

Adaptation to (non)valent task disturbance

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Abstract The cognitive system adapts to disturbances caused by task-irrelevant information. For example, interference due to irrelevant spatial stimulation (e.g., the spatial Simon effect) typically diminishes right after a spatially incongruent event. These adaptation effects reflect processes that help to overcome the impact of task-irrelevant information. Interference with (or interruption of) task processing can also result from valent (i.e., positive or negative) stimuli, such as in the “affective Simon” task. In the present study, we tested whether the resolution of valence-based task disturbances generalizes to the resolution of other cognitive (spatial) types of interference, and vice versa. Experiments 1 and 2 explored the interplay of adaptation effects triggered by spatial and affective interference. Incongruent spatial information modified the spatial Simon effect but not affective interference effects, whereas incongruent affective information modified affective interference effects to some extent, but not spatial Simon effects. In Experiment 3, we investigated the interplay of adaptation effects triggered by spatial interference and by the interruption of task processing from valent information that did not overlap with the main task (“emotional Stroop” effect). Again we observed domain-specific adaptation for the spatial Simon effect but found no evidence for cross-domain modulations. We assume that the processes used to resolve task disturbance from irrelevant affective and spatial information operate in largely independent manners.

Keywords Cognitive control · Affective processing · Conflict resolution

Whenever we act, some stimuli are relevant for reaching a current goal and deserve attention, while other stimuli are irrelevant and should be ignored. For example, when typing a text, the computer display and the keyboard are relevant and deserve attention, while the telephone that might invite one to make a call to a daughter, or perhaps the door of the office inviting one to go home, are best ignored. Although this works quite well, in the office as well as outside, experimental psychology has shown many times that information processing in general is not entirely shielded against task-irrelevant information. This becomes apparent when the task-irrelevant information is in conflict with relevant stimulus information or with required responses. For example, in the Stroop task (Stroop, 1935) the task-relevant color of a word can be at conflict with the task-irrelevant meaning of that word, or in the Simon task (Simon, 1969) the task-irrelevant stimulus location can be in conflict with the required response. Typically, response times and error rates increase when such incongruency occurs—thus, a congruency effect takes place.

Situations in which irrelevant information had tended to disturb task performance in the recent past are important for the organism, and there has been growing interest in the processes prompted by such disturbances (see, e.g., Botvinick, Braver, Barch, Carter, & Cohen, 2001, and Egner, 2008, for reviews). Such situations may, among other things, alert the actor to focus more strongly on relevant aspects of the environment (Egner & Hirsch, 2005). At the empirical level, such troublesome task episodes leave traces in behavior. Most notably, when irrelevant information has interfered with task processing—such that, for example, when the irrelevant meaning of the color word in a Stroop task is different from its physical color—response times increase (Verguts, Notebaert, Kunde, & Wühr, 2011) and congruency effects

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diminish in the next encounter with such a stimulus (e.g., Gratton, Coles, & Donchin, 1992; Kerns et al., 2004). Apparently, encountering interference prompts strategies to more efficiently overcome the impact of irrelevant information, such that the costs of incongruent information, as well as the benefits of congruent information, decrease. Although alternative explanations of such adaptation effects have been proposed (Hommel, Proctor, & Vu, 2004), studies have clearly pointed to a substantial contribution of control-related processes to these effects (Egner, 2007).

In the present study, we explored whether disturbances by valent and nonvalent irrelevant stimulation prompt common or distinct adaptation processes. We will first describe different types of valence-based disturbances, and then we explain how the existence of common adaptation processes can be studied. The basic question is whether a disturbance of one kind (e.g., valence-based interference) modifies the impact of subsequent irrelevant information from another domain (e.g., spatial interference). Finally, we present three experiments that followed this experimental approach.

Valence-based interruption and interference

The types of information that disturb processing in the original Stroop task (a color word) or the original Simon task (stimulus location) can be said to be *nonvalent*. Sometimes, however, information disturbs processing because it is valence-laden—that is, either positive or negative—and it has been argued that this sort of disturbance is particularly effective (LeDoux, 2000; Öhman & Mineka, 2001). For example, in the so-called emotional Stroop task, participants respond to a certain nonvalent stimulus feature, such as the color of a picture frame (Kunde & Mauer, 2008). Typically, responding is delayed when the valence of the irrelevant picture is either positive (e.g., a flower) or negative (e.g., a wounded victim), as compared to being neutral (e.g., a chair; see William, Mathews, & MacLeod, 1996, for a review).

In another version of the task, participants have to judge whether a face expresses a positive or negative emotion while positive and negative words are superimposed on it. Typically, responding is delayed when the irrelevant valence of the word is incongruent with the task-relevant emotional expression, such that, for instance, the word “happy” is projected on the background of a fearful face (e.g., Egner, Etkin, Gale, & Hirsch, 2008; Etkin, Egner, Peraza, Kandel, & Hirsch, 2006).

Although superficially similar, these forms of valence-based processing disturbances differ structurally. In the first version of the “emotional Stroop task,” valence is not part of the primary task (judging color). Thus, the valence of the irrelevant stimuli affects task processing without overlap with valence in the relevant task. This form of disturbance

can be characterized as *interruption*. In the second version of the emotional Stroop task, however, the irrelevant valence does overlap with task-relevant features of the task (facial expressions), and thus the valence of the irrelevant features competes with the processing of (e.g., with encoding of or response to) the valence of relevant features when the two mismatch. This form of disturbance can be characterized as *interference*.¹

Interestingly, valence-based interruption and interference both appear to prompt subsequent processing adaptations, though apparently of different kinds. For example, Kunde and Mauer (2008) studied adaptations to valence-based interruption. They observed that interruption effects increased when the preceding trial contained valent information, relative to when it did not. This observation suggests that the irrelevant stimulus valence increases the impact of subsequent valent information. Egner et al. (2008) studied adaptation to valence-based interference in a word–picture interference task. However, they observed that valence-based interference effects were smaller after incongruent than after congruent trials, which suggests that valence-based incongruency reduces the impact of the subsequent, task-irrelevant valence. These observations make clear that valence-based interruption and interference effects not only differ at a conceptual level but may prompt different adaptation processes. These effects therefore should be distinguished, conceptually and empirically. In any case, it is fair to say that studies on adaptation to valence-based interruption and interference are still few and require extension.

Domain-specific and domain-general adaptation effects

Scientific explanations must be as parsimonious as possible. The most parsimonious model of adaptation effects is that adaptations to all kinds of task disturbances, be they based on valent or nonvalent information, are mediated by a common adaptation mechanism. This is certainly a theoretically possible option. Consider, for example, that one consequence of task disturbance is a stronger focus on subsequent task-relevant information. If the task-relevant information remains the same across the experiment, a stronger focus on relevant information would then show up in subsequent performance after whatever task disturbance was invoked. To the best of our knowledge, this possibility has not been systematically investigated.

To explore whether adaptation to one type of interference generalizes to other types, a combination of different types

¹ Having said this, it is clear that the first version of the “emotional Stroop” task is different from the original Stroop task because it lacks the crucial aspect of an overlap between irrelevant and relevant task dimensions (cf. Algom et al. 2004).

of interference is obviously needed. There are different ways to achieve such combinations, with either a “factorial task-crossing design” or a “task-switching design” (Egner, 2008). With a factorial task-crossing design, one creates an experiment such that in each individual trial two forms of interference/interruption can occur. Then one tests whether these effects are statistically independent and, more importantly, whether interference of one type impacts interference of the other type in a subsequent trial. Modulations across different types of interference would indicate reliance on a common adaptation process, whereas interference-type-specific effects would indicate independently operating adaptation processes.

To illustrate this approach, consider a study by Kunde and Wühr (2006). Participants responded to the direction (left or right) of a target arrow by pressing a left or right response button. The target arrow was preceded by a prime arrow that pointed in the same or in another direction. Consequently, the prime and target were either congruent or incongruent, and this caused a substantial prime–target congruency effect in performance. On top of that, the target arrows were presented in either a left or right position on the display. Consequently, the location of the stimuli and the position of the required response did or did not match, and this caused a substantial spatial Simon effect. First of all, interference-specific adaptation effects were found. Thus, an incongruent prime in the preceding trial reduced the prime–target congruency effect in the current trial, and an incongruent stimulus position reduced the spatial Simon effect in the current trial. More importantly, Kunde and Wühr also found interference-general adaptation effects: An incongruent stimulus position in the preceding trial reduced the prime–target congruency effect in the current trial, and an incongruent prime–target pair in the preceding trial tended to reduce the Simon effect in the current trial. We used such a factorial-crossing design in Experiments 1 and 3 of the present study by combining different forms of valence-based task disturbance with different forms of spatial interference.

Another way of combining two types of interference is the task-switching design. With this design, there are also two types of interference, but each individual trial uses only one type of interference, which either repeats or changes on the next trial. Adaptation effects that generalized across different types of nonaffective interference have already been obtained with this approach, so we employed it in Experiment 2 (cf. Cho, Orr, Cohen, & Carter, 2009; Freitas, Bahar, Yang, & Banai, 2007; Notebaert & Verguts, 2008).

The crucial question in all of our experiments was whether valence-based disturbances have an impact on subsequent spatial interference effects, or conversely, whether spatial interference has an impact on subsequent valence-based disturbance effects. On the basis of the available evidence,

it is hard to predict whether spatial and valence-based adaptation effects would be domain-specific or domain-general. On the one hand, some arguments favor the domain-specific position. First, Egner et al. (2008) observed that conflict due to both emotional and nonemotional distracting information was linked to activity in dorsal anterior cingulate cortex (ACC). However, subsequent adaptation effects were linked to activity in different brain areas—namely, lateral prefrontal cortex (PFC) for resolving non-emotional conflict, and rostral ACC for resolving emotional conflict. The authors argued that a common conflict-monitoring process is associated with dorsal ACC, but that domain-specific conflict resolution processes also play a role. Importantly, however, this study used a design with emotional and nonemotional distractors blocked rather than a trial-wise manipulation of type of interference, which would be needed to unambiguously demonstrate common adaptation processes. The same argument applies to a study by Ochsner, Hughes, Robertson, Cooper, and Gabrieli (2009), who revealed different brain activity due to valent (rostral ACC and medial PFC) and nonvalent (left ventrolateral PFC) interference but did not explore conflict adaptation effects at all. A related observation that may speak in favor of domain-specific processes is the different potentials of valent and nonvalent distractors for disturbing information processing: Valent but not nonvalent distractors interfere with task processing when they are task-irrelevant, indicating “affective privilege” (Reeck & Egner, 2011).

On the other hand, some arguments have favored domain-general adaptation effects. First, adaptation effects bridge different types of interference when they are both of the nonvalent kind (Cho et al., 2009; Freitas et al., 2007; Kunde & Wühr, 2006; Notebaert & Verguts, 2008), although this does not occur in every instance (Funes, Lupiáñez, & Humphreys 2010; Kunde & Stöcker, 2002; Notebaert & Verguts, 2008). Some conditions seem to be favorable for obtaining such general adaptation. One precondition is that the relevant stimulus feature should remain the same for both sorts of interference (Notebaert & Verguts, 2008). For example, in Kunde and Wühr’s study, participants in each trial responded to the direction of target arrows, and interference caused by the irrelevant stimulus position reduced subsequent interference by prime identity (and, to some extent, also vice versa). By contrast, in a study by Kiesel, Kunde, and Hoffmann (2006), participants performed different tasks (responding to either the magnitude or parity of digits), and no general conflict adaptation effects occurred. As another precondition for general adaptation effects, the “source” of the interference effects should remain the same (Egner, 2008). “Source” here means whether the irrelevant stimulus features affected task processing at the level of stimulus processing (S–S interference) or of response preparation (S–R interference). In an incongruent

trial of a Stroop task (with manual responses), S–S interference occurs because the irrelevant meaning of the word does not match the relevant physical color of the word, whereas there is no overlap of the word meaning with the response (e.g., a left or right keypress). In contrast, in an incongruent trial of a spatial Simon task, S–R interference occurs because the irrelevant stimulus location does not match the location of the required response, whereas there is no overlap with the relevant stimulus feature (e.g., color). In Kunde and Wühr’s study, both the direction of the task-irrelevant prime arrows and the irrelevant location on the screen overlapped with the location of the required response. Hence, both forms of interference were of the S–R type, and adaptation effects were general.

Furthermore, it has been suggested that information processing does not adapt to the processing of conflict, as such, but to the aversive affect that comes along with conflict (Botvinick, 2007). In line with this proposal, conflict adaptation effects can be offset by presenting a positive event at about the same time as the conflict unfolds, whereby subsequent interference effects increase as compared to preceding negative events (van Steenbergen, Band, & Hommel, 2009). Thus, there might be an unifying cause for the invoking of control—namely, negative affect. First of all, this approach suggests that all types of conflict should have the power to invoke control, which obviously sets the stage for domain-general conflict adaptation. Second, not only should conflict prompt control processes, but so should all other events that induce negative affect (see also van Steenbergen, Band, & Hommel, 2010, for increased cognitive control with negative affect). Therefore, in the corollary analyses of the present experiments, we explored whether negative events have the power to subsequently reduce interference effects, as compared to positive events.

Overview of the experiments

The purpose of the present study was to look for general adaptation effects—that is, adaptation effects that cross the border between valence-based and non-valence-based task disturbances. We used both designs that have been suggested for the study of general adaptation effects—the factorial task-crossing design as well as the task-switching design—in order to reduce the chance that our conclusions would be based on methodical peculiarities. In Experiments 1a and 1b, we used a factorial task-crossing design in which spatial interference was combined with valence-based interference in each individual trial. The experiments differed with regard to the relevant stimulus attribute, which was a word in Experiment 1a but a picture in Experiment 1b, with the respective other stimulus attribute serving as a congruent or

incongruent distractor. In Experiment 2, we used a task-switching design with either spatial interference or valence-based interference in each trial and a change or repetition of the type of interference from one trial to the next. Finally, in Experiment 3, general adaptation effects were tested by combining valence-based interruption with spatial interference in individual trials. In all of these experiments, general adaptation processes would be indicated by an impact of valence-based interference (or interruption) on subsequent spatial interference effects or, conversely, of spatial interference on subsequent valence-based interference or interruption effects.

Experiment 1a

In Experiment 1a, we investigated the mutual interactions of adaptations to valence-based interference and spatial interference. Participants were to respond to the words “positive” and “negative” superimposed over affective pictures by making a left or right manual response (see Fig. 1). The pictures were presented on the left or the right side of the display. Consequently, two types of potential interference could occur in each individual trial. Valence-based interference was prompted by a mismatch of the valence of the target word and the affective content of the pictures (e.g., the word “positive” on the background of the picture of a crying child). Spatial interference was prompted by a mismatch of the spatial location of the stimulus and the required manual response (e.g., the word “positive,” which might require a left response, presented on the right side of the screen). Note that the relevant stimulus was always the same (the target word), which is an important precondition for observing domain-general adaptation effects (Notebaert & Verguts, 2008).

We expected to find, first, main effects of spatial interference (a Simon effect) and valence-based interference. Second, we expected to find domain-specific adaptation effects—that is, a reduced spatial interference effect following spatial interference on the previous trial, and a reduced valence-based interference effect following valence-based interference on the previous trial. The important question was whether there would also be domain-general adaptation effects—that is, a reduced valence-based interference effect following spatial-interference trials and, conversely, a reduced spatial interference effect following valence-based interference.

On top of these main predictions, we also had a look at the impact of the type of valence in the preceding trial on subsequent spatial interference. It has been suggested that nonvalent interference is reduced after a brief induction of negative affect (van Steenbergen, et al., 2009). Therefore, it might be predicted that spatial interference would be

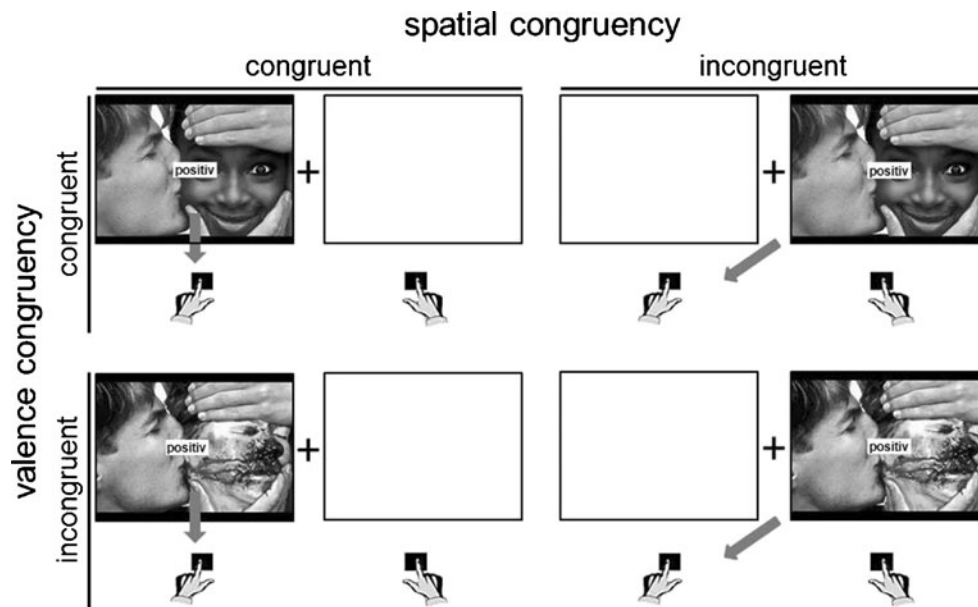


Fig. 1 In Experiment 1a, the participants responded to the words “positive” and “negative” (in German) superimposed on positive and negative pictures by pressing a left or right key. The stimuli (picture and word) appeared to the left or right of the center of the display (+). This figure illustrates an example in which the word “positive” required a left

buttonpress, as indicated by the arrows. Valence congruency was defined by the (mis)match of the valences of the target word and distractor picture. Spatial congruency was determined by the (mis)match of the stimulus and response locations. In Experiment 1b, participants responded to the picture valence, whereas the words served as distractors

reduced after being exposed to a trial in which the relevant and irrelevant information were both negative, as compared to trials in which they were both positive.

Method

Participants A group of 16 volunteers (9 female, 7 male) with a mean age of 24.6 years (range: 20–30) participated in the experiment. The session lasted approximately 1 h, for which the participants received €10.

Apparatus and materials A PC with a 16-in. monitor was used for the 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. The stimuli and instructions were presented in white on a black background, and participants responded by pressing the “y” or the “-” key on a standard QWERTZ keyboard.

The target stimuli consisted of the German words “positiv” and “negativ” written in black, which were presented in a frame with a white background (2.7×0.6 cm). The frame was centrally superimposed on an IAPS picture (18.7×13.4 cm). The picture was presented vertically centered to the left or the right of the vertical midline of the monitor. In 12.5 % of the trials (catch trials, see below), the last two letters of the words were exchanged (e.g., “positvi”). The set of IAPS pictures consisted of 20 positively and 20 negatively

valenced pictures that were selected on the basis of a previous study (Kleinsorge, 2009b).

Procedure and design Each trial started with the presentation of a central fixation mark for 500 ms. Then the imperative stimulus (a word and picture) was presented until the participant responded or until 2,500 ms had elapsed. Error feedback was provided for 1,000 ms when participants pressed the wrong key or failed to respond within 2,500 ms. Without error feedback, the next trial commenced immediately after the participant’s response.

Each participant performed 16 blocks of 80 trials each. The assignment of the two words to the two responses was counterbalanced across participants. During each block, the 40 IAPS pictures were presented twice without immediate repetitions of the same picture. Each picture was paired once apiece with the two words “positiv” and “negativ.” Stimulus position (left vs. right) was counterbalanced across combinations of words and picture valence. A random subset of 10 of the 80 trials of each block were converted into catch (no-go) trials by exchanging the last two letters of the word. The inclusion of the no-go trials served to hinder participants from discriminating the words by attending only to their initial letters.

The experimental design consisted of a factorial combination of the within-subjects factors Spatial Congruency (congruent vs. incongruent), Valence Congruency (congruent vs. incongruent), Spatial Congruency in the Preceding Trial (that is, trial $n - 1$; congruent vs. incongruent),

and Valence Congruency in Trial $n - 1$ (congruent vs. incongruent). *Spatial congruency* refers to the congruency of stimulus position and response position—that is, the Simon effect. *Valence congruency* refers to the congruency of the valence of the picture with the meaning of the word.

Results

The first block of trials was considered practice and not included in the analyses. Trials with response times (RTs) below 150 ms were considered outliers and removed (0.005 % of all trials), as were responses later than 2,500 ms (0.05 %; see the Procedure section). Sequential trial-to-trial analyses require correct responses in the current and the previous trial. Hence, only trials with correct responses in the current and previous trials were considered for the RT analyses (97.63 % of all trials). A preliminary analysis of false alarms in catch trials (11.3 %) yielded no significant effects of the design factors. Therefore, catch trials were excluded from further analyses.

The mean individual RTs of correct trials and the mean error percentages (PEs; see Table 1) were entered into repeated measures ANOVAs with the factors Valence Congruency (congruent vs. incongruent), Spatial Congruency (congruent vs. incongruent), Valence Congruency in Trial $n - 1$ (congruent vs. incongruent), and Spatial Congruency in Trial $n - 1$ (congruent vs. incongruent).

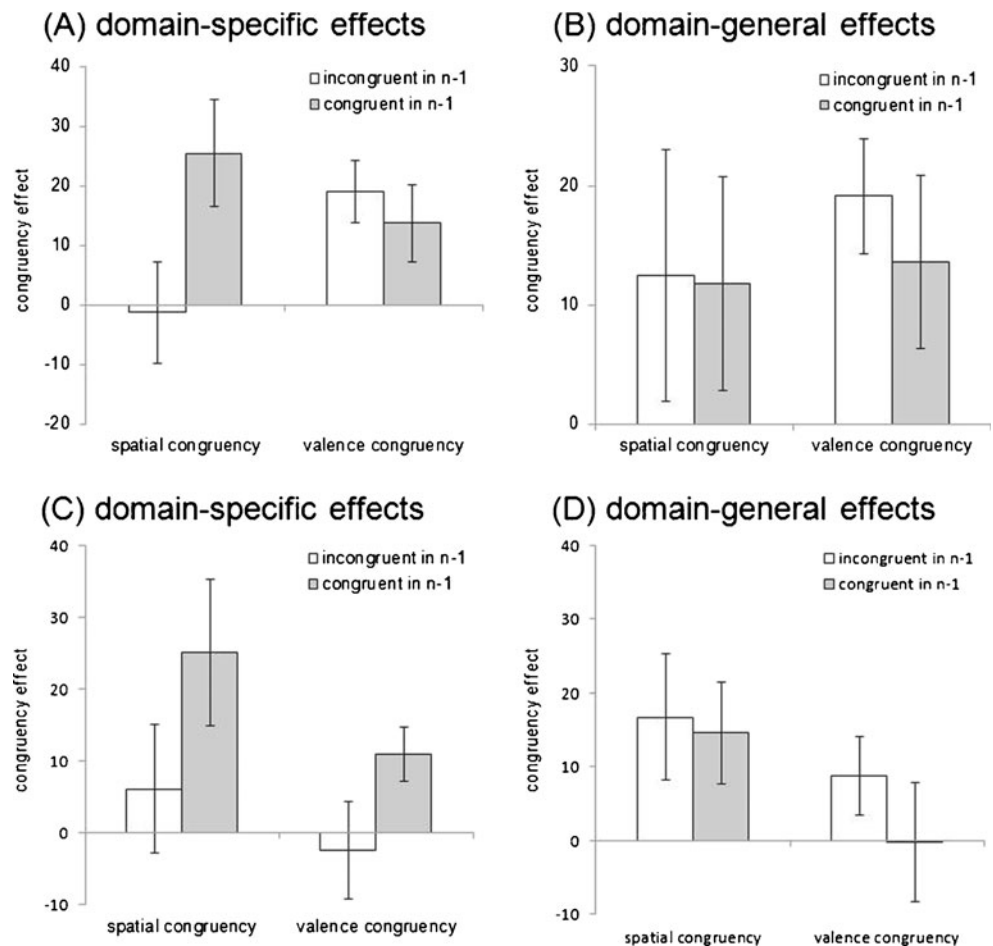
Response times The analysis of RTs yielded significant main effects of valence congruency, $F(1, 15) = 38.63$, $p < .001$, $\eta_p^2 = .72$, and spatial congruency, $F(1, 15) = 9.53$, $p = .008$, $\eta_p^2 = .39$, indicating a valence congruency effect of 16 ms and a spatial congruency effect of 12 ms. These congruency effects were additive [$F(1, 15) = 0.045$, $p = .836$, $\eta_p^2 < .01$, for the interaction]. There were also lagged effects of valence congruency in trial $n - 1$, $F(1, 15) = 26.45$, $p < .001$, $\eta_p^2 = .64$, as well as of spatial congruency in trial $n - 1$, $F(1, 15) = 7.44$, $p = .016$, $\eta_p^2 = .33$, indicating RT increases of 16 and 12 ms, respectively, as a function of incongruency in the preceding trial. The two lagged effects interacted, $F(1, 15) = 8.21$, $p = .012$, $\eta_p^2 = .35$, indicating especially slow responses (832 ms) with incongruencies of both types in trial $n - 1$, whereas RTs in conditions with incongruency on only the affective (811 ms) or the spatial (807 ms) level did not differ significantly from each other, or from the conditions with congruency on both levels (804 ms) in trial $n - 1$.

Regarding the main topic of the present study—namely, adaptation effects as sequential modulations of interference and/or interruption effects—we observed only a domain-specific modulation of spatial interference (see Fig. 2A, left side). As is indicated by an interaction of spatial congruency and spatial congruency in trial $n - 1$, $F(1, 15) = 18.59$, $p = .001$, $\eta_p^2 = .55$, a pronounced Simon effect of 25 ms followed spatially congruent trials, whereas the Simon effect was absent (−1 ms) following spatially incongruent trials. We observed neither a domain-specific modulation of

Table 1 Experiment 1: Mean response times (RTs, in milliseconds) and mean percentages of errors (PEs) as a function of current congruency and congruency in trial $n - 1$ for spatial and valence congruency—Domain-specific and domain-general effects

Trial $n - 1$	Spatial Congruency in Trial n				Valence Congruency in Trial n			
	Incongruent		Congruent		Incongruent		Congruent	
	RT	PE	RT	PE	RT	PE	RT	PE
Experiment 1a								
Domain-Specific Effects								
Incongruent	819	2.1	820	1.7	831	2.5	812	1.8
Congruent	820	2.7	794	2.0	812	2.6	798	2.6
Domain-General Effects								
Incongruent	828	2.3	815	2.0	829	2.3	810	2.2
Congruent	811	3.2	799	2.0	814	2.9	800	2.1
Experiment 1b								
Domain-Specific Effects								
Incongruent	649	4.8	643	5.1	645	5.1	647	4.8
Congruent	656	7.3	630	3.6	649	5.8	638	5.1
Domain-General Effects								
Incongruent	654	5.5	637	4.3	651	5.5	642	4.3
Congruent	651	6.5	636	4.4	643	5.4	643	5.5

Fig. 2 Experiment 1: Congruency effects—that is, the difference between the mean response times (RTs) in current incongruent minus current congruent trials—as a function of the congruency in trial $n - 1$, for spatial and valence congruency. Panels A and C show domain-specific effects, whereas panels B and D show domain-general effects. Error bars represent within-subjects confidence intervals (see Loftus & Masson, 1994)



valence-based interference, $p > .2$ (see Fig. 2A, right side), nor any cross-domain modulation, both $ps > .2$ (see Fig. 2B). No other effects reached significance.

Error percentages The analysis of PEs yielded no significant effects. The mean error percentages are shown in Table 1.

In auxiliary analyses, we investigated the effect of spatial interference that followed upon affectively congruent trials in which the word and picture were both either negative or positive. These analyses were based on the suggestion that nonvalent interference is reduced after a brief induction of negative affect in the preceding trial (van Steenbergen et al., 2009). The individual mean RTs and PEs of this subset of the data were subjected to ANOVAs with the factors Valence (positive vs. negative; note that this captures the valence of the preceding trial) and Spatial Congruency (congruent vs. incongruent). In the analysis of RTs and PEs, the interaction of valence and spatial congruency did not even approach significance, both $Fs < 1$. The spatial congruency effect was equally pronounced after both positive (14 ms, 1.5 %) and negative (9 ms, 0.9 %) valences. In both analyses, only the main effect of spatial congruency reached significance [for RTs, $F(1, 15) = 5.64$, $p = .031$,

$\eta_p^2 = .27$; for PEs, $F(1, 15) = 5.94$, $p = .028$, $\eta_p^2 = .28$], indicating a Simon effect of 12 ms and 1.2 %.

Experiment 1b

In Experiment 1b, we used basically the same stimuli and procedures as in Experiment 1a, but participants were now asked to respond according to the valence of the pictures, while the German words “positiv” (i.e., positive) and “negativ” (i.e., negative) served as distractors. This manipulation was employed to test for any peculiarities of distractor words as compared to distractor pictures.

Method

Participants A group of 12 volunteers (8 female, 4 male) with a mean age of 23.4 years (range: 19–30) participated in the experiment. The session lasted approximately 1 h, for which the participants received €10.

Apparatus and materials These were the same as in Experiment 1a, except that the pictures now were the relevant

stimuli, whereas the words served as distractors, and the catch trials, which became dispensable in Experiment 1b, were omitted.

Procedure and design These were the same as in Experiment 1a.

Results

The first block of trials was considered practice and not included in the analyses. Trials with RTs below 150 ms (0.02 % of all trials) or above 2,500 ms (0.23 % of all trials) were considered outliers and removed. Additionally, 5.3 % of trials were excluded due to errors in the current or the previous trial.

The mean individual RTs of correct trials and the mean PEs (see Table 1) were entered into repeated measures ANOVAs with the factors Valence Congruency (congruent vs. incongruent), Spatial Congruency (congruent vs. incongruent), Valence Congruency in Trial $n - 1$ (congruent vs. incongruent), and Spatial Congruency in Trial $n - 1$ (congruent vs. incongruent).

Response times The analysis of RTs yielded a significant main effect of spatial congruency, $F(1, 11) = 19.80$, $p = .001$, $\eta_p^2 = .64$, indicating a spatial congruency effect of 16 ms. Regarding the main topic of the present study—namely, sequential modulations of interference effects—we observed domain-specific modulation of both valence-based and spatial interference (see Fig. 2C). The valence-based congruency effect after valence-congruent trials (11 ms) was absent after valence-incongruent trials (–2 ms), which produced an interaction of valence congruency in the preceding and current trials, $F(1, 11) = 10.91$, $p = .007$, $\eta_p^2 = .50$. Likewise, the spatial Simon effect after spatially congruent trials (25 ms) was reduced to 6 ms after spatially incongruent trials [$F(1, 11) = 5.61$, $p = .037$, $\eta_p^2 = .34$, for the interaction of spatial congruency in the previous and current trials]. No other effects reached significance (see Fig. 2D).

Error percentages The analysis of PEs yielded a significant main effect of spatial congruency, $F(1, 11) = 7.86$, $p = .017$, $\eta_p^2 = .42$, indicating a congruency effect of 1.6 %. The main effect of valence congruency in trial $n - 1$, $F(1, 11) = 6.00$, $p = .032$, $\eta_p^2 = .35$, also turned out to be significant, indicating a lagged effect of valence congruency of –0.5 %, meaning that participants committed fewer errors after a valence-based incongruent than after a valence-based congruent trial. In addition, the interaction of spatial congruency and spatial congruency in trial $n - 1$ reached significance, $F(1, 11) = 10.34$, $p = .008$, $\eta_p^2 = .48$. After a spatially congruent trial, the Simon effect amounted to 3.6 %,

whereas there was an inverted Simon effect of –0.3 % following a spatially incongruent trial. No other effects reached significance.

In auxiliary analyses, we again investigated the effect of spatial interference that followed upon affectively congruent trials in which the word and picture were both either negative or positive. Individual mean RTs and PEs of this subset of the data were subjected to ANOVAs with the factors Valence (positive vs. negative; note that this captures the valence of the preceding trial) and Spatial Congruency (congruent vs. incongruent). In the analysis of RTs, the interaction of valence and spatial congruency reached significance, $F(1, 11) = 5.27$, $p = .042$, $\eta_p^2 = .32$, with a pronounced spatial congruency effect of 24 ms after a negative-valence trial, but an insignificant spatial congruency effect (5 ms) after positive valence. This interaction did not reach significance in the analysis of PEs ($p > .05$). In both analyses, the main effect of spatial congruency reached significance [for RTs, $F(1, 11) = 13.62$, $p = .004$, $\eta_p^2 = .56$; for PEs, $F(1, 11) = 7.57$, $p = .019$, $\eta_p^2 = .41$], indicating Simon effects of 14 ms and 2 %, respectively.

Discussion of Experiments 1a and 1b

In Experiment 1, there were two potential sources of interference in each individual trial—namely, spatial interference due to a mismatch of stimulus location and response location, and valence-based interference due to a mismatch between the valences of the target words and the irrelevant pictures (Exp. 1a) or of the target pictures and the irrelevant words (Exp. 1b). We made three important observations.

First, spatial and valence-based interference both affected performance, and they did so independently of each other. Thus, there was no interaction of these types of interference within the current trial. Similar additive effects have been reported for combinations of two types of nonvalent interference, such as Stroop and Eriksen interference, Stroop and Simon interference, or spatial and temporal Simon-type interference (e.g., Fan, Flombaum, McCandliss, Thomas, & Posner, 2003; Kunde & Stöcker, 2002; Kunde & Wühr, 2006; Simon & Berbaum, 1990). Such additive effects are typically taken to imply that these interference effects arise at independent, serially organized processing stages (Sternberg, 1969). Conceivably, the valence-based interference effect, based on S–S incongruency, could result from a perceptual stage, whereas the spatial Simon effect, based on S–R incongruency, could result from a later, response selection stage.

Second, we found adaptation effects within domains. The spatial Simon effect was reduced following incongruent spatial Simon trials in Experiments 1a and 1b. The valence-based interference effect was reduced following valence-

incongruent trials in Experiment 1b (with target pictures and distractor words), while this effect was not observed in Experiment 1a (with target words and distractor pictures). If we assume that adaptation effects reflect the amplification of relevant information (Egner & Hirsch, 2005) or the suppression of irrelevant information (Wühr & Ansorge, 2005), this observation suggests that either the processing of target pictures is more easily amplified than the processing of target words, or that the processing of distractor words is more easily suppressed than the processing of distractor pictures. This issue should be clarified by future research.

Third, and most importantly in the present context, we found no adaptation effects that crossed the border between valence-based and non-valence-based interference. Spatial interference did not reduce valence-based congruency effects, nor did valence-based interference reduce spatial congruency effects. The existence of within-interference-type adaptation effects, with a lack of cross-type effects, suggests independently operating adaptation processes. The only general effect was a slowing down of responding when the preceding trial was incongruent in both the spatial and valence-based features (Exp. 1a). However, such “postconflict slowing” is hard to interpret when the conflict-laden irrelevant stimulus features repeat, as was the case here (see Verguts et al., 2011, for a discussion of this issue). We therefore refrain from an extended discussion of this observation.

Finally, we did not observe that the experience of a negative event (as compared to a positive event) had the potential to reduce subsequent spatial interference (Botvinick, 2007; van Steenbergen et al., 2009). The spatial Simon effect was equally pronounced with preceding negative or positive stimuli in Experiment 1a, and was in fact *larger* with preceding negative as compared to preceding positive stimuli in Experiment 1b. We will postpone a discussion of this pattern after further exploration of this issue in Experiments 2 and 3.

Experiment 2

In Experiment 1, we found few hints of domain-general adaptation effects. However, the conditions might have been suboptimal for observing such general adaptation. Most notably, we combined spatial S–R interference with affective S–S interference, and it might be that domain-general effects ensue more easily with two types of interference at the same locus (Egner, 2008).

Therefore, in Experiment 2 we induced S–R interference in both domains. Specifically, we combined a spatial Simon effect (Wühr, 2006) with an affective Simon effect (cf. De Houwer & Eelen, 1998): Participants were presented with affective stimuli at varying positions on the screen and had to verbally respond to the color of the stimuli. We used

smiley and grumpy faces (see Fig. 3) because these affective stimuli have already been used to successfully implement affective Simon effects with verbal responses (Voß, Rothmund, & Wentura, 2003). Two of the colors required a spatial response (vocalizing “left” or “right” in German), whereas the remaining two colors required an affective response (vocalizing “bad” or “good” in German; see Fig. 3). Thus, color was the relevant stimulus attribute that determined the response in each individual trial, but depending on the required response, either the stimulus position or the stimulus valence overlapped with the response. Therefore, trials requiring a spatial response will subsequently be denoted as the “spatial task,” and trials requiring an affective response will be denoted as the “affective task.” When the color required a “left–right” response, we expected a spatial Simon effect such that, for instance, responding “left” would be delayed when the stimulus occurred on the right rather than on the left of the screen (Proctor & Vu, 2002; Wühr, 2006). When the color required a “good–bad” response, we expected an affective Simon effect such that, for instance, responding “good” would be delayed when a grumpy instead of a smiley was shown (De Houwer & Eelen, 1998). The main question was, again, whether there would be any adaptation effects from spatial interference to subsequent affective interference, or vice versa.

Note that this manipulation changed the factorial task-crossing design of Experiment 1 to a task-switching design. Yet, general adaptation effects across different types of non-valent interference have been obtained with this design, as well (Cho et al., 2009; Freitas et al., 2007; Notebaert & Verguts, 2008), so there is no strong argument that this design would preclude the observation of domain-general effects for some principled reason.

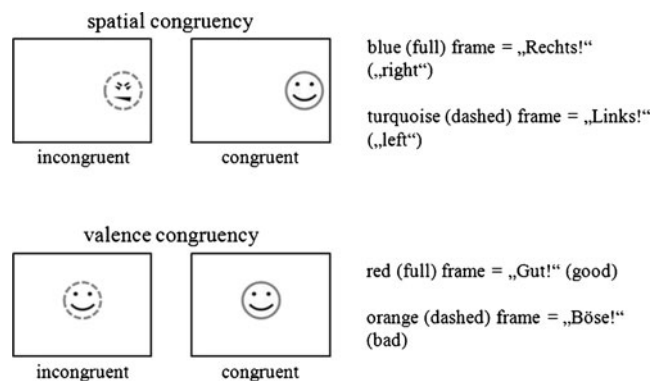


Fig. 3 Experiment 2: Participants responded to the frame colors of pictures. In the spatial task, the stimuli were shown in a left or right position, and the German words “links” (“left”) or “rechts” (“right”) had to be vocalized according to the stimulus color. In the affective task, the stimuli were presented in the center of the screen and the German word “gut” (“good”) or “böse” (“bad”) had to be vocalized, according to the stimulus color

Method

Participants A group of 16 volunteers (11 female, 5 male) with a mean age of 25.8 years (range: 21–32) participated in the experiment. The session lasted approximately 40 min, for which the participants received €5.

Apparatus and materials An IBM-compatible computer with a 16-in. monitor was used for stimulus presentation. The viewing distance was not restricted but amounted to approximately 60 cm. The stimuli and instructions were presented in white on a black background. Participants had to give verbal responses that were recorded, and RTs were measured by a voice key connected to the parallel port of the computer. Therefore, participants had to wear a headset throughout the experiment.

The target stimuli consisted of two emotional faces that were selected according to the criteria of Voß, Rothermund, and Wentura (2003). We used the friendly (smiley) and hostile (grumpy) faces and additionally gave them colored body frames (blue, turquoise, red, and orange), which resulted in eight target stimuli. These were presented at one of three possible positions on the screen: centered in the middle, on the left, or on the right. Participants were instructed to respond verbally as quickly and accurately as possible to the color of the frames by saying “Links!” (left), “Rechts!” (right), “Gut!” (good), or “Böse!” (bad). Trials on which participants gave other responses and trials on which the microphone picked up noise before a response were excluded from the analyses.

Procedure and design In each trial, after an intertrial interval of 1,000 ms the target was presented for 2,000 ms, and participants had to give their verbal response within 1,500 ms after stimulus onset. Responses were counterbalanced between participants, whereby blue and turquoise could be the “left–right” responses (spatial task) and orange and red could be the “good–bad” responses (affective task), or vice versa. Stimuli that required “left–right” responses emerged only in the left and right positions on the screen, whereas stimuli that required “good–bad” responses appeared only in the middle of the screen. Different colors for the two tasks were used because otherwise stimulus location would be the only clue as to which task to carry out. This would render stimulus location obviously task-relevant, which would violate the basic structure of the spatial Simon task, in which stimulus location is nominally task-irrelevant. The stimuli were presented equally often in a random order. Thus, tasks could switch from trial to trial. In the spatial task, stimuli occurred randomly but equally often in the left or the right position. In total, participants had to perform 320 trials, split into five blocks.

The experimental design consisted of a factorial combination of the within-subjects factors Task (affective vs. spatial), Congruency (congruent vs. incongruent), Task Switch (task repetition vs. task switch), and Congruency in Trial $n - 1$ (congruent vs. incongruent). The factor Task stands for whether a “left–right” or a “good–bad” response had to be made. *Congruency* refers to the correspondence of the required response to the actual position (e.g., a “right” response being made to a stimulus that appeared on the right of the screen—that is, the Simon effect) or to the emotional expression of the face (e.g., a “good” response being required for a smiley—that is, the affective Simon effect). The factor Congruency in Trial $n - 1$ indicates the correspondence that had been in effect in trial $n - 1$. Finally, the factor Task Switch indicates whether the same task had to be done in trial $n - 1$ (task repetition) or not (task switch).

Results

Trials with RTs below 150 ms (0.02 % of all trials) or above 1,500 ms (3.69 % of all trials) were considered outliers and removed. Only trials with correct responses in both the current and previous trials were considered for the RT analyses (91.7 % of all trials).

Response times Mean individual RTs (see Table 2) were entered into a repeated measures ANOVA with the factors Task (spatial vs. affective), Congruency (congruent vs. incongruent), Task Switch (repetition vs. switch), and Congruency in Trial $n - 1$ (congruent vs. incongruent). This analysis revealed a significant main effect of task switch, $F(1, 15) = 287.05$, $p < .001$, $\eta_p^2 = .95$, with faster responses when tasks repeated (660 ms) than when they switched (793 ms). Also, we found a significant main effect of congruency, $F(1, 15) =$

Table 2 Experiment 2: Mean response times (RTs, in milliseconds) and mean percentages of errors (PEs) as a function of current congruency and congruency in trial $n - 1$ for spatial and affective task repetition and task switch trials

Trial $n - 1$	Spatial Task in Trial n		Affective Task in Trial n					
	Incongruent	Congruent	Incongruent	Congruent				
	RT	PE	RT	PE	RT	PE	RT	PE
Task Repetition								
Incongruent	644	0.5	669	2.1	665	6.7	667	1.0
Congruent	690	2.6	633	0.7	676	5.9	636	2.1
Task Switch								
Incongruent	788	1.4	781	1.3	831	3.2	787	0.9
Congruent	796	2.4	769	1.5	816	6.4	775	2.1

38.46, $p < .001$, $\eta_p^2 = .72$ —that is, an overall congruency effect of 24 ms. Moreover, two interactions reached significance. First, we observed an interaction of congruency with congruency in trial $n - 1$, $F(1, 15) = 20.49$, $p < .001$, $\eta_p^2 = .58$, with a smaller congruency effect after incongruency in trial $n - 1$ (6 ms) than after congruency in the preceding trial (41 ms)—that is, an overall sequential modulation of interference. Additionally, the second-order interaction of congruency, congruency in trial $n - 1$, and task switch was clearly significant, $F(1, 15) = 13.59$, $p = .002$, $\eta_p^2 = .48$, indicating a sequential modulation of interference only if the task repeated, but not when it switched (see Figs. 4A and 4B). No other effects reached significance.

Regarding the main topic of the present experiment—namely, adaptation to interference—we first analyzed task repetition trials to investigate domain-specific effects (see Fig. 4A). Therefore, we entered mean individual RTs for this subset of the data into a repeated measures ANOVA with the factors Task (spatial vs. affective), Congruency (congruent vs. incongruent), and Congruency in Trial $n - 1$ (congruent vs. incongruent). We observed a significant main effect of congruency, $F(1, 15) = 13.5$, $p = .002$, $\eta_p^2 = .47$, indicating a congruency effect of 18 ms in task repetition trials. Furthermore, the interaction of congruency with congruency in trial $n - 1$ reached significance, $F(1, 15) = 41.53$, $p < .001$, $\eta_p^2 = .74$, with a pronounced congruency effect (49 ms) following congruent trials and a slightly reversed effect (–13 ms) following incongruent events. This sequential modulation of congruency effects was present for both spatial congruency, $F(1, 15) = 21.05$, $p < .001$, $\eta_p^2 = .58$ (see Fig. 4A, left side), and valence-based congruency, $F(1, 15) = 7.45$, $p = .016$, $\eta_p^2 = .33$ (see Fig. 4A, right side). Thus, we found domain-specific sequential modulation of interference within both domains—the spatial and the affective.

To investigate whether these sequential modulations of interference also occur across the domains, we entered the mean individual RTs for task switch trials into a repeated measures ANOVA with the factors Task,

Congruency, and Congruency in Trial $n - 1$ (see Fig. 4B). This analysis revealed a significant main effect of congruency, $F(1, 15) = 14.13$, $p = .002$, $\eta_p^2 = .49$, indicating a congruency effect of 30 ms in task switch trials. Yet there was no interaction of previous trial congruency and current trial congruency, either when switching to the spatial Simon task, $F(1, 15) = 1.15$, $p = .301$, $\eta_p^2 = .07$, or when switching to the affective Simon task, $F(1, 15) = 0.53$, $p = .822$, $\eta_p^2 < .01$. Thus, there were no domain-general sequential modulations of interference.

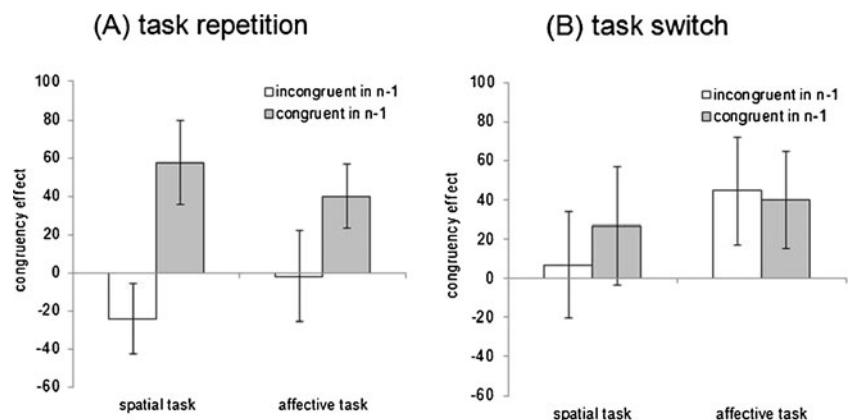
Error percentages The mean individual PEs (see Table 2) were entered into a repeated measures ANOVA with the factors Task (spatial vs. affective), Congruency (congruent vs. incongruent), Task Switch (repetition vs. switch), and Congruency in Trial $n - 1$ (congruent vs. incongruent). This analysis revealed a significant effect of task switch, $F(1, 15) = 8.68$, $p = .010$, $\eta_p^2 = .37$, with fewer errors if the task repeated (1.6 %) than on task switch trials (3.6 %). Furthermore, responding was 2.2 % more accurate with congruent than with incongruent trials, $F(1, 15) = 13.21$, $p = .002$, $\eta_p^2 = .47$. Finally, the interaction of task switch with congruency reached significance, $F(1, 15) = 18.41$, $p = .001$, $\eta_p^2 = .55$, with similar PEs in congruent trials, regardless of whether the task had switched (1.5 %) or was repeated (1.4 %), but with task switch costs of 3.9 % in incongruent trials.

An ANOVA with only task repetition trials revealed no significant effects. However, separate analyses for the two tasks revealed a significant interaction of congruency with congruency in trial $n - 1$ only for the spatial task, $F(1, 15) = 11.63$, $p = .004$, $\eta_p^2 = .44$, with a congruency effect of 1.9 % after congruent trials, whereas the congruency effect was reversed (–1.7 %) after incongruent trials, indicating a sequential modulation of spatial interference in task repetition trials. No other effects reached significance.

An ANOVA on only the task switch trials revealed a significant effect of congruency, $F(1, 15) = 17.44$, $p =$

Fig. 4 Experiment 2:

Congruency effects—that is, the difference between mean response times (RTs) in current incongruent minus current congruent trials—as a function of congruency in trial $n - 1$, for the spatial and affective tasks. Panel A shows the effects in task repetition trials, whereas panel B shows the effects in task switch trials. Error bars represent within-subjects confidence intervals (see Loftus & Masson, 1994)



.001, $\eta_p^2 = .54$, with fewer errors in congruent (1.5 %) than in incongruent (5.6 %) trials, indicating an overall congruency effect in task switch trials. Separate analyses for the two tasks revealed significant main effects of congruency for each domain [spatial, $F(1, 15) = 6.96$, $p = .019$, $\eta_p^2 = .32$; affective, $F(1, 15) = 11.1$, $p = .005$, $\eta_p^2 = .43$], with a spatial Simon effect of 4.8 % and an affective Simon effect of 3.3 %. No other effects reached significance.

In auxiliary analyses, we investigated the impact of trials in which picture and response were both positive versus negative on subsequent spatial interference. These analyses were based on the suggestion that nonvalent interference decreases after a brief induction of negative affect in the preceding trial (van Steenbergen et al., 2009). The individual mean RTs and PEs in this subset of the data were subjected to ANOVAs with the factors Valence in the Preceding Trial (positive vs. negative) and Spatial Congruency (congruent vs. incongruent). In the analysis of RTs, neither the main effects of valence and congruency nor their interaction reached significance (all $ps > .1$). However, in the analysis of PEs, the main effect of congruency, $F(1, 15) = 8.41$, $p = .011$, $\eta_p^2 = .36$ (indicating a Simon effect of 8.2 %), as well as the interaction of valence and congruency, $F(1, 15) = 6.33$, $p = .024$, $\eta_p^2 = .30$, reached significance. We found a pronounced congruency effect of 7.9 % after negative valence, which was absent (0.3 %) after positive valence.

Discussion

The conditions to obtain adaptation effects that would cross the border between valent and nonvalent interference could be considered ideal in Experiment 2. The relevant stimulus feature (color) was the same in both tasks (cf. Notebaert & Verguts, 2008), and the type of interference (S–R) was the same as well (Egner, 2008). We observed sequential modulations within domains, for both the spatial and the affective Simon tasks. The observation of sequential modulation of the affective Simon task with verbal responses is, to the best of our knowledge, a novel finding. It fits quite well with the adaptation effects that have been observed with affective versions of interference tasks and manual responses (Egner et al., 2008; Etkin et al., 2006; Frings & Wentura, 2008). Still, no domain-general adaptation effects were obtained. Finally, and similar to Experiment 1, the experience of a clearly positive or negative event in the preceding trial left the RTs of subsequent spatial interference unaltered. However, it did affect PEs, in that a negative event caused even *larger* error percentages in subsequent spatial interference than did a positive event. We will discuss this after further exploration of this issue in Experiment 3.

Experiment 3

So far, we have obtained no indications that valence-based interference prompted modulations of spatial interference effects, or vice versa. Yet, in addition to valence-based interference effects, there are valence-based interruption effects. These are task disturbances due to irrelevant valent information that does not overlap with the main task. In Experiment 3, we tested whether these interruption effects would enter into any kind of interaction with spatial interference effects of the Simon type. Subjects judged the frame color of to-be-ignored pictures (see Fig. 5). The position of the stimuli did or did not correspond to the required manual response. Thus, spatial interference and valence-based interruption could occur in each individual trial, which satisfied the criterion of a factorial task-crossing experiment, in terms of the nomenclature of Egner (2008).

The question was, again, whether we would find any after-effects of valence-based interruption on subsequent spatial interference or, conversely, of spatial interference on subsequent valence-based interruption, such that stimuli of either valence (as compared to neutral stimuli) would reduce subsequent spatial interference, or conversely, spatial interference would reduce the impact of valence-based interruption.

Method

Participants A group of 16 volunteers (8 female, 8 male) with a mean age of 25.1 years (range: 20–30) participated in the experiment. The session lasted approximately 1 h, for which the participants received €10.

Apparatus and materials The apparatus was the same as in Experiment 1. The target stimuli consisted of IAPS pictures (16.7×11.4 cm) that were surrounded by a yellow or blue

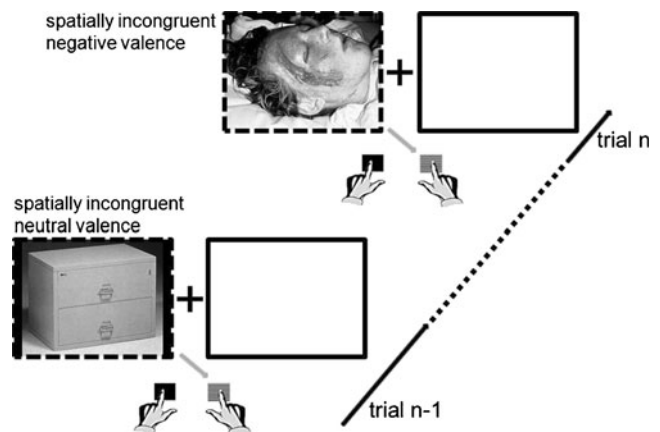


Fig. 5 Experiment 3: Participants responded to the colors of the frames of negative, neutral, and positive pictures by making left and right manual responses while the pictures were presented on the left or the right side of the display

frame of 1-cm thickness. The picture was presented vertically centered to either the left or the right of the vertical midline of the monitor. The set of IAPS pictures consisted of 20 neutral, 20 positively valenced, and 20 negatively valenced pictures that were selected on the basis of a previous study (Kleinsorge, 2009a). The participants were instructed to respond via keypress according to the color of the frame, with the color-to-response assignments balanced across participants.

Procedure and design Each trial started with the presentation of a central fixation mark for 500 ms. Then the imperative stimulus (a picture surrounded by a frame) was presented until the participant responded or until 2,500 ms had elapsed. Error feedback was provided for 1,000 ms when participants pressed the wrong key or failed to respond within 2,500 ms. Without error feedback, the next trial commenced immediately after the participants' response.

Each participant performed 13 blocks of 120 trials each. During each block, each of the 60 IAPS pictures was presented twice without immediate repetitions of the same picture. Each picture was paired once apiece with a blue and with a yellow frame. Stimulus position (left vs. right) was counterbalanced across combinations of frame color and picture valence.

The experimental design consisted of a factorial combination of the within-subjects factors Spatial Congruency (congruent vs. incongruent), Picture Valence (neutral, positive, or negative), Spatial Congruency in Trial $n - 1$ (congruent vs. incongruent), and Valence in Trial $n - 1$ (neutral, positive, or negative). *Spatial congruency* refers to the congruency of stimulus position and response position—that is, the Simon effect.

Results

The first block of trials was considered practice and was not included in the analyses. Trials with RTs below 150 ms

(0.005 % of all trials) or above 2,500 ms (no responses) were considered outliers and removed. Only trials with correct responses in the current and the previous trials were considered for the RT analyses (95.5 % of all trials).

Response times RTs (see Table 3) of correct responses were subjected to an ANOVA with the within-subjects factors Spatial Congruency (congruent vs. incongruent), Picture Valence (neutral, positive, or negative), Spatial Congruency in Trial $n - 1$ (congruent vs. incongruent), and Picture Valence in Trial $n - 1$ (neutral, positive, or negative). This analysis yielded significant main effects of picture valence, $F(2, 30) = 3.55, p = .041, \eta_p^2 = .19$, and spatial congruency, $F(1, 15) = 49.81, p < .001, \eta_p^2 = .77$. Neutral pictures elicited a mean RT of 416 ms, which was increased by both positively and negatively valenced pictures to 420 ms. The Simon effect amounted to 17 ms. The effects of spatial interference and valence-based interruption were additive [$F(2, 30) = 0.518, p = .601, \eta_p^2 = .03$, for the interaction]. The spatial Simon effect was modulated by the spatial congruency in trial $n - 1$, $F(1, 15) = 144.93, p < .001, \eta_p^2 = .91$. After a spatially congruent trial, there was a large Simon effect of 47 ms, which was reversed to -13 ms following a spatially incongruent trial (see Fig. 6A, left side). We found neither a domain-specific modulation of valence-based interruption, $p > .4$ (see Fig. 6A, right side), nor any cross-domain modulations, all $ps > .1$ (see Fig. 6B).

Error percentages The analysis of PEs (see Table 3) as a function of spatial congruency (congruent vs. incongruent), picture valence (neutral, positive, or negative), spatial congruency in trial $n - 1$ (congruent vs. incongruent), and picture valence in trial $n - 1$ (neutral, positive, or negative) revealed that responding was 2 % more accurate when the current trial was congruent rather than incongruent, $F(1, 15) = 17.17, p = .001, \eta_p^2 = .53$, and 0.8 % more accurate when the preceding trial was congruent rather than

Table 3 Experiment 3: Mean response times (RTs, in milliseconds) and mean percentages of errors (PEs) as a function of current spatial congruency and spatial congruency in trial $n - 1$ and of interruption caused by

the valences in the current trial and in trial $n - 1$ —Domain-specific and domain-general effects

Trial $n - 1$	Spatial Congruency in Trial n				Valence in Trial n			
	Incongruent		Congruent		Valent		Neutral	
	RT	PE	RT	PE	RT	PE	RT	PE
Domain-Specific Effects								
Incongruent/valent	412	2.7	425	5.6	420	4.5	417	4.4
Congruent/neutral	441	8.4	394	1.6	419	5.0	412	4.6
Domain-General Effects								
Incongruent/valent	427	5.3	412	3.6	421	4.2	415	4.2
Congruent/neutral	427	6.0	406	3.6	419	5.1	416	4.7

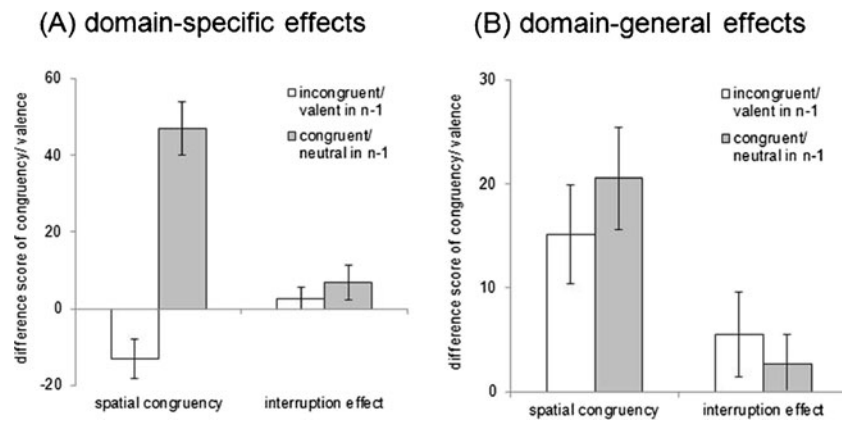


Fig. 6 Experiment 3: Response time (RT) difference scores for congruency or interruption caused by valence as a function of spatial congruency (congruent vs. incongruent) or valence (valent vs. neutral) in trial $n - 1$. Panel A shows domain-specific effects, with difference scores for congruency as a function of spatial congruency in trial $n - 1$ on the left and difference scores for interruption as a function of

incongruent, $F(1, 15) = 4.71, p = .046, \eta_p^2 = .24$. Also, the interaction of spatial congruency and spatial congruency in trial $n - 1$ was significant, $F(1, 15) = 44.02, p < .001, \eta_p^2 = .75$, with a spatial Simon effect of 6.8 % following a spatially congruent trial, but a slightly inverted Simon effect of -2.9 % following a spatially incongruent trial. No other effects reached significance.

In auxiliary analyses, we investigated the effect of positive versus negative valence on subsequent nonvalent interference. The individual mean RTs and PEs of this subset of data were subjected to ANOVAs with the factors Picture Valence in the Preceding Trial (negative, neutral, or positive) and Spatial Congruency (congruent vs. incongruent). In the analysis of RTs and PEs, the interaction of picture valence and spatial congruency did not reach significance, both $ps > .1$. The spatial congruency effect was equally pronounced after negative (14 ms, 1.9 %), neutral (20 ms, 2.5 %) and positive (17 ms, 1.6 %) valences. In both analyses, the main effect of spatial congruency reached significance [for RTs, $F(1, 15) = 48.02, p < .001, \eta_p^2 = .76$; for PEs, $F(1, 15) = 15.18, p = .001, \eta_p^2 = .5$], indicating Simon effects of 17 ms and 2.0 %, respectively.

Discussion

Experiment 3 tested for mutual adaptations to valence-based interruption and spatial interference. We obtained a standard spatial Simon effect and a small but reliable interruption by positive/negative as compared to neutral pictures. Positive pictures delayed responding to the same extent as negative pictures relative to neutral ones. In other words, there was no negativity bias—that is, stronger interruption by negative events (Pratto & John, 1991). The negativity bias is to some

extent due to higher arousal levels induced by negative as compared to positive pictures (Schmuck, 2005). Because the positive/negative pictures were balanced regarding their mean arousal ratings (Kleinsorge, 2009a), that lack of a negativity bias did not come as a big surprise here.

The spatial Simon effect and the valence-based interruption effect exerted additive effects in the current trial, which suggests that they affected performance independently of each other. Valence-based interruption effects are typically small (cf. Kleinsorge, 2007, 2009a), which, however, does not preclude in principle that they might become yet smaller after spatial interference trials (or, conversely, increase after trials free of spatial interference). This, however, was not the case. No cross-domain adaptation effects ensued. Although spatial interference did reduce the spatial Simon effect in a subsequent trial, it did not affect subsequent valence-based interruption.

Interestingly, there was also no aftereffect of valence-based interruption on the subsequent impact of valence in the next trial. We found neither a general increase of RTs right after negative stimuli (McKenna & Sharma, 2004) nor a more detrimental impact of subsequent negative stimuli (Kunde & Mauer, 2008). The reasons for this are not entirely clear. It might be that adding a different source of interference to the experiment (spatial interference, in this case) generally reduces valence-based interruption effects in a more long-term (rather than trial-wise) manner. This would also explain why the valence-based interruption effects were relatively small in comparison to those in previous studies. We consider the possibility of such more long-term effects of mutual interactions of valence-based and spatial interference a question for future research. Finally, in accordance with the results of Experiment 1a and, partially, with those of Experiment 2, a negative picture did not alter the impact of subsequent spatial interference as compared to a positive picture.

General discussion

The present study explored whether the processes that resolve task disturbances from task-irrelevant spatial or valent stimulus features generalize to the resolution of disturbance from the respective other domain. Domain-general processes would be indicated by influences of irrelevant spatial information on subsequent valence-based disturbance and, conversely, by influences of irrelevant valent information on subsequent spatial disturbance. Domain-specific processes would be indicated by influences of irrelevant spatial information on subsequent spatial disturbance and by influences of irrelevant valent information on subsequent valence-based disturbances.

Experiments 1 and 2 investigated domain-general adaptation effects to interference—thus, disturbance from irrelevant stimulus features that overlapped with task-relevant features. Experiment 3 explored domain-general adaptation between spatial interference and valence-based interruption effects—thus, disruption from task-irrelevant valence that did not overlap with any task-relevant feature.

While we observed adaptation effects within spatial and valence-based processing of disruption, there were few indications of adaptations that generalized across spatial and valence-based disruption. In no experiment did we find an influence of spatial interference on subsequent valence-based interference/interruption or, conversely, of valence-based interference/interruption on subsequent spatial interference. Moreover, spatial and valence-based interference affected performance in statistically independent manners in the current trials, which also suggests that these types of interference are resolved by functionally, and perhaps neurally, independent mechanisms (Fan et al., 2003; Ochsner et al., 2009). This independence ensued even under conditions that have been considered favorable for observing cross-task adaptation effects—namely, identical types of (S–R) interference (Egner, 2008) and identical task-relevant stimulus features in both tasks (Notebaert & Verguts, 2008).

Such independence of adaptation effects does not support models that consider “conflict” as a unifying control signal whereby the processing of task-relevant features is strengthened, as is proposed in the prominent conflict-monitoring model (Botvinick et al., 2001). This model predicts that top-down changes of task-relevant information are prompted by the detection of any kind of conflict, be it spatial or valence-based, and should affect all types of interference, provided that the relevant stimulus feature remains the same in these interference tasks. Despite constant relevant task features across types of interference (word meaning in Exp. 1, color in Exps. 2 and 3), no general adaptation effects were observed.

The lack of significant domain-general effects raises the question of the statistical power to detect such effects. First of all, it should be noted that we did not observe domain-general effects, although we did replicate the typically observed

spatial Simon effect, its sequential modulation, and valence-based disturbance effects in all three experiments. Even the small (4-ms) valence-based interruption effect in Experiment 3 was clearly significant. Thus, there obviously was sufficient power to render even numerically small effects reliable. For a formal treatment of this issue, some estimate of the expected sizes of domain-general adaptation effects would be necessary. A reasonable assumption could be that domain-general effects are of a size similar to that of adaptation effects within the spatial and valence-based domains. The sizes of the spatial adaptation effects (in terms of the d_z effect size measure; Mayr, Erdfelder, Buchner, & Faul, 2007) in Experiments 1–3 amounted to 1.07 (Exp. 1a), 0.68 (Exp. 1b), 1.14 (Exp. 2), and 3.0 (Exp. 3), and the sizes of the within-domain valence-based adaptation effects were $d_z = 0.95$ in Experiment 1b and $d_z = 0.62$ in Experiment 2. The power ($1 - \beta$) to detect domain-general effects of these sizes ranged between .99 to .72 (given $n = 16$ [12 in Exp. 1b] and $\alpha = 5\%$). Hence, although the power of the present experiments could certainly be improved, it seems sufficient to detect domain-general adaptation effects that were of similar size as the present domain-specific (in particular the spatial) adaptation effects.

Finally, we found no indications that negative affect instead of conflict might fare better as a candidate for a trigger signal to prompt general adaptation effects (Botvinick, 2007; van Steenbergen et al., 2009). In two of our four experiments (1a and 3), there was no indication that interference was smaller after negative than after positive events, and in the other two experiments (1b and 2), interference was even larger after negative events (in Exp. 1b in RTs, and in Exp. 2 in PEs). It should be noted that the question of whether negative or positive affect reduces conflict adaptation is not yet settled. While van Steenbergen et al. (2009) observed that *positive* reward feedback reduced subsequent conflict adaptation, Padmala, Bauer, and Pessoa (2011) reported reduced conflict adaptation after brief inductions of *negative* affect. Thus, the conditions for an impact of affect on conflict adaptation remain to be clarified. In any case, we did find at least one indication of a domain-general adaptation effect, in the present Experiment 1: RTs increased when the preceding trial contained both spatial and valence-based interference. This observation suggests a kind of postconflict slowing that generalizes to all types of conflict after a sufficiently strong conflict signal. This finding should be viewed with caution, however, first because postconflict slowing is hard to interpret when the task-interfering features repeat from trial to trial (cf. Verguts et al., 2011), and second because the effect was not replicated in Experiment 3.

It has been suggested that sequential modulations of congruency effects (of the type studied in Exps. 1 and 2) reflect processes other than conflict resolution—namely, the benefits of complete repetitions and complete changes of

relevant and irrelevant task features with congruency-level repetitions (e.g., two subsequent congruent trials) as compared to partial repetitions of only some features with congruency level changes (e.g., a congruent trial followed by an incongruent trial; Hommel et al., 2004; Mayr, Awh, & Laurey, 2003). First of all, it should be noted that due to the use of many different pictures, identical repetitions were rare in Experiment 1 (0.02 % of all trials), and the removal of such trials did not change the data pattern in any significant respect. So, literal identical stimulus repetitions are an unlikely explanation for the effects in at least Experiment 1. One may argue, however, that picture valence (positive vs. negative) rather than picture identity (e.g., flower) is coded as a feature, so that feature repetitions/alternations would occur more frequently.

The present study was not designed to decide between conflict adaptation and feature repetition accounts, so that a clear evaluation of this account is not easy. Nevertheless, we tried to explore this issue through a multiple regression approach (cf. Notebaert & Verguts, 2007). The basic idea was to predict participants' RTs in individual trials by a multiple regression model that included the congruency of the given trial, the congruency in the previous trial, and the interaction of these variables—hence, the conflict adaptation effect. The crucial question was whether the interaction of current and previous trial congruency would still explain the variance of RTs when the model included a binary feature integration predictor variable that coded whether the current trial contained a complete repetition/alternation of all task features (0) or a partial repetition of features (1). This analysis was first done for each participant, and it was then tested if the mean of the regression weights of a given predictor across participants differed significantly from zero (Lorch & Myers, 1990).

For Experiment 1, we assigned the feature integration variable the value 0 when a given trial was a complete repetition/alternation of all task features (valence of the target, valence of the distractor stimulus, and stimulus position) and the value 1 when it was a partial repetition. The other variables in the model were valence-based congruency, spatial congruency, valence-based congruency in the preceding trial, and spatial congruency in the preceding trial (all coded 0 or 1), as well as the interactions of current and previous valence-based congruency and current and previous spatial congruency. The mean regression weights for the interaction of previous and current congruency remained significant for spatial congruency in Experiment 1a, $t(15) = -3.09$, $p = .007$, and in Experiment 2, $t(15) = -4.31$, $p = .001$, but not for Experiment 1b, $t(11) = -1.46$, $p = .171$. The regression weights for the sequential modulation of valence-based congruency approached significance in Experiment 1b, $t(11) = -2.01$, $p = .069$, but not in Experiment 2, $t(15) = 0.770$, $p = .454$ (all two-tailed). These analyses should

be viewed as preliminary because some of the predictor variables were correlated, but they suggest that feature repetition does not provide a full explanation of the present sequence effects. This conclusion fits quite well with recent evidence showing that conflict adaptation effects remain when such feature repetition effects are controlled for experimentally (Egner, 2007; Kerns et al., 2004; Kunde & Wühr, 2006; Ullsperger, Bylsma, & Botvinick, 2005).

To conclude, when placing the present study into the literature on the domain generality of conflict adaptation, it appears that there might be some general adaptation mechanisms within nonaffective types of interference, such as between Stroop and Eriksen interference (Freitas et al., 2007) or between SNARC-like (“spatial numerical association of response codes”) and Simon interference (Notebaert & Verguts, 2008) or priming-like and Simon interference (Kunde & Wühr, 2006). However, the present findings clearly suggest that adaptation effects do not cross the border between valence-based and spatial interference. This outcome complies quite well with the existence of two neurally distinct adaptation mechanisms for resolving cognitive and emotional conflict (Ochsner et al., 2009). An interesting question for future research might be whether general adaptation effects exist within the affective domain, such as when combining valence-based interference at the stimulus level with valence-based interference at the response level.

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References

- Algom, D., Chajut, E., & Lev, S. (2004). A rational look at the emotional Stroop phenomenon: A generic slowdown, not a Stroop effect. *Journal of Experimental Psychology: General*, *133*, 323–338.
- Botvinick, M. M. (2007). Conflict monitoring and decision making: Reconciling two perspectives on anterior cingulate function. *Cognitive, Affective, & Behavioral Neuroscience*, *7*, 356–366. doi:10.3758/CABN.7.4.356
- Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., & Cohen, J. D. (2001). Conflict monitoring and cognitive control. *Psychological Review*, *108*, 624–652. doi:10.1037/0033-295X.108.3.624
- Cho, R. Y., Orr, J. M., Cohen, J. D., & Carter, C. S. (2009). Generalized signaling for control: Evidence from postconflict and posterror performance adjustments. *Journal of Experimental Psychology: Human Perception and Performance*, *35*, 1161–1177.
- De Houwer, J., & Eelen, P. (1998). An affective variant of the Simon paradigm. *Cognition & Emotion*, *12*, 45–61.
- Egner, T. (2007). Congruency sequence effects and cognitive control. *Cognitive, Affective, & Behavioral Neuroscience*, *7*, 380–390. doi:10.3758/CABN.7.4.380
- Egner, T. (2008). Multiple conflict-driven control mechanisms in the human brain. *Trends in Cognitive Science*, *12*, 374–380. doi:10.1016/j.tics.2008.07.001
- Egner, T., Etkin, A., Gale, S., & Hirsch, J. (2008). Dissociable neural systems resolve conflict from emotional versus nonemotional distracters. *Cerebral Cortex*, *18*, 1475–1484.

- Egner, T., & Hirsch, J. (2005). Cognitive control mechanisms resolve conflict through cortical amplification of task-relevant information. *Nature Neuroscience*, *8*, 1784–1790. doi:10.1038/nm1594
- Etkin, A., Egner, T., Peraza, D. M., Kandel, E. R., & Hirsch, J. (2006). Resolving emotional conflict: A role for the rostral anterior cingulate cortex in modulating activity in the amygdala. *Neuron*, *51*, 871–882.
- Fan, J., Flombaum, J. I., McCandliss, B. D., Thomas, K. M., & Posner, M. I. (2003). Cognitive and brain consequences of conflict. *NeuroImage*, *18*, 42–57.
- Freitas, A. L., Bahar, M., Yang, S., & Banai, R. (2007). Contextual adjustments in cognitive control across tasks. *Psychological Science*, *18*, 1040–1043. doi:10.1111/j.1467-9280.2007.02022.x
- Frings, C., & Wentura, D. (2008). Trial-by-trial effects in the affective priming paradigm. *Acta Psychologica*, *128*, 318–323.
- Funes, M. J., Lupiáñez, J., & Humphreys, G. (2010). Analyzing the generality of conflict adaptation effects. *Journal of Experimental Psychology: Human Perception and Performance*, *36*, 147–161. doi:10.1037/a0017598
- Gratton, G., Coles, M. G. H., & Donchin, O. (1992). Optimizing the use of information: Strategic control of activation of responses. *Journal of Experimental Psychology: General*, *121*, 480–506. doi:10.1037/0096-3445.121.4.480
- Hommel, B., Proctor, R. W., & Vu, K.-P. L. (2004). A feature-integration account of sequential effects in the Simon task. *Psychological Research*, *68*, 1–17. doi:10.1007/s00426-003-0132-y
- Kerns, J. G., Cohen, J. D., MacDonald, A. W., III, Cho, R. Y., Stenger, V. A., & Carter, C. S. (2004). Anterior cingulate conflict monitoring and adjustments in control. *Science*, *303*, 1023–1026. doi:10.1126/science.1089910
- Kiesel, A., Kunde, W., & Hoffman, J. (2006). Evidence for task-specific resolution of response conflict. *Psychonomic Bulletin & Review*, *13*, 800–806.
- Kleinsorge, T. (2007). Anticipatory modulation of interference induced by unpleasant pictures. *Cognition & Emotion*, *21*, 404–421.
- Kleinsorge, T. (2009a). Anticipation selectively enhances interference exerted by pictures of negative valence. *Experimental Psychology*, *56*, 228–235.
- Kleinsorge, T. (2009b). Stimulus–response compatibility based on affective arousal. *Cognition & Emotion*, *23*, 663–674.
- Kunde, W., & Mauer, N. (2008). Sequential modulations of valence processing in the emotional Stroop task. *Experimental Psychology*, *55*, 151–156.
- Kunde, W., & Stöcker, C. (2002). A Simon effect for stimulus–response duration. *Quarterly Journal of Experimental Psychology*, *55A*, 581–592.
- Kunde, W., & Wühr, P. (2006). Sequential modulations of correspondence effects across spatial dimensions and tasks. *Memory & Cognition*, *34*, 356–367. doi:10.3758/BF03193413
- LeDoux, J. E. (2000). Emotion circuits in the brain. *Annual Review of Neuroscience*, *23*, 155–184. doi:10.1146/annurev.neuro.23.1.155
- Loftus, G. R., & Masson, M. E. J. (1994). Using confidence intervals in within-subject designs. *Psychonomic Bulletin & Review*, *1*, 476–490. doi:10.3758/BF03210951
- Lorch, R. F., Jr., & Myers, J. L. (1990). Regression analyses of repeated measures data in cognition research. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *16*, 149–157. doi:10.1037/0278-7393.16.1.149
- Mayr, U., Awh, E., & Laurey, P. (2003). Does conflict adaptation require executive control? *Nature Neuroscience*, *6*, 450–452.
- Mayr, S., Erdfelder, E., Buchner, A., & Faul, F. (2007). A short tutorial of GPower. *Tutorials in Quantitative Methods for Psychology*, *3*, 51–59.
- McKenna, F. P., & Sharma, D. (2004). Reversing the emotional Stroop effect reveals that it is not what it seems: The role of fast and slow components. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*, 382–392.
- Notebaert, T., & Verguts, T. (2007). Dissociating conflict adaptation from feature integration: A multiple regression approach. *Journal of Experimental Psychology: Human Perception and Performance*, *33*, 1256–1260.
- Notebaert, W., & Verguts, T. (2008). Cognitive control acts locally. *Cognition*, *106*, 1071–1080.
- Ochsner, K. N., Hughes, B., Robertson, E. R., Cooper, J. C., & Gabrieli, J. D. E. (2009). Neural systems supporting the control of affective and cognitive conflicts. *Journal of Cognitive Neuroscience*, *21*, 1841–1854. doi:10.1162/jocn.2009.21129
- Öhman, A., & Mineka, S. (2001). Fears, phobias, and preparedness: Towards an evolved module of fear and fear learning. *Psychological Review*, *108*, 483–522.
- Padmala, S., Bauer, A., & Pessoa, L. (2011). Negative emotion impairs conflict-driven executive control. *Frontiers in Emotion Science*, *4*, 192.
- Pratto, F., & John, O. P. (1991). Automatic vigilance: The attention grabbing power of negative social information. *Journal of Personality and Social Psychology*, *61*, 380–391.
- Proctor, R. W., & Vu, K.-P. L. (2002). Mixing location-irrelevant and location-relevant trials: Influence of stimulus mode on spatial compatibility effects. *Memory & Cognition*, *30*, 281–293. doi:10.3758/BF03195289
- Reeck, C., & Egner, T. (2011). Affective privilege: asymmetric interference by emotional distracters. *Frontiers in Psychology*, *2*, 1–7.
- Schimmack, U. (2005). Attentional interference effects of emotional pictures: Threat, negativity, or arousal? *Emotion*, *5*, 55–66.
- Simon, J. R. (1969). Reactions towards the source of stimulation. *Journal of Experimental Psychology*, *81*, 174–176.
- Simon, J. R., & Berbaum, K. (1990). Effect of conflicting cues on information processing: The “Stroop effect” vs. the “Simon effect.”. *Acta Psychologica*, *73*, 159–170.
- Sternberg, S. (1969). The discovery of processing stages: Extensions of Donders’ method. *Acta Psychologica*, *30*, 276–315. doi:10.1016/0001-6918(69)90055-9
- Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, *18*, 643–662. doi:10.1037/0096-3445.121.1.15
- Ullsperger, M., Bylsma, L. M., & Botvinick, M. M. (2005). The conflict adaptation effect: It’s not just priming. *Cognitive, Affective, & Behavioral Neuroscience*, *5*, 467–472. doi:10.3758/CABN.5.4.467
- van Steenbergen, H., Band, G. P. H., & Hommel, B. (2009). Reward counteracts conflict adaptation: Evidence for a role of affect in executive control. *Psychological Science*, *20*, 1473–1477.
- van Steenbergen, H., Band, G. P. H., & Hommel, B. (2010). In the mood for adaptation: How affect regulates conflict-driven control. *Psychological Science*, *21*, 1629–1634.
- Verguts, T., Notebaert, W., Kunde, W., & Wühr, P. (2011). Post-conflict slowing: Cognitive adaptation after conflict processing. *Psychonomic Bulletin & Review*, *18*, 76–82. doi:10.3758/s13423-010-0016-2
- Voß, A., Rothermund, K., & Wentura, D. (2003). Estimating the valence of single stimuli: A new variant of the affective Simon task. *Experimental Psychology*, *50*, 86–96.
- Williams, J. M. G., Mathews, A., & MacLeod, C. (1996). The emotional Stroop task and psychopathology. *Psychological Bulletin*, *120*, 3–24. doi:10.1037/0033-2909.120.1.3
- Wühr, P. (2006). The Simon effect in vocal responses. *Acta Psychologica*, *121*, 210–226. doi:10.1016/j.actpsy.2004.12.003
- Wühr, P., & Ansorge, U. (2005). Exploring trial-by-trial modulations of the Simon effect. *Quarterly Journal of Experimental Psychology*, *58A*, 705–731. doi:10.1080/02724980443000269