Würzburg, Roentgenring 11, 97070 Würzburg, Germany
e-mail: Susanne.Augst@uni-wuerzburg.de

example is the emotional Stroop effect (Mathews & MacLeod, 1985; Williams, Mathews & MacLeod, 1996, for a review). Participants have to name the color of words and are slower in color naming if the word is valent, especially if it is negative, as compared to neutral although the word meaning itself is task irrelevant (see, e.g., Dresler, Mériau, Heekeren & van der Meer, 2009; Frings, Englert, Wentura & Bermeitinger, 2010; McKenna & Sharma, 2004). The valence of the words thus causes interruption according to the above definition. This observation, valent stimuli disrupting task processing despite being unrelated, is certainly a cue for their strong impact.

However, very little is known about the possibilities and limitations to control such unintended disturbance. Is it possible to shield an observer from disturbances by task-irrelevant valence? It is surprising that we know very little about this question, because the inhibition of processing of irrelevant information, be it valent or not, has been studied quite extensively with interference, thus in cases in which irrelevant information overlaps with relevant aspects of the task (see Egner, 2008, for a review). Two types of control have been identified that are involved in resolving interference: *reactive* and *proactive* control (cf. the dual-mechanism framework; Braver, 2012).

Reactive and proactive control

Reactive control, as we understand it here, denotes aftereffects of previously experienced interference (see Wühr & Kunde, 2008). Experiencing interference, such as an incongruent Stroop trial, helps to overcome reappearing interference in the next trial. Thus, a previously experienced incongruent situation manifests in reduced interference effects on a subsequent trial, whereas after a congruent (interference-free) situation, the typical interference effect emerges. Such reactive adaptation effects have been demonstrated with interference based on nonvalent information (Gratton, Coles & Donchin, 1992; Kerns, Cohen, MacDonald, Cho, Stenger & Carter, 2004; Kunde & Wühr, 2006) as well as interference based on valent stimulation (e.g., Egner, Etkin, Gale & Hirsch, 2008; Kunde, Augst & Kleinsorge, 2012; Soutschek & Schubert, 2012). It is likely that such reactive control already starts with the first onset of interference, as suggested by Braver (2012). Thus, basically every correct response in the presence of interference is a result of early reactive control. However, we want to focus here on the traces of control that manifest slightly later in subsequent stimulus–response episodes.

Proactive control denotes the preparation of the cognitive system for expected interference. This is typically studied by announcing that interference will occur (e.g., by an explicit cue), or by manipulating the probability of subsequent interference. For example, announcing an incongruent (interfering) situation reduces interference by a subsequent incongruent situation (Gratton et al., 1992), though limitations of such proactive regulation have been identified as well (Wühr & Kunde, 2008).

Control of interruption

Although there is evidence that interference caused by stimuli that do overlap with task-relevant aspects can be controlled in a reactive as well as a proactive manner, little is known about the regulation of interruption—that is, disturbance by stimuli that do not overlap with task-relevant features. There is no principled reason to assume that interference but not interruption could be controlled in reactive and proactive manners. For example, control could be exerted by focusing more strongly on task-relevant information, and that might well happen after all types of disturbance, be it caused by irrelevant information that does or does not overlap with the task. Preliminary evidence suggests, however, that reactive regulation of disturbance by irrelevant valent stimulation is limited. Kunde and Mauer (2008) had participants respond to the frame color of positive, neutral, and negative pictures. Although pictures were task-irrelevant, responding was delayed at judging the frame colors of valent as compared to neutral pictures. More importantly, having encountered a valent picture did not reduce the disturbing impact of a subsequent valent picture in the next trial. In fact, disturbance *increased* if a valent rather than neutral picture had been encountered previously, especially if it had been a negative picture. Paradoxically, overcoming disturbance by a valent stimulus did not help, but rather hindered overcoming disturbance by another valent stimulus.

Regarding *proactive* control, Munneke, Van der Stigchel and Theeuwes (2008) found regulation of disturbance by irrelevant, nonvalent stimulation. Announcing the location of an upcoming distractor indeed reduced its disturbing impact in visual search. Apparently, participants manage to actively inhibit the spatial location from which disturbance by a salient visual event is expected. In contrast, Kleinsorge (2007, 2009) reported a paradoxical effect with *proactive* control of task disturbance by irrelevant valent stimulation. If participants were informed in advance about the valence of a potentially distracting picture, performance in solving a mathematical equation dropped, as compared to a condition without preinformation, specifically if negative pictures were announced.

A crucial role in affective processing in general (Anderson & Phelps, 2001; LeDoux, 2000; Vuilleumier, 2005) and in emotional conflict in particular (Etkin, Egner, Peraza, Kandel & Hirsch, 2006) is ascribed to the amygdalae. Also, prefrontal cortices (PFCs) and anterior cingulate cortices (ACCs) play a critical role in cognitive and affective conflict and their resolutions. More precisely, activation in the lateral prefrontal cortex (lPFC) is linked to conflict resolution by increasing attention to task-relevant rather than task-irrelevant stimuli (Egner & Hirsch, 2005; Kerns et al., 2004). The lPFC like the ventrolateral prefrontal cortex (vlPFC) is especially concerned with nonaffective cognitive conflict (Egner et al., 2008; Ochsner, Hughes, Robertson, Cooper & Gabrieli, 2009). In contrast, the dorsolateral prefrontal cortex (dlPFC) is activated by nonemotional and emotional distractors (Egner et al., 2008; Etkin et al., 2006; Ochsner et al., 2009) and is mostly associated with behavioral response control (Botvinick, Braver, Barch, Carter & Cohen, 2001). The ACC is suggested as emotion regulation region and together with the medial prefrontal cortex (mPFC) especially activated by negative information (Etkin, Egner & Kalisch, 2011). Cognitive control of distracting emotional and nonemotional stimuli by monitoring performance is associated with activity in the dorsal anterior cingulate cortex (dACC; Botvinick et al., 2001; Egner et al., 2008; Kerns et al., 2004). For example, dACC and dlPFC are activated when interfering affective pictures are presented while participants have to make cognitive judgments (Blair, Smith, Mitchell, Morton, Vythilingam, Pessoa & Blair, 2007). In contrast to dACC, the rostral ACC (rACC) is activated only by emotional distractors (Egner et al., 2008; Etkin et al., 2006) and is especially involved in processing task-irrelevant information (Bishop, Duncan, Brett & Lawrence, 2004). Furthermore, activity in rACC is related to the resolution of emotional conflict by inhibition of activity in the amygdala (Egner et al., 2008; Etkin et al., 2006).

Consequently, cognitive control to enhance attention to task-relevant stimuli is most likely mediated by the lPFC. Although nonemotional conflict is primarily detected by the dACC, emotional conflict detection hinges heavily on the rACC. Thus, we assume that control of disturbance by task-irrelevant emotional stimuli is signaled by projections to the PFC that originate from rACC and inhibit activity in the amygdalae. A crucial question in this respect is whether such control processes could be evoked by preceding conflict (reactive) and advanced information (proactive).

Overview of the experiments

Altogether, previous studies suggest limitations to the regulation of valence-based task disturbance. Yet, it is fair to say that research on this issue is scarce and requires replication and extension. Thus, the purpose of the present study was to investigate reactive and proactive adaptation to disturbance by irrelevant valent stimulation in more detail.

Experiment 1 was concerned with reactive adaptation—that is, modulation of disturbance by valent information if a disturbing situation had been experienced briefly before. We basically aimed to (and actually did) replicate a previously observed pattern under different experimental conditions: increased disturbance if a disturbing rather than nondisturbing situation had been experienced previously (see Kunde & Mauer, 2008).

Experiments 2 and 3 were engaged in proactive adaptation by cueing subsequent emotional content of distractors in a trialwise manner. Thereby we employed different means of announcement: a 100 %-valid valence cueing in Experiment 2, and a procedure that allowed for comparing valid with invalid cueing in Experiment 3. Although we found some proactive effects, the nature of these effects was not easily reconciled with the assumption that preknowledge facilitates effective preparation for disturbance.

Finally, Experiment 4 was concerned with proactive adaptation by manipulating the list-wide probability of the emotional content of distractors. Here we found preliminary hints that encountering negative events frequently facilitates down-regulation of negative distraction.

Altogether, these findings suggest remarkable limitations to the regulation of valence-based task disturbance.

Experiment 1

Experiment 1 investigated reactive adaptation to task disturbance by valent pictures. Participants had to categorize two peripheral bars regarding their parallelism (parallel vs. differently oriented) by pressing a left or right key while additionally, negative, neutral, and positive pictures appeared in the center of the screen (see Erthal, De Oliveira, Mocaiber, Pereira, Machado-Pinheiro, Volchan & Pessoa, 2005). Note that pictures were task irrelevant and should therefore be ignored.

We expected to find interruption—that is, slower responses in the categorization task if the irrelevant picture was valent rather than neutral. More importantly, we explored reactive adaptation to such interruption: a modulation of interruption effects by irrelevant valent pictures after interruption had been experienced in the preceding trial. Kunde and Mauer (2008) reported a paradoxical adaptation effect—that is, increased interruption effects after interruption trials than after interruption-free trials. In Experiment 1, we tested the robustness of this pattern under modified conditions. Whereas in the previous study the task-irrelevant pictures were an inherent part of the task-relevant object feature (frame color), the relevant and irrelevant objects were spatially separated in the present study (see Fig. 1). This modification might favor perceptual suppression of the irrelevant valence information, because visual attention could now select distinct objects.

Method

Participants A group of 16 volunteers (14 female, two male) with a mean age of 24.1 years participated in the experiment.

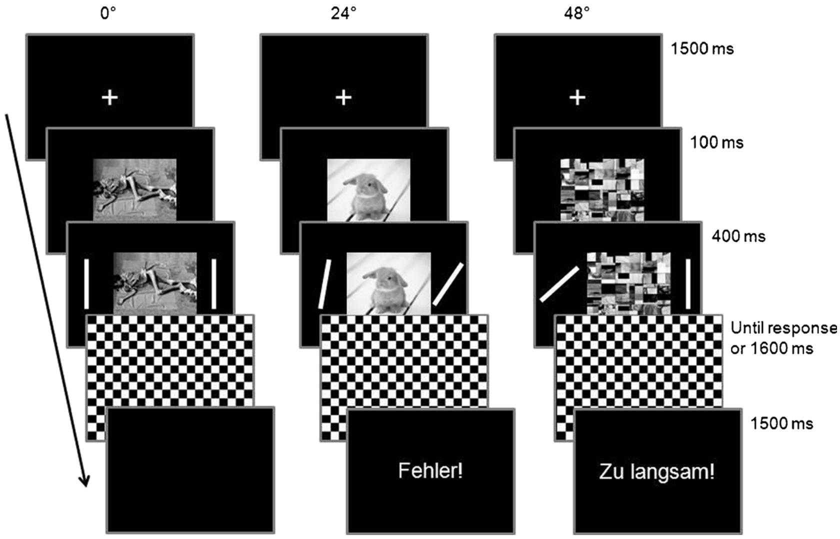

Fig. 1 Experiment 1: Participants responded to two peripheral bars regarding their parallelism (parallel vs. differently oriented) by pressing a left or right key. In the middle of the two bars appeared a negative, positive, or neutral picture that had to be ignored. The composed stimuli (picture and bars) occurred at the center of the display (+). The figure illustrates trial sequences with three possible orientation differences (0°, 24°, or 48°; note that participants only had to differentiate between parallel vs. differently oriented), the three possible picture valences (negative, positive, or neutral; note that valence was task irrelevant and had to be ignored), and the three possible feedback displays (blank=correct, *Fehler!*="Wrong!," *Zu langsam!*="Too slow!").

A session lasted approximately 1 h, for which the participants received €7.

Apparatus and materials An IBM-compatible computer with a 16 in. monitor was used for stimulus presentation. Viewing distance was not restricted but amounted to approximately 60 cm, so that 1 cm on the monitor corresponded to 0.95 deg of visual angle. Stimuli and instructions were presented in white on a black background. Participants responded by pressing the "d" or "l" key on a standard QWERTZ keyboard.

The target stimuli consisted of two peripheral bars (0.3°× 3.0°), one presented on the right and the other presented on the left hand side of a central picture (9°×11.5°). Peripheral bars were presented in white on a black background at 8.5° to the right and left of the center of the screen. They were either parallel or differently oriented, with a deviation of 24° (i.e., intermediate condition) or 48° (i.e., easy condition).

The picture set for the present experiment consisted of 30 negative, 30 positive, and 30 neutral pictures, some of them chosen from the IAPS and extended by pictures from the Internet. For the negative picture category, we chose the lowest-valence-rated IAPS pictures from the themes mutilation, burn victims, dead bodies, and dead animal bodies, and extended the set by same-theme pictures from the Internet, resulting in 65 negative pictures. For the positive category, we chose the highest-valence-rated IAPS pictures from the themes babies, family, animals, and baby animals and extended the set by same-theme pictures from the Internet, resulting in 115 positive pictures. The 65 negative, 115 positive, and an additional 45 neutral IAPS pictures went into a rating procedure. A total of 28 volunteers evaluated pleasantness and arousal each on a 9-point rating scale. The 30 highest-rated pictures on pleasantness formed our set of positive pictures, whereas the 30 lowest-rated formed the negative set. Note that the negative and positive pictures also differed in terms of arousal (mean arousal for negative pictures, 7.2; mean arousal for positive pictures, 4.9). Thus, interruption effects might originate from high valence, arousal, or a combination of both. We will refer to this issue in the General Discussion section. For our experiment, we created a set of neutral pictures by cutting each negative and positive picture into 25 pieces and recomposing it, mixing negative and positive pictures, and then again cutting all pictures into 36 pieces each, assembling all of the pieces into 60 new pictures, and finally choosing 30 of them. The pictures so created had the exact same perceptual characteristics (e.g., luminance, color) as the negative and positive pictures, but were neutral in valence. Thus, the sole difference between the pictures of different valence categories was the meaningfulness of the pictures (neutral pictures were meaningless compositions of picture pieces) and the valence itself.

Procedure and design Figure 1 illustrates the trial structure. Each trial started with the presentation of a centered fixation cross, displayed for 1,500 ms. After the cross disappeared, the task-irrelevant picture was presented on the screen center for 100 ms and was followed by a composition of the target (two peripheral bars) and distractor (the irrelevant picture) for 400 ms. Participants were asked to categorize the orientation of the bars as being either parallel or differently oriented as fast as possible while trying to avoid errors. Afterward, a checkerboard mask was presented for 1,600 ms, followed by a feedback screen for 1,500 ms, which in the case of a right response was a blank screen; in the case of a wrong response was the term *Falsch!* (i.e., "Wrong!"); and if participants failed to give their response within 2,000 ms after stimulus onset, was the term *Zu langsam!* (i.e., "Too slow!"). Responses (right and left keystrokes) were counterbalanced between participants. All of the stimuli (bars and pictures) were presented equally often in random order. First, participants had to perform 16 practice trials that served to acquaint them with the task. Therefore, 16 neutral pictures were taken from the IAPS. In total, participants had to perform 16 practice trials and 540 experimental trials, split into six blocks.

The experimental design consisted of a factorial combination of the within-subjects factors Task Difficulty (parallel=0° vs. intermediate=24° vs. easy=48°), Valence (negative vs. neutral vs. positive), and Valence in Trial $n-1$ (negative vs. neutral vs. positive). The factor Task Difficulty concerned the orientation difference between the two bars, in degrees. Valence referred to the valence of the irrelevant picture on the screen center, whereas valence in trial $n-1$ indicated the valence of the picture in the previous trial.

Results

Practice trials served to acquaint participants with the task and are therefore not included in the analyses (2.88 % of all trials).

Response times Response times (RTs) greater than 2.5 standard deviations above or below the participant's mean in the respective design cell (2.35 % of all trials) were considered outliers and excluded from further analyses, as were errors (9.91 % of all trials) and trials without responses (0.35 % of all trials). Mean individual RTs (see Table 1) were entered into a within-subjects analysis of variance (ANOVA) with the factors Valence (negative vs. neutral vs. positive) and Task Difficulty (0° vs. 24° vs. 48°). The analysis revealed pronounced main effects of both factors: valence, $F(2, 30)=15.39$ ($\varepsilon=.65$), $p<.001$, $\eta_p^2=.51$; task difficulty, $F(2, 30)=30.85$, $p<.001$, $\eta_p^2=.67$ (see Fig. 2). Responses were slower with irrelevant negative pictures (562 ms) than with positive (537 ms), $t(15)=4.32$, $p=.001$, $d=1.08$, or neutral (534 ms), $t(15)=5.11$, $p<.001$, $d=1.28$, pictures, whereas neutral and positive pictures did not differ significantly from each other, $t(15)=-1.53$, $p=.146$, $d=0.38$. Also, responses were slower with the peripheral bars differing 24° in orientation (580 ms) than when they differed by 48° (516 ms) or 0° (i.e., parallel bars, 536 ms); all pairwise comparisons were significant [all $|ts(15)| > 2.56$, $p<.022$, $d>0.64$]. The interaction between valence and task difficulty did not approach significance, $F<1$.

In a second analysis, we investigated reactive adaptation effects. Again, RTs greater than 2.5 standard deviations above or below the participant's mean in the respective design cell (2.15 % of all trials) were considered outliers and excluded from further analyses, as well as errors in the current and previous trials (19.81 % of all trials). The mean individual RTs (see Table 2) were entered into a within-subjects ANOVA with the factors Valence (negative vs. neutral vs. positive) and Valence in the Previous Trial (i.e., trial $n-1$; negative vs. neutral vs. positive). We observed a main effect of valence, $F(2, 30)=15.80$, $p<.001$, $\eta_p^2=.51$; responses were slower with irrelevant negative (553 ms) than with positive (529 ms), $t(15)=4.19$, $p=.001$, $d=1.05$, or neutral (524 ms), $t(15)=4.42$, $p<.001$, $d=1.11$, pictures, whereas neutral and positive pictures did not differ significantly from each other, $t(15)=-1.14$, $p=.274$, $d=0.28$. More importantly, a significant interaction emerged of picture valence in trial n and trial $n-1$, $F(4, 60)=4.16$, $p=.005$, $\eta_p^2=.22$ (see Fig. 3). Post hoc t tests revealed significant interruption effects by current negative pictures (i.e., the mean RT difference between current negative minus current neutral trials) for all previous valence conditions [negative in trial $n-1$, $t(15)=3.75$, $p=.002$, $d=0.94$; neutral in trial $n-1$, $t(15)=3.18$, $p=.006$, $d=0.80$; positive in trial $n-1$, $t(15)=3.47$, $p=.003$, $d=0.87$]. This negative interruption effect was by trend more pronounced after previous negative (36 ms) or positive (33 ms) trials than after previous neutral trials (16 ms), $t(15)=2.04$, $p=.059$, $d=0.51$, and $t(15)=-1.78$, $p=.096$, $d=0.44$, for the comparison of negativity-based interruption following negative versus neutral and positive versus neutral trials, respectively. Negative interruptions after negative versus positive trials did not differ

Table 1 Experiment 1: Mean response times (RTs; in milliseconds) and percentage errors (PEs) as a function of current valence and task difficulty

	Parallel (0°)		Intermediate (24°)		Easy (48°)	
Valence	RT	PE	RT	PE	RT	PE
Negative	553	12.6	599	15.9	535	5.4
Neutral	524	8.5	571	13.1	505	3.8
Positive	532	8.8	570	12.6	509	3.4

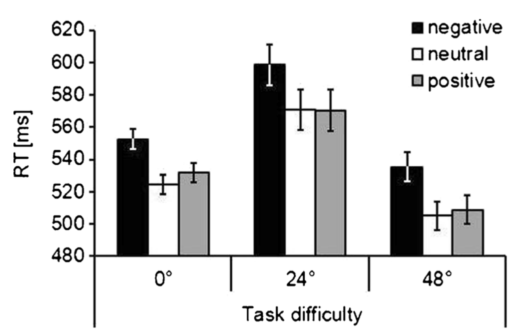

Fig. 2 Experiment 1: Response times (RTs) as a function of the valence of the irrelevant picture and the orientation difference of the target bars. Error bars represent within-subjects confidence intervals (see Loftus & Masson, 1994).

Table 2 Experiment 1: Mean response times (RTs; in milliseconds) and percentage errors (PEs) as a function of current valence and valence in trial *n* – 1

	Negative		Neutral		Positive	
Trial *n* – 1	RT	PE	RT	PE	RT	PE
Negative	553	11.6	517	8	532	8.7
Neutral	544	11.9	528	8.6	533	7.6
Positive	562	12.4	529	8.3	522	8.9

significantly, $t(15)=0.42$, $p=.678$, $d=0.11$. Furthermore, post hoc analyses revealed a significant interruption effect by current positive pictures (i.e., the mean RT difference between current positive minus current neutral trials) after previous negative stimulation [$t(15)=-2.81$, $p=.013$, $d=0.70$; difference of 15 ms], but not after neutral [$t(15)=-1.01$, $p=.329$, $d=0.25$; difference of 6 ms] or positive [$t(15)=1.15$, $p=.268$, $d=0.29$; difference of –6 ms] stimulation in trial *n* – 1.

To further investigate the specialization of reactive control processes, we conducted two separate two-by-two ANOVAs analyzing the sequential effects of negative and neutral stimulation, on the one hand, and sequential effects of positive and neutral stimulation, on the other hand. These analyses with the factors Current Valence and Valence in Trial *n* – 1 revealed significant effects only for the analysis with negative and neutral valence: a main effect of valence, $F(1, 15)=19.38$, $p=.001$, $\eta_p^2=.56$, and an interaction of current valence with valence in trial *n* – 1 by trend, $F(1, 15)=4.16$, $p=.059$, $\eta_p^2=.22$. Negative pictures delayed responding, relative to neutral pictures, to a larger extend after previous negative stimulation (36 ms) than after neutral stimulation (16 ms), $t(15)=2.04$, $p=.059$, $d=0.51$. No other effects reached significance.

Error percentages The analysis of error percentages (PEs; see Table 1) with the factors Valence and Task Difficulty revealed the same pattern of results: a main effect of valence [$F(2, 30)=6.59$, $p=.004$, $\eta_p^2=.31$], as well as a main effect of task

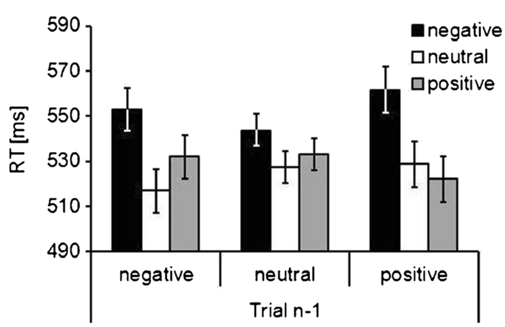

Fig. 3 Experiment 1: Response times (RTs) as a function of the valence of the distractor picture in the current trial and the valence of the irrelevant picture in the previous trial (i.e., trial *n* – 1). Error bars represent within-subjects confidence intervals (see Loftus & Masson, 1994).

difficulty [$F(2, 30)=30.54$, $p<.001$, $\eta_p^2=.67$]. Responses were more erroneous with irrelevant negative (11.3 %) than with positive (8.4 %), $t(15)=4.12$, $p=.001$, $d=1.03$, or neutral (8.3 %), $t(15)=3.00$, $p=.009$, $d=0.75$, pictures, whereas neutral and positive pictures did not differ significantly from each other, $t(15)=0.15$, $p=.883$, $d=0.04$. Also, responses were more erroneous with the peripheral bars differing 24° in orientation (13.9 %) than with those differing 48° (4.2 %) or 0° (i.e., parallel bars, 9.9 %) in orientation; all pairwise comparisons were significant [all $|ts(15)| > 2.81$, $p<.013$, $d>0.7$]. The interaction between valence and task difficulty did not approach significance, $F<1$.

A second analysis of error percentages (see Table 2) with the factors Valence and Valence in Trial *n* – 1 revealed only the main effect of valence, $F(2, 30)=12.16$, $p<.001$, $\eta_p^2=.45$. Responding was more erroneous with irrelevant negative (12.0 %) than with positive (8.4 %), $t(15)=4.12$, $p=.001$, $d=1.03$, or neutral (8.3 %), $t(15)=3.00$, $p=.009$, $d=0.75$, pictures, whereas neutral and positive pictures did not differ significantly from each other, $t(15)=0.15$, $p=.883$, $d=0.04$. No other effects reached significance. Post hoc *t* tests revealed significant negative interruption after negative [$t(15)=2.74$, $p=.015$, $d=0.68$; difference of 3.6 %] and positive [$t(15)=2.64$, $p=.019$, $d=0.66$; difference of 4.1 %] stimulation, but not after neutral stimulation [$t(15)=1.77$, $p=.097$, $d=0.44$; difference of 3.3 %]. Positive interruption never approached significance. The two separate two-by-two ANOVAs only revealed a main effect of valence in the analysis with negative and neutral valence, $F(1, 15)=8.20$, $p=.012$, $\eta_p^2=.35$. Negative pictures caused more errors (11.8 %) than did neutral pictures (8.3 %), $t(15)=2.96$, $p=.010$, $d=0.74$. No other effects reached significance.

Discussion

In Experiment 1, we investigated task disturbance by irrelevant emotional information and reactive adaptation to previously experienced task disturbance. As is typically observed, negative (high arousing) stimuli reduced performance in an unrelated task relative to neutral or positive stimuli. Furthermore, disturbance was independent of the attentional requirements of the main task (degrees of bar orientation difference). Since task difficulty revealed only a main effect and did not interact with any of the experimental factors in any of the reported experiments, we dropped this factor for subsequent analyses for the sake of simplicity.

More importantly, we found hints for a "paradoxical" effect of valence-based disturbance on subsequent disturbance; disturbance by negative distractors tended to be *larger* after trials with valent stimulation than after trials without valent stimuli (see Kunde & Mauer, 2008). It seems that processing an emotion-laden event in the environment does in no way help to overcome disturbance by subsequent emotion-laden, especially negative stimuli, but rather sensitizes the observer to process such stimuli briefly later.

To summarize, we observed variation of valence-based disturbance as a function of previous disturbance, but it was opposite what one would expect from adaptation effects to interference by stimulation that overlaps with task-relevant features (Egner et al., 2008). Whereas resolving interference facilitates resolving subsequent interference, resolving disturbance hinders resolving subsequent disturbance. We will refer to this issue in more detail in the General Discussion section.

Experiment 2

After having identified a paradoxical reactive adaption to valence-based interruption, in Experiment 2 we investigated proactive adaptation to interruption. The main task remained the same as in Experiment 1. However, now an anticipation condition was included, in which a verbal cue announced the valence of the upcoming picture 100 % validly (see Fig. 4). Performance in this condition was compared to that in a nonword condition, in which the cue was a meaningless letter string. We varied cue condition (anticipation vs. nonword) between subjects in this experiment. This was done to make the verbal cues as informative about the upcoming valence as possible. Otherwise, uninformative nonword cues would have to be presented to the same subjects, and the lack of specific information in such trials (or blocks) could discourage participants from processing cues in general (see Exp. 3 for a within-subjects manipulation of cue type). We expected to replicate the common interruption effect in the nonword condition: slower responses in the categorization task if the irrelevant picture was valent, especially negative, rather than neutral. The crucial question was whether preknowledge about the valence of the upcoming irrelevant picture in the anticipation condition would allow for any reduction of disturbance by emotion-laden pictures.

Method

Participants A group of 48 volunteers (36 female, 12 male) with a mean age of 25.5 years participated in the experiment. Half of the participants received informative word cues, whereas the other half received nonword cues. A session lasted approximately one hour, for which the participants received €7.

Apparatus and materials The apparatus and materials were the same as in the first experiment. For the condition without anticipation, 28 letter strings served as the cues. Those were created by randomly concatenating seven letters to a string, three of them vowels, and four of them consonants, starting with a consonant. Seventy so-created letter strings were rated by 22 volunteers regarding their pleasantness on a 9-point rating scale. We chose letter strings with a mean valence rating between 3.5 and 5.5, resulting in 28 nonwords.

Procedure and design Figure 4 illustrates the trial structure. Each trial started with the presentation of a centered fixation cross for 1,500 ms. After the cross disappeared, a cue was presented for 1,050 ms, announcing either the valence category of the upcoming picture (anticipation condition) or nothing at all (nonword condition). Participants were instructed to use the information of the cue in order to get prepared for the picture, and therefore to ignore it as best they could, or just to read the cue, respectively. After another centered fixation cross displayed for 1,500 ms, the task-irrelevant picture appeared alone in the screen center for 100 ms and was followed by a composition of the target (two peripheral bars) and the distractor (the irrelevant picture) for 400 ms. Participants were asked to categorize the orientation of the bars as being either parallel or differently oriented as fast as possible while trying to avoid errors. Thereafter, a checkerboard mask was presented for 1,600 ms, followed by a feedback screen for 1,500 ms, which in the case of a right response was a blank screen; in the case of a wrong response was the term *Falsch!* (i.e., “Wrong!”); and if participants failed to give a response within 2,000 ms after stimulus onset, was the term *Zu langsam!* (i.e., “Too slow!”). Responses (right and left keypresses) were counterbalanced between participants. All stimuli (bars and pictures) were presented equally often in a random order. First, participants had to perform 16 practice trials that served to acquaint them with the task. Therefore, 16 neutral pictures were taken from the IAPS. In total, participants had to perform 16 practice trials and 540 experimental trials, split into six blocks.

The experimental design consisted of a factorial combination of the between-subjects factor Condition (anticipation vs. nonword) and the within-subjects factor Valence (negative vs. neutral vs. positive). The factor Condition indicated whether participants could anticipate the valence of the upcoming picture or just read a letter string. Valence indicated the valence of the irrelevant picture on the screen center.

Results

Practice trials served to acquaint participants with the task and are therefore not included in the analyses (2.88 % of all trials). RTs greater than 2.5 standard deviations above or below the participant’s mean in the respective design cell (2.87 % of all trials) were considered outliers and excluded from further analyses, as were errors (8.56 % of all trials) and trials without responses (0.49 % of all trials).

Response times Mean individual RTs (see Table 3) were entered into a repeated measures ANOVA with the between-

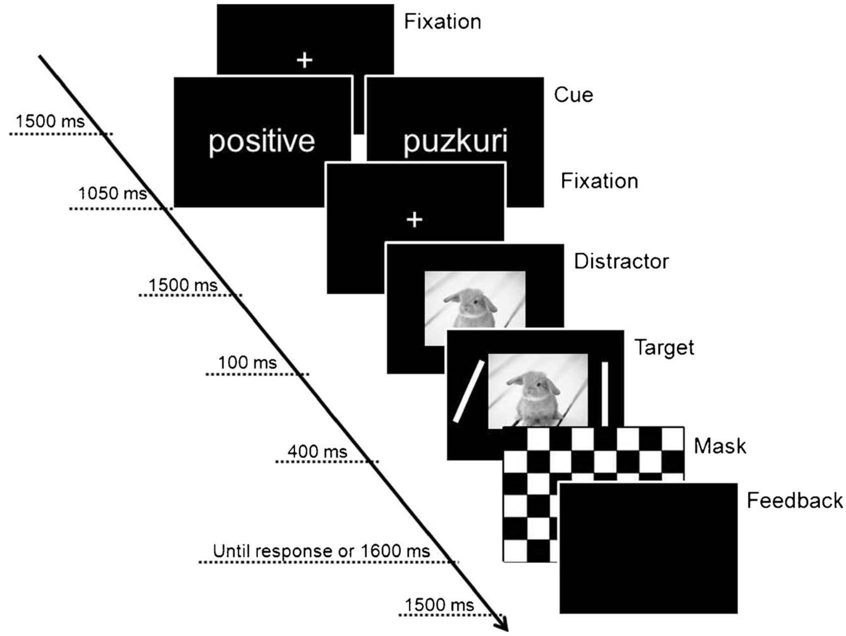

Fig. 4 Experiment 2: Participants responded to two peripheral bars regarding their parallelism (parallel vs. differently oriented) by pressing a left or right key. In the middle of the two bars appeared a negative, positive, or neutral picture that had to be ignored. The composed stimuli (picture and bars) occurred at the center of the display (+). Additionally, participants were randomly assigned to two cue conditions; in the anticipation condition, the word *negative*, *neutral*, or *positive* announced the valence of the upcoming distractor with 100 % validity, whereas participants in the nonword condition had to read a letter string that announced nothing at all.

subjects factor Condition (anticipation vs. nonword) and the within-subjects factor Valence (negative vs. neutral vs. positive). The analysis revealed a main effect of valence, $F(2, 92)=22.96$, $p<.001$, $\eta_p^2=.33$ (see Fig. 5): Responses were slower with irrelevant negative pictures (562 ms) than with positive pictures (543 ms), and both were slower than responses with neutral pictures (538 ms); all pairwise comparisons were significant [all $|ts(47)| > 2.65$, $p<.011$, $d>0.38$]. No other effects reached significance (condition: $F<1$, interaction Condition × Valence: $F<1$).

Error percentages The analysis of error percentages (see Table 3) revealed the same pattern of results, namely a main effect of valence, $F(2, 92)=15.50$, $p<.001$, $\eta_p^2=.25$. Responses were more erroneous with irrelevant negative (9.8 %) than with positive (8.0 %), $t(47)=5.85$, $p<.001$, $d=0.84$, or neutral (8.2 %), $t(47)=3.92$, $p<.001$, $d=0.57$, pictures, whereas neutral and positive pictures did not differ significantly from each other, $t(47)=-0.68$, $p=.498$, $d=0.10$. No other effects reached significance, both $Fs<1$.

Table 3 Experiment 2: Mean response times (RTs; in milliseconds) and percentage errors (PEs) as a function of condition and valence

	Negative		Neutral		Positive	
Condition	RT	PE	RT	PE	RT	PE
Anticipation	554	9.8	529	7.8	532	7.9
Nonword	569	9.8	547	8.5	555	8.1

Discussion

In Experiment 2, we investigated proactive adaptation processes by validly cueing the valence of potentially disturbing stimulation.

Basically, anticipating the upcoming valence of an irrelevant picture did not reduce its disturbing impact at all. Instead, we found slower responses with negative than with neutral pictures (and, to a lesser extent, also with positive than with neutral pictures) in both the anticipation and nonword conditions. Thus, although participants in the anticipation condition knew that something negative or positive would occur, and could therefore prepare for this interruption, valent pictures

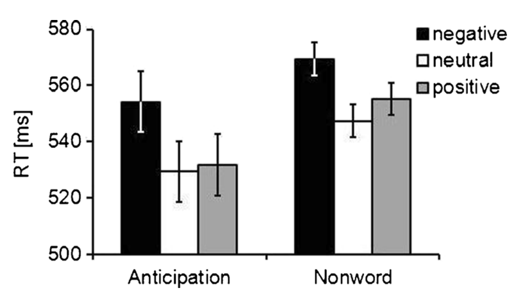

Fig. 5 Experiment 2: Response times (RTs) as a function of the cue condition and the valence of the irrelevant picture. Error bars represent within-subjects confidence intervals (see Loftus & Masson, 1994).

disturbed their performance as intensely as if the participants had seen a senseless letter string. Thus, we found no indication of proactive regulation based on trialwise cueing.

Interestingly, there was no paradoxical preparation effect, either, such that disturbance would have been larger if a negative stimulus had been announced (Kleinsorge, 2007, 2009). It should be noted, however, that negative pictures delayed responding at least numerically more strongly when they were expected (25 ms) rather than unexpected (22 ms), although the interaction was far from significant. As was suggested by Kleinsorge (2009), the paradoxical preparation effect might not be driven by expectation per se, but by an actual increase in the subjective probability that a negative stimulus will be encountered, which we did measure here. Furthermore, the between-subjects design we chose here might have lacked statistical power to detect such subtle effects. Therefore, we employed a more sensitive, within-subjects cueing procedure in Experiment 3.

Experiment 3

In Experiment 3, we investigated proactive adaptation to valence-based task disturbance by valence announcement in a within-subjects design. The main task remained the same as in Experiments 1 and 2. Again, a verbal cue, presented shortly before the target, announced the valence of the upcoming picture. However, whereas the valence announcement was correct on the majority of all trials (80 %), another, unexpected valence occurred on the remaining trials (20 %), which were equally distributed among the two remaining valences (see Fig. 6). Proactive regulation should show up as an improvement of task performance with expected (validly cued) as compared to unexpected (invalidly cued) valent stimulation. Yet, given the paradoxical reactive adaptation effect in Experiment 1 and in previous studies on valence cueing (Kleinsorge, 2007, 2009), we should be equally prepared to encounter a similar paradoxical effect here. Hence, decreases in task performance due to valent stimulation might be larger if such a valent rather than a neutral event had been announced.

Method

Participants A group of 32 volunteers (25 female, seven male) with a mean age of 26.8 years participated in the experiment. A session lasted approximately 1 h, for which the participants received €7.

Apparatus and materials The apparatus and materials were the same as in Experiment 2, but we did not use nonwords in the present experiment.

Procedure and design The trial structure was the same as in Experiment 2. Each trial started with the presentation of a centered fixation cross displayed for 1,500 ms. After the cross disappeared, a cue was presented for 1,050 ms, announcing the valence of the upcoming picture with a validity of 80 %. Figure 6 illustrates this manipulation. Participants were instructed that the cue would be invalid on 20 % of the trials, but that they should use the information of the cue to get prepared for the picture, and therefore to ignore it as best they could on most of the trials. After another centered fixation cross for 1,500 ms, the task-irrelevant picture appeared alone in the screen center for 100 ms and was followed by a composition of target (two peripheral bars) and distractor (the irrelevant picture) for 400 ms. Participants were asked to categorize the orientation of the bars as being either parallel or differently oriented as fast as possible while trying to avoid errors. Thereafter, a checkerboard mask was presented for 1,600 ms, followed by a feedback screen for 1,500 ms, which in the case of a right response was a blank screen; in the case of a wrong response was the term *Falsch!* (i.e., "Wrong!"); and if participants failed to give a response within 2,000 ms after stimulus onset, was the term *Zu langsam!* (i.e., "Too slow!"). Responses (right and left keypresses) were counterbalanced between participants. All stimuli (bars and pictures) were presented equally often in a random order. First, participants had to perform 16 practice trials that served to acquaint them with the task. Therefore, 16 neutral pictures were taken from the IAPS. In total, participants had to perform 16 practice trials and 540 experimental trials, split into six blocks.

The experimental design consisted of a factorial combination of the within-subjects factors Valence (negative vs. neutral vs. positive) and Anticipation (i.e., the valence of the cue, negative vs. neutral vs. positive).

Results

Practice trials served to acquaint the participants with the task, and are therefore not included in the analyses (2.88 % of all trials). RTs greater than 2.5 standard deviations above or below the participant's mean in the respective design cell (2.65 % of all trials) were considered outliers and excluded from further analyses, as were errors (8.13 % of all trials) and trials without responses (0.44 % of all trials).

Response times In a first analysis, we investigated whether a validly cued valence reduced interruption, as compared to an invalidly cued valence. Mean individual RTs (see Table 4) were therefore submitted to a repeated measures ANOVA with the factors Cue Validity (valid vs. invalid) and Valence (negative vs. neutral vs. positive). This analysis revealed a main effect of valence, $F(2, 62)=20.40$, $p<.001$, $\eta_p^2=.40$. Responses were slower with irrelevant negative (557 ms) than

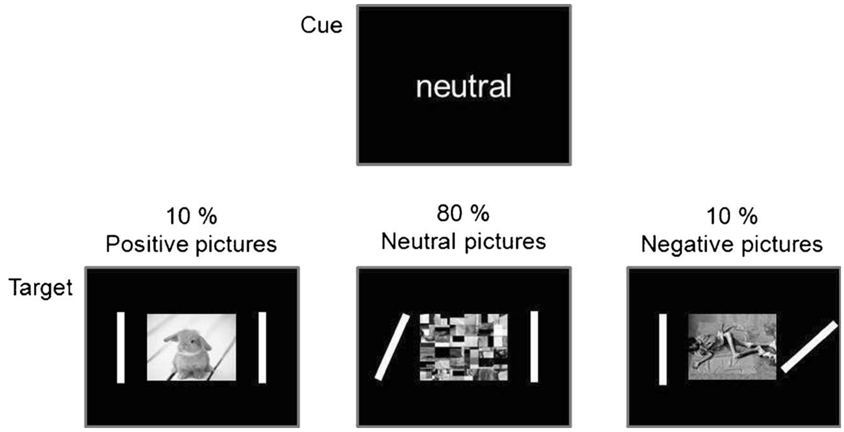

Fig. 6 Experiment 3: Participants responded to two peripheral bars regarding their parallelism (parallel vs. differently oriented) by pressing a left or right key, while in the middle of the two bars an irrelevant negative, positive, or neutral picture appeared. Additionally, a cue announced the valence of the upcoming distractor validly on 80 % of all trials. Thus, the cue *neutral* was followed by a neutral picture on 80 % of all trials, but was followed by a positive or a negative irrelevant picture on 10 % apiece of all trials.

with positive (541 ms), $t(31)=5.11$, $p<.001$, $d=0.90$, or neutral (540 ms), $t(31)=5.25$, $p<.001$, $d=0.93$, pictures, whereas neutral and positive pictures did not differ significantly from each other, $t(31)=0.85$, $p=.400$, $d=0.15$. No other effects reached significance [validity, $F<1$; Validity × Valence interaction, $F(2, 62)=1.90$, $p=.158$, $\eta_p^2=.06$].

To get more insight into the effects of cuing, we split the data into all combinations of cued and experienced valence (see Fig. 7). Mean individual RTs (see Table 5) were entered into a repeated measures ANOVA with the within-subjects factors Valence (negative vs. neutral vs. positive) and Anticipation (negative vs. neutral vs. positive). As in the main analysis, we observed an effect of valence, $F(2, 62)=17.52$, $p<.001$, $\eta_p^2=.36$: Responses were slower with irrelevant negative pictures (559 ms) than with positive (542 ms), $t(31)=5.18$, $p<.001$, $d=0.92$, or neutral (539 ms), $t(31)=5.36$, $p<.001$, $d=0.95$, pictures, whereas neutral and positive pictures did not differ significantly from each other, $t(31)=0.76$, $p=.454$, $d=0.13$. No other effects reached significance [anticipation, $F(2, 62)=2.25$, $p=.114$, $\eta_p^2=.07$; Anticipation × Valence interaction, $F(4, 124)=1.10$ ($\varepsilon=.67$), $p=.359$, $\eta_p^2=.03$].

Error percentages The analysis of error percentages (see Table 4) with the factors Cue Validity (valid vs. invalid) and Valence (negative vs. neutral vs. positive) revealed a main effect of valence, $F(2, 62)=16.55$, $p<.001$, $\eta_p^2=.35$: Responses were more erroneous with irrelevant negative (11.2 %) than with positive (7.2 %), $t(31)=3.75$, $p=.001$, $d=0.66$, or neutral (7.1 %), $t(31)=4.32$, $p<.001$, $d=0.76$, pictures, whereas neutral and positive pictures did not differ significantly from each other, $t(31)=-1.56$, $p=.129$, $d=0.28$. This valence effect was slightly more pronounced with invalid cueing (4.9 % more errors with negative than with neutral pictures) than with valid cueing (2.7 % more errors with negative than with neutral pictures), $F(2, 62)=3.63$, $p=.032$, $\eta_p^2=.11$, for the Validity × Valence interaction. No other effects reached significance (validity: $F<1$).

As with RTs, in a subsequent ANOVA we analyzed error percentages (see Table 5) as a function of cued and experienced valence (negative vs. neutral vs. positive, respectively). We found a main effect of valence, $F(2, 62)=14.92$, $p<.001$, $\eta_p^2=.33$: Responses were more erroneous with irrelevant negative (11.2%) than with positive (7.2 %), $t(31)=3.75$, $p=.001$, $d=0.66$, or neutral (7.1 %), $t(31)=4.32$, $p<.001$, $d=0.76$,

Table 4 Experiment 3: Mean response times (RTs; in milliseconds) and percentage errors (PEs) as a function of cue validity and valence

	Negative		Neutral		Positive	
Cue Validity	RT	PE	RT	PE	RT	PE
Valid	556	9.6	543	6.9	540	7.8
Invalid	557	12	537	7.1	543	6.9

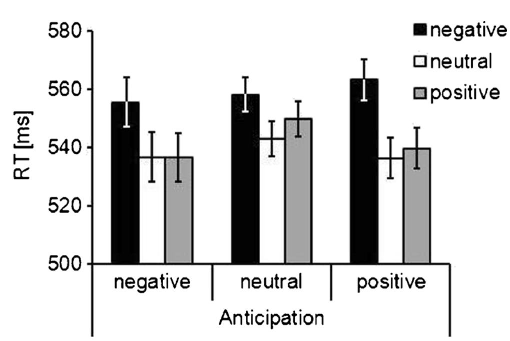

Fig. 7 Experiment 3: Response times (RTs) as a function of anticipated valence due to cueing and the actually occurring valence of the irrelevant picture. Error bars represent within-subjects confidence intervals (see Loftus & Masson, 1994).

Table 5 Experiment 3: Mean response times (RTs; in milliseconds) and percentage errors (PEs) as a function of anticipated and actual valence

	Negative		Neutral		Positive	
Anticipation	RT	PE	RT	PE	RT	PE
Negative	574	12.1	552	8.8	554	9.8
Neutral	576	14.4	564	8.4	566	7.8
Positive	590	17.4	557	6.4	558	10.1

pictures, whereas neutral and positive pictures did not differ significantly from each other, $t(31)=-1.56$, $p=.129$, $d=0.28$. No other effects reached significance [anticipation, $F(2, 62)=0.99$, $p=.379$, $\eta_p^2=.03$; Anticipation × Valence interaction, $F(4, 124)=1.02$, $p=.399$, $\eta_p^2=.03$].

Discussion

In Experiment 3, we investigated proactive adaptation processes by comparing valid with invalid valence cueing. By and large, valence cueing did not significantly moderate the interruption by subsequent emotion-laden pictures. No matter what participants anticipated and prepared for, negative stimuli prolonged RTs. It should be noted, though, that error percentages decreased when negative valence was cued validly rather than invalidly (see Table 4). However, we are reluctant to see this as strong support for valence preparation, since the effect was small, did not manifest in our primary dependent variable (RT), and vanished with a more fine-grained analysis of all combinations of cued and actually experienced valence.

Experiment 4

So far, we have not found compelling evidence for reactive regulation, nor for proactive regulation of valence-based interruption. Common to all experiments was that we accessed a mode of cognitive control that can be qualified as *transient*: moment-to-moment changes in the processing of irrelevant information, as a response to either experienced (Exp. 1) or cued (Exps. 2 and 3) valence.

Perhaps control of emotional disturbance is not possible in such a quickly changing manner, but requires a *sustained* mode of control (see Funes, Lupiáñez & Humphreys, 2010a, 2010b; Pereira et al., 2006, for the transient–sustained distinction). Such sustained changes in the processing of task-irrelevant information can be implemented by list-wide manipulations of the percentage of potentially interrupting stimuli. Logan and Zbrodoff (1979) were the first to observe that increasing the percentage of incongruent trials reduces the Stroop effect, probably due to anticipatory control processes that discourage word processing. List-wide manipulations of interfering information have since then become a standard way to manipulate sustained proactive cognitive control (Braver, 2012; Ridderinkhof, 2002).

In Experiment 4, we addressed a sustained control mode of valence-based disturbance by a list-wide manipulation of the percentages of negative, neutral, and positive distractors. Participants again categorized peripheral bars regarding their parallelism (parallel vs. differently oriented). However, they went through separate blocks in which either negative, positive, or neutral pictures were frequent (80 % of the trials), whereas the other picture categories were rare (10 % each for the other two categories). Sustained proactive control would be revealed by reduced disturbance by valent (particularly negative) distractors if valent (particularly negative) distractors were frequent.

Method

Participants A group of 36 volunteers (33 female, three male) with a mean age of 20.4 years participated in the experiment. A session lasted approximately 1 h.

Apparatus and materials The apparatus and materials were the same as in Experiment 1.

Procedure and design Each trial started with the presentation of a centered fixation cross displayed for 1,500 ms. After the cross disappeared, the task-irrelevant picture was presented in the screen center for 100 ms and was followed by a composition of the target (two peripheral bars) and distractor (the irrelevant picture) for 400 ms. Participants were asked to categorize the orientation of the bars as being either parallel or differently oriented as fast as possible while trying to avoid errors. Thereafter, a checkerboard mask was presented for 1,600 ms, followed by a feedback screen for 1,500 ms, which in the case of a right response was a blank screen; in the case of a wrong response was the term *Falsch!* (i.e., "Wrong!"); and if participants failed to give their response within 2,000 ms after stimulus onset, was the term *Zu langsam!* (i.e., "Too slow!"). Responses (right and left keypresses) were counterbalanced between participants. All stimuli (bars and pictures) were presented equally often in a random order. Valence percentage was thereby manipulated in a blocked fashion, resulting in frequently negative blocks (i.e., negative pictures in 80 %, neutral pictures in 10 %, and positive pictures in 10 % of the trials), frequently positive blocks, and frequently neutral blocks. First, participants had to perform 16 practice trials that served to acquaint them with the task. Therefore, 16 neutral pictures were taken from the IAPS. In total, participants had to perform 16 practice trials and 540 experimental trials, split into six blocks.

The experimental design consisted of a factorial combination of the within-subjects factors List-Wide Valence Percentage (negative block vs. neutral block vs. positive block) and Valence (negative vs. neutral vs. positive). The factor List-Wide Valence Percentage concerned which valence was presented on 80 % of the trials. Valence referred to the valence of the picture in the screen center.

Results

Practice trials served to acquaint participants with the task and were therefore not included in the analyses. RTs greater than 2.5 standard deviations above or below the participant's mean in the respective design cell (2.14 % of all trials) were considered outliers and excluded from further analyses, as were errors (11.02 % of all trials) and trials without responses (0.54 % of all trials).

Response times Mean individual RTs (see Table 6) were entered into a repeated measures ANOVA with the factors List-Wide Valence Percentage (negative block vs. neutral block vs. positive block) and Valence (negative vs. neutral vs. positive). This analysis revealed a pronounced main effect of valence, $F(2, 70)=13.50$ ($\varepsilon=.65$), $p<.001$, $\eta_p^2=.28$: Responses were slower with irrelevant negative (548 ms) than with positive (527 ms), $t(35)=4.56$, $p<.001$, $d=0.76$, or neutral (525 ms), $t(35)=5.73$, $p<.001$, $d=0.96$, pictures, whereas neutral and positive pictures did not differ significantly from each other, $t(35)=-1.32$, $p=.195$, $d=0.22$. Additionally, the interaction of list-wide valence percentage and valence reached significance, $F(4, 140)=4.26$ ($\varepsilon=.74$), $p=.007$, $\eta_p^2=.11$ (see Fig. 8). Negative interruption was more pronounced in frequently neutral blocks (37 ms) than in frequently negative blocks (24 ms), $t(35)=-4.23$, $p<.001$, $d=0.71$. Frequently positive blocks (24 ms) did not differ significantly from negative [$t(35)=-1.56$, $p=.129$, $d=0.26$] or neutral [$t(35)=1.22$, $p=.230$, $d=0.20$] blocks. Positive interruption was pronounced only in frequently neutral blocks (15 ms) but was reversed in frequently negative blocks (–1 ms) [$t(35)=-2.07$, $p=.046$, $d=0.35$, for the comparison of frequently neutral vs. negative blocks] and frequently positive blocks (–8 ms) [$t(35)=3.67$, $p=.001$, $d=0.61$, for the comparison of frequently neutral vs. positive blocks], whereas frequently negative and positive blocks did not differ significantly, $t(35)=0.94$, $p=.353$, $d=0.16$.

One problem with the list-wide manipulation of valence percentage is that it implies a manipulation of trials that *follow* the high-percentage valence. For example, in blocks with frequent negative stimuli, the percentage of trials following such negative stimuli is also high, whereby additional reactive control processes might be invoked. To rule out reactive influences, at least from the immediately preceding trials, we excluded from the analysis all trials in which valence repeated from trial to trial (65.5 % of all trials). Mean individual RTs were then entered into a repeated measures ANOVA with the factors List-Wide Valence Percentage (negative block vs. neutral block vs. positive block) and Valence (negative vs. neutral vs. positive). This analysis fully replicated the analysis of the unselected data. It revealed a main effect of valence, $F(2, 70)=5.68$ ($\varepsilon=.75$), $p=.011$, $\eta_p^2=.14$: Responses were slower with irrelevant negative (547 ms) than with positive (531 ms), $t(35)=3.03$, $p=.005$, $d=0.51$, or neutral (531 ms), $t(35)=2.83$, $p=.008$, $d=0.47$, pictures, whereas neutral and positive pictures did not differ significantly from each other, $t(35)=-0.22$, $p=.826$, $d=0.04$. Additionally, the interaction of list-wide valence percentage and valence reached significance, $F(4, 140)=3.27$ ($\varepsilon=.75$), $p=.024$, $\eta_p^2=.09$. Negative interruption was more pronounced in frequently neutral blocks (26 ms) than in frequently negative blocks (–0.2 ms), $t(35)=-3.56$, $p=.001$, $d=0.59$, and more pronounced in positive blocks (23 ms) than in negative blocks, $t(35)=-2.03$, $p=.050$, $d=0.34$, whereas positive and neutral blocks did not differ significantly, $t(35)=0.28$, $p=.779$, $d=0.05$. Positive interruption was more pronounced by trend in frequently neutral blocks (8 ms) than in frequently positive blocks (–6 ms), $t(35)=2.01$, $p=.053$, $d=0.33$. Neither frequently negative blocks (–2 ms) as compared to frequently neutral blocks, $t(35)=-1.18$, $p=.247$, $d=0.20$, nor the comparison of frequently negative with positive blocks, $t(35)=0.43$, $p=.671$, $d=0.07$, approached significance. No other effects reached significance, Fs<1.

Table 6 Experiment 4: Mean response times (RTs; in milliseconds) and percentage errors (PEs) as a function of frequency and valence

	Negative		Neutral		Positive	
Frequency	RT	PE	RT	PE	RT	PE
Negative	542	12.1	535	10.1	534	10.3
Neutral	551	14.4	514	9.7	528	11.5
Positive	550	14.3	526	9.7	519	10.6

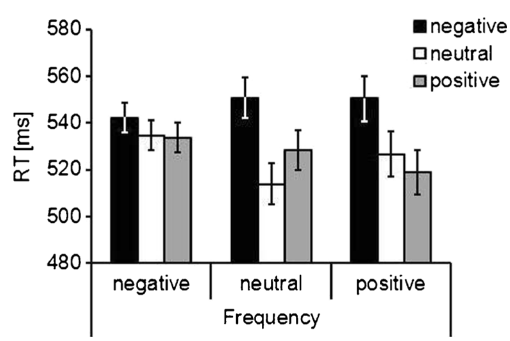

Fig. 8 Experiment 4: Response times (RTs) as a function of list-wide valence percentage—that is, the valence that occurs frequently in this block—and the valence of the current distractor. Error bars represent within-subjects confidence intervals (see Loftus & Masson, 1994).

Error percentages The analysis of error percentages (see Table 6) with the factors List-Wide Valence Percentage and Valence only revealed a main effect of valence, $F(2, 70)=7.98$, $p=.001$, $\eta_p^2=.19$: Responses were more erroneous with irrelevant negative (13.6 %) than with positive (10.8 %), $t(35)=3.04$, $p=.004$, $d=0.51$, or neutral (9.9 %), $t(35)=3.93$, $p<.001$, $d=0.65$, pictures, whereas neutral and positive pictures did not differ significantly from each other, $t(35)=-1.45$, $p=.156$, $d=0.24$. No other effects reached significance, both Fs<1.

The within-subjects ANOVA with valence repetition trials excluded revealed a main effect of valence, $F(2, 70)=5.36$, $p=.007$, $\eta_p^2=.13$: Responses were more erroneous with irrelevant negative (13.8 %) than with positive (11.1 %), $t(35)=2.47$, $p=.019$, $d=0.41$, or neutral (10.1 %), $t(35)=2.71$, $p=.010$, $d=0.45$, pictures, whereas neutral and positive pictures did not differ significantly from each other, $t(35)=-0.82$, $p=.420$, $d=0.14$. No other effects reached significance, both Fs<1. Again, negative interruption was pronounced in frequently neutral (4.4 %) and positive (4.4 %) blocks, but was half the size in frequently negative blocks (2.2 %); none of the pairwise comparisons approached significance [all $|t\text{s}(35)| < 1.18$, $p>.245$, $d<0.20$]. Positive interruption was equally pronounced in frequently negative (0.2 %), neutral (1.4 %), and positive (1.3 %) blocks; none of the pairwise comparisons approached significance [all $|t\text{s}(35)| < 0.54$, $p>.595$, $d<0.09$].

Discussion

In Experiment 4, we investigated sustained proactive adaptation to distracting emotional pictures by a valence percentage manipulation. Increasing the percentage of negative pictures reduced the performance drop with negative as compared to neutral pictures. This might be the first evidence for a regulation of valence-based disturbance in a sustained manner; perhaps the cognitive system is able to get prepared for negative distraction if such distraction occurs frequently. However, on closer look, the data pattern is not unequivocally in accordance with such regulation. Figure 8 illustrates the reduction of the RT difference between negative and neutral trials (i.e., the indicator of disturbance in this sort of task) with frequently occurring negative pictures. This decrease is, however, not primarily driven by a reduction of RTs with negative pictures in that condition, but rather by an *increase* of RTs with neutral pictures, relative to conditions with frequently occurring neutral or positive stimuli. In fact, comparing RTs with negative pictures between the different blocks of valence percentages does not deliver a significant effect, $F(2, 70)=0.54$ ($\varepsilon=.85$), $p=.559$, $\eta_p^2=.02$. Thus, RTs with negative pictures were not affected by valence percentage. On the contrary, RTs with neutral stimuli were instead affected by valence percentage, $F(2, 70)=5.91$ ($\varepsilon=.82$), $p=.007$, $\eta_p^2=.14$. RTs with neutral stimuli were accelerated if neutral stimuli were probable (514 ms) rather than improbable (frequently negative, 535 ms; frequently positive blocks, 526 ms). Thus, participants manage to block out neutral pictures if they occur frequently, whereas performance changes little with the frequency manipulation of negative stimuli.

With list-wide percentage manipulations, proactive and reactive control processes are not fully separated. However, we aimed to reduce the impact of reactive control by excluding valence repetitions. In blocks in which a valence is frequent, successions of that particular valence are frequent as well. Without valence repetitions, the performance drop with negative as compared to neutral pictures even disappeared when the percentage of negative pictures increased. This supports the assumption of proactive regulation of valence-based disturbance that is rather independent from reactive regulatory processes. It might also be worth noting that the assumption of a negative context effect (general increase of RTs during negative blocks) is not strongly supported by the data. For example, the comparison of positive trials in blocks of either frequently negative or frequently neutral valence (in which positive trials were equally frequent) reveals no significant difference, $t(35)=0.75$, $p=.457$, $d=0.13$. The same applies to comparing the equiprobable neutral trials in frequently negative and frequently positive blocks, $t(35)=1.14$, $p=.261$, $d=0.19$.

In Experiment 4, we used a list-wide valence percentage manipulation. Recently, this particular method has been criticized, since it implies another confound. Typically assumed, modified interference effects in a list-wide percentage congruency manipulation are due to strategically adjusted information processing. For example, in a mostly incongruent context, participants focus more on relevant information while shielding themselves from irrelevant information, whereas in a mostly congruent context irrelevant stimuli are also processed, since they most often reveal the correct response. However, such congruency conditions are confounded with contingencies. In the congruent context, an irrelevant stimulus occurs frequently with its congruent relevant stimulus. Thus, contingencies between irrelevant information and correct responses are established that are (implicitly) learned by the participants. Previous studies have suggested a stronger influence of learned contingencies on modified interference effects (Bugg, Jacoby & Toth, 2008; Schmidt & Besner, 2008). However, in our experiment a list-wide percentage manipulation did not alter the contingencies. For example, in frequently negative blocks, neither negative nor positive nor neutral pictures predicted the correct response more probably, since parallel and differently oriented bars occurred equally often with all three valence conditions. Thus, we provide evidence here that modified interference effects in list-wide percentage settings do not exclusively rely upon learned contingencies.

General discussion

The present study explored possibilities and limitations of shielding from disturbance by irrelevant valent stimulation. One conceivable way of control would be reactive adaptation in response to previously experienced disturbance. The other way would be proactive adaptation, that is, preparation for a foreseeable disturbance. In Experiment 1 we investigated reactive adaptation processes, and in Experiments 2, 3, and 4 we explored proactive adaptation.

In Experiment 1, we qualitatively replicated a previously observed paradoxical reactive adaptation pattern; negative irrelevant pictures disturbed performance more intensely if an emotional picture had been experienced in the previous trial, as compared to a previous neutral picture. This data pattern does not fit with the assumption that processes needed to overcome task disturbance in one trial are transferred to a following encounter of task disturbance in the next trial (e.g., Scherbaum, Fischer, Dshemuchadse & Goschke, 2011). If this were the case, a trial with disturbance (e.g., with negative valence) should *reduce* disturbance by negative stimuli in a subsequent trial. The observed data pattern was more in line with the assumption of sensitization for valence information after such valence information had occurred in the environment. Stated conversely, if there had been nothing particularly important (i.e., a neutral situation) in the environment previously, the disturbing impact of emotional pictures decreases (Kunde & Mauer, 2008). This is quite surprising, given the finding of reduced valence-based interference (on the basis of a nonmatch between overlapping relevant and irrelevant aspects of the task) if such interference had been experienced previously (e.g., Egner et al., 2008; Etkin et al., 2006). At the present stage, we can only speculate about this discrepancy. Overall, observations seem to suggest that cognitive control serving the regulation of conflict is restricted to a modulation of task-relevant processing pathways. Therefore, cognitive control is able to reduce interference but not interruption effects. Modulations of disturbance, in contrast, seem to be confined to rather basal processes of sensitization and habituation that occur outside the realm of pathways involved in task-relevant processing.

Although we found little indication for strategic reactive adaptation to valence-based disturbance, there were few hints for proactive adaptation, either. Validly announcing the emotional content of an upcoming distractor did not decrease the disturbing impact of such distractors (Exp. 2). In a more sensitive within-subjects cueing design (Exp. 3) the announcement of emotional content again did not consistently decrease disturbance by negative stimuli. Thus, subjects were not able to strategically prepare for subsequent emotional disturbance. We did not find compelling evidence for a regulation of valence-based disturbance if such adaptations were required in a transient (i.e., trialwise) manner.

Experiment 4, however, revealed some hints for sustained proactive control, that is, in a blockwise manner. Disturbance by negative pictures (relative to neutral distractors) was reduced if negative stimulation was experienced very often. Yet, again the data pattern is not completely in accordance with this conclusion. Performance with negative distractors was quite unaffected by the percentage of negative events, whereas performance with neutral distractors was substantially affected by the percentage of neutral trials. This speaks more for control of disturbance by neutral rather than by negative distraction. However, a criticism of list-wide percentage manipulations is that it could reflect expectancy of probable events, aftereffects of having experienced such events, or both. A possible aftereffect of frequent encounters of negative stimuli might be habituation. Events, such as loud tones, typically lose their attention-grabbing potential with repeated presentation (Sokolov, 1965). Such habituation might occur with repeated presentation of valence information, as well.

All of our experiments revealed a disturbing impact of negative information on task performance. According to traditional stage models of information processing, three different processing stages are conceivable at which this disturbance could occur, a perceptual, central, and motor-related stage (e.g., Pashler, 1994). First, negative stimuli could prolong the perceptual processing of actually relevant information. Thus, it might take longer to encode relevant information, when disturbing irrelevant negative information is present, perhaps because that negative information captures visual attention. Evidence supports the view of the attention-grabbing power of emotional stimuli (e.g., Contreras, Megías, Maldonado, Cándido & Catena, 2013; Huang, Baddeley & Young, 2008; Okon-Singer, Tzelgov & Henik, 2007), and especially of negative stimuli (e.g., Öhman, Flykt & Esteves, 2001; Pratto & John, 1991; Van Dillen & Koole, 2009).

Second, negative stimuli could disturb information processing on a central, capacity-limited stage. In theory this stage is concerned with decision making and response selection based on input available from the preceding perceptual stage. Performance interruption by negative information seems to be dependent on central capacity since it does not occur under high working memory load when resources are scarce (see Erthal et al., 2005; Okon-Singer et al., 2007; Pessoa, Padmala & Morland, 2005; Van Dillen & Koole, 2009). Pessoa and his colleagues suggest that interruption effects are due to an emotional control system that stands in a suppressive relationship to a cognitive-control system, in such a way that when one system is active, the other one is suppressed. In line with this assumption, Melcher et al. (2011) found reduced activity in the amygdala and rACC, which are associated with emotional processing during higher-order cognitive processes and reduced activation in dlPFC and dACC, which are related to cognitive control during emotional states.

Finally, negative stimuli could affect subjects' performance on a post-central, motor stage by causing a temporary freezing of all motor functions (Öhman et al., 2001) or delaying responses via key presses since they constitute an approach rather than an avoidance behavior (Chajut, Mama, Levy & Algom, 2010). A recent study in our laboratory (Janczyk, Augst, & Kunde, 2013) that aimed to distinguish between these accounts found an impact of negative stimuli on the central stage. Valent, especially negative stimulation claims resources for its prioritized processing and thereby delays central processing of the main task since such processing is capacity-limited.

By and large, the present study suggests more constraints to, than potentials for control of valence-based task disturbance. This is remarkable, since evidence for the intentional shielding from disturbance by nonvalent singletons has been obtained recently (Munneke et al., 2008). Given the procedure differences, it is not easy to attribute these differences to the valent versus nonvalent nature of distraction. Knowing where a distractor is going to appear as in the experiments by Munneke et al. (2008) might be more helpful since a physical feature like location is more easily spared from attention, than a nonphysical feature like valence. In accordance with this assumption, Reeck, LaBar and Egner (2012) found that the negative impact of emotional stimuli disappeared when attention was cued away from the location of the distractor. Orienting attention away from the location of picture presentation in our experiments was very hard anyway, since the bars on both sides of the picture had to be attended for task processing. Future research should contrast the control of valent versus nonvalent distraction more directly and in the same task.

The finding of restricted control of negative distraction is not contradictory to findings in the field of emotion regulation (e.g., Gross, 1998, 2002; Gross & Thompson, 2007). The cognitive system is in fact able to regulate emotions if this is necessary. However, contrary to studies in the field of emotion regulation, we did not study the extent of emotional experience, but rather how emotion-laden stimulation affects cognitive functions.

Perhaps the best advice derived from the present study for someone willing to overcome emotion-based task disturbance is the following. If you have a chance to familiarize with negativity-based disruption, do so. Experiment 4 suggests that exposing oneself frequently to such negative disruption helps to reduce its negative impact. If you have no chance to familiarize with negativity-based disruption, but must prepare for it instantaneously, better to avoid the experience or expectation of negative stimulation. The latter advice originates from the theory of ironic processes of mental control (Wegner, 1994), which suggests that two processes are working while trying to ignore stimuli in the environment: an operating process that establishes the anticipated state and a monitoring process that checks whether the operating process is needed. Thus, the monitoring process searches for hints that the distracting picture is not ignored yet, while the operating process tries to ignore it. Since the monitoring process requires less effort, it can still work while cognitive load is high—for example, due to an additional task (judging the parallelism of two bars)—and thereby activate the distracting picture. Similarly, Gollwitzer (1999) describes the intense impact of implementation intentions on effective action initializing. Implementation intentions are short orders that contain the when, where, and how of an action (e.g., "if it is Monday, I will go to the aerobic class at the gym"). However, negations (like "do not attend to distracting pictures") do not constitute effective implementation intentions. Viewed from that angle, it is not surprising that participants failed to reduce emotion-based disturbance if they formed a negation strategy to not attend to the pictures. Perhaps, a positive implementation intention, such as, "if a negative picture is announced, I will particularly focus on the orientation of the two bars" might fare better.

A weakness of the present study is that we did not control for arousal in the manipulation of valence. Hence, the disturbing impact of the negative pictures could have been due to high arousal, to the negative affective value, or to a composition of both. However, emotional stimuli typically come along with a higher arousal in the natural environment. Furthermore, studies that have controlled for arousal have still demonstrated a disturbing impact of negative stimulation (e.g., Kleinsorge, 2007, 2009).

Taken together, the present study has revealed several limitations to the control of emotional disturbance. Experiencing or expecting an emotion-laden, but task-irrelevant stimulation does not consistently reduce distraction by that stimulation. However, future research should further investigate the peculiarities of disturbance by emotion-laden as compared to emotionally neutral stimulation.

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