Asymmetric transfer effects between cognitive and affective task disturbances

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Task-irrelevant features of a stimulus can disturb performance on a given task, and this can occur for cognitive reasons such as irrelevant stimulus position, and affective reasons such as high stimulus valence. The human brain adapts to such disturbances in order to ensure successful task performance. Adaptations can occur in a transient manner in response to recent events, and they can also be sustained to account for overall probabilities of disturbances. Here, we study the mutual interplay between affective and cognitive task disturbances under conditions of sustained conflict adaptation. More precisely, we examined the trajectory of finger movements in a speeded classification task and investigated whether adaptation to a high probability of spatial disturbances transfers to the impact of affective disturbances (Experiment 1) and whether adaptation to a high probability of affective disturbances transfers to the impact of spatial disturbances (Experiment 2). Our observations point towards an asymmetric transfer from adaptation to affective onto the processing of cognitive disturbances, but not the other way around.

In a constantly changing and ambiguous environment, it is important to focus on currently task-relevant information to guarantee successful behaviour. At the same time, currently irrelevant information that conflicts with relevant information needs to be suppressed or inhibited. The human cognitive system is prone to errors caused by irrelevant stimulus information, such as the location of a stimulus (Simon & Rudell, 1967). When a stimulus is supposed to elicit a right-hand response, but is presented on the left side, the irrelevant location conflicts with the upcoming motor response and thereby deteriorates performance. In this case,

cognitive control ensures the success of future actions by reconfiguring the cognitive system according to the current task affordances, focusing on the relevant and inhibiting the irrelevant information (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Egner & Hirsch, 2005). On the next trial, interference effects would therefore be reduced; the task-irrelevant stimulus information would be less detrimental to the current performance (Gratton, Coles, & Donchin, 1992). Such *transient* conflict adaptations to recent events by adjusting perceptual selection and regulating response biases are the main process that counteracts short-term task disturbances.

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Besides transient adaptations, there are *sustained* adaptations to the frequency of interfering events (Logan & Zbrodoff, 1979; Lowe & Mitterer, 1982; West & Baylis, 1998), which can occur independently of transient effects (Funes, Lupiáñez, & Humphreys, 2010). Take for example a block with very few incongruent Simon trials. Here, giving in to the automatic response tendencies elicited by the mainly congruent stimulus location is beneficial, because in most cases, the location of the stimulus suggests the required response. Therefore, the task-irrelevant stimulus dimension is taken into account. In a block in which incongruent trials are frequent, giving in to the automatic response tendency elicited by the stimulus location would be harmful to performance, because it frequently conflicts with the planned motor response. Cognitive control processes should in this case weigh the stimulus' location to a far lesser extent to secure an adequate level of speed and accuracy. That is why, in a high-conflict environment, congruency effects are overall smaller, because task-irrelevant information is considered less and can therefore neither benefit in congruent, nor harm in incongruent trials.

Another important source of task disturbance is the valence of a stimulus. In the emotional Stroop task (Kunde & Mauer, 2008; Schimmack & Derryberry, 2005), participants respond to a relevant dimension of a stimulus (e.g., the colour of a word or the frame colour of a picture) while ignoring the irrelevant information (word meaning or picture content). Additionally, the target has a valent dimension that can either be positive such as the picture of a baby, neutral such as the picture of a chair or negative such as the picture of a corpse. The emotional Stroop effect denotes the response slowdown in trials with affective (positive, negative) compared to neutral targets. In contrast to the Simon task, however, there is no dimensional overlap between the irrelevant (affective) and the relevant information of the target, but still the valent information may deteriorate performance. Therefore, these task disturbances are referred to as valence-based task *interruptions*, rather than interferences (Augst, Kleinsorge, & Kunde, 2014; Kunde, Augst, & Kleinsorge, 2012). Several

accounts have been proposed to explain how, without interfering with the primary cognitive task, affective stimuli can decrease performance. The most prominent explanation ascribes the slowdown to an automatic capture of the participant's attention to the affective dimension of the stimulus, hence limiting the capacity available for the cognitive task (Pratto & John, 1991). The cognitive system then exercises cognitive control in order to keep performance on a high level, making responses in trials following those of high stimulus valence slower, but less vulnerable to errors (Kunde & Mauer, 2008).

Recent studies on the relation of cognitive and affective task disturbances have approached the question of whether or not these stimulus dimensions hold separate roles in information processing (Botvinick, 2007; Dreisbach & Fischer, 2012). These studies argued that both kinds of task disturbances are coded in the same *language* and might therefore interact with each other. There is in fact empirical support for the aversive character of cognitive conflict. When for example confronted with incongruent Stroop words, subsequent responses to negative targets are faster compared to those responses following congruent Stroop words. Conversely, positive targets are evaluated slower after incongruent Stroop words than after congruent Stroop words (Dreisbach & Fischer, 2012; Fritz & Dreisbach, 2013, in press). Cognitive conflict might thus serve as another negative signal that helps maintain a certain level of performance by means of transient adjustments to the experienced aversive event. But whether these adaptations caused by cognitive and affective signals are equally universal and prepare the cognitive system to the same extent to upcoming cognitive and affective task disturbances has yet to be demonstrated.

Whether or not actual performance adaptations can transfer across different kinds of task disturbance is still under debate. With respect to transient adaptations, one type of cognitive task disturbance (e.g., of the Simon type) seems to rarely modulate disturbance of another type (e.g., of the Stroop type), though several exceptions exist (for a review cf. Braem, Abrahamse, Duthoo, & Notebaert, 2014). In an own study we found no transfer of

transient adaptations across spatial and affective task disturbances (Kunde, Augst, & Kleinsorge, 2012). In that study, participants completed a Simon task that contained a valence-based interrupting stimulus dimension (valent picture on the left/right side of the screen). While there were reduced Simon effects after spatially incongruent trials, never were there cross-domain adaptations that we would expect under the premise of universal adaptation processes.

With respect to sustained adaptations, the transfer between different kinds of task disturbance has been studied less frequently. Still, the evidence so far shows that such transfer of sustained effects is possible. When for example in a combined conflict paradigm with Simon and Stroop conflict, the proportion of incongruent Simon trials increases, the congruency effect in interspersed Stroop trials reduces as well, even when the Stroop congruency proportion is not varied at all (Funes et al., 2010; Torres-Quesada, Funes, & Lupiáñez, 2013; Wühr, Duthoo, & Notebaert, 2014).

The evidence for transfer of sustained adaptation effects is thus encouraging. Consequently sustained adaptations present a fitting candidate for studying whether the adjustments that are triggered by cognitive or affective signals in principle can transfer between both types of task disturbance. Specifically, we designed experiments that involved spatial conflict, as well as valence-based task interruptions by adding a valent dimension to the target stimulus. Crucially, we varied presentation frequencies, which allowed for triggering sustained adaptations by manipulating the proportion of congruent trials (Experiment 1) or the proportion of negative trials (Experiment 2) between blocks, calling for higher sustained control in blocks with a high frequency of incongruent/negative trials. The critical question was whether manipulating the frequency one type of task disturbance would change the impact of the respectively other (but not manipulated) type of task disturbance.

We applied an innovative two-dimensional finger-tracking design in order to differentiate between response initiation and response execution (Song & Nakayama, 2008). This approach also gives access to continuous parameters of a motor

response, making it possible to measure the impact of task disturbances not only as an extra amount of time that it takes to complete incongruent or interfering trials, but also as distinct spatial affordances. Thereby, subtle differences in the execution of the response can be registered and analysed. The application of continuous measurements has been shown to be sensitive towards both, cognitive factors (Pfister, Janczyk, Wirth, Dignath, & Kunde, 2014; Scherbaum, Dshemuchadse, Fischer, & Goschke, 2010; Spivey, Grosjean, & Knoblich, 2005) and affective factors (Dignath, Pfister, Eder, Kiesel, & Kunde, 2014; Koop & Johnson, 2013).

EXPERIMENT 1

In Experiment 1, participants completed a simple Simon task by sweeping their finger from a starting area to a left or a right target-area on the touchscreen of an iPad. We induced cognitive conflict in terms of congruent and incongruent Simon trials, and valence-based interruptions by varying the valence of the stimulus. Most importantly, we manipulated the proportion of congruent trials of the Simon task across blocks in order to create high- and low-conflict environments, which, in turn, called for high- and low amount of sustained cognitive control. First, we expected to observe a regular proportion congruency effect in terms of reduced congruency effects in the mainly incongruent context. The critical question, however, was whether or not the proportion congruency manipulation also affected the valence-based interruption effect, i.e., whether the size of the interruption effect would be reduced for blocks that featured mainly incongruent trials.

Method

Participants

Sixteen participants from the University of Würzburg were recruited and received either course credit or €5 monetary compensation (mean age = 24.8 years, SD = 6.3, 5 male, one left-handed). All participants gave informed consent, were naive to

the purpose of the experiment and were debriefed after the session.

Apparatus and stimuli

The experiment was run on an iPad in portrait mode, which sampled the participants' finger movements at 100 Hz. Viewing distance was about 50 cm and target stimuli were taken from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999). We used 20 pictures per valence (negative, neutral and positive), with 10 human and 10 non-human pictures for each valence (for example a corpse, a cut-up hand, a dirty toilet or a cockroach for negative, a man sitting on a train, a man standing on a corner, a hydrant or a light bulb for neutral and a baby, a happy couple, a puppy or dolphins for positive trials, see Table A1 in the Appendix, for a detailed list of the picture set). Picture boxes measured 6.1 cm × 4.6 cm and were presented in the upper left and right corners of the screen. The boxes were filled with either an IAPS picture or with dark grey colour. The box locations were separated by 7.5 cm (centre-to-centre). The starting position for the movement (a circle of 1 cm in diameter) was located 15 cm from the middle of the two target positions at an angle of 25° to each side. Stimuli were presented against a light grey background (see Figure 1).

Procedure

Each trial started by touching the starting area with the index finger. Both picture boxes (one filled with an IAPS picture, one filled with grey colour) appeared after a dwell time of 500 ms, highlighting the two possible destinations of the finger's movement. Half of the participants were instructed to make a smooth finger movement to the left box if the picture showed a human and to the right box if it did not, irrespective of the position of the picture itself. The second half of participants was instructed with the opposite S-R mapping for counterbalancing. In any case, this procedure yielded both, spatially congruent trials (picture position corresponding to movement-endpoint) and spatially incongruent trials (picture position opposite to movement-endpoint). The pictures remained

Figure 1. Setting of the experiments: Participants dragged their finger in a smooth, continuous movement from the starting area on the bottom of the screen to one of the two areas marked by the rectangles. The target-area was determined by the content of the picture, not its position. This example shows a spatially incongruent trial with a positive picture.

on-screen until the finger was lifted. Error feedback was displayed if the wrong target-area was chosen, response initiation or execution was too slow or if participants took too long to start a new trial. Participants were instructed to respond quickly and accurately; still the experiment was self-paced, so participants chose on their own when to start a trial and how long they took breaks in between blocks.

Participants completed 16 blocks of 60 trials, with each of the 60 IAPS pictures being presented once per block, either in the left or the right picture box. Picture position was counterbalanced across blocks, so that every picture appeared equally often on the left and on the right side of the screen. In the first 8 blocks of the experiment there was a high

proportion of spatially congruent trials (80% congruent trials), whereas there was a low proportion of congruent trials (20%) in the last 8 blocks for half of the participants, the other half was presented with the reversed proportion congruency order.

Results

Data treatment

We analysed four variables of each movement: The time from stimulus onset to movement initiation (initiation time; IT), the duration of the movement (movement time; MT), the starting angle of the movement (starting angle; SA) and the area between the actual trajectory and a straight line from start- to endpoint (area under the curve; AUC). Positive values for AUC and smaller (or negative) values of SA indicate that a movement is attracted to the competing response alternative and mirror the spatial effects of Simon-incongruent trials (Figure 1).

IT was recorded as soon as the finger left the starting area. From this point, x- and y-coordinates were recorded; MT was determined when the finger left the touchscreen. Movements to the left were mirrored at the vertical midline for further analysis. AUC and SA were processed from the

time-normalised coordinate data for each trial by using custom MATLAB scripts (The Mathworks, Inc.).

Data selection and analyses

For the following analyses, we omitted trials in which participants ended their movement on the wrong target-area (errors; 1.4%) or failed to hit any of the two target-areas at all (omissions; 6.3%). Trials were discarded as outliers if any of the measures (IT, MT, SA, AUC) deviated more than 2.5 standard deviations from their respective cell mean (8.4%). The four measures were then analysed in separate 3 × 2 × 2 ANOVAs with picture valence (negative, neutral, positive), spatial congruency (congruent vs. incongruent) and proportion congruency (80% congruent blocks vs. 20% congruent blocks) as within-subject factors (for condition means, see Table 1). Post-hoc t-tests for all analyses were two-tailed.

Response initiation

Initiation times. There was a significant effect of picture valence, $F(2, 14) = 7.97$, $p = .005$, $\eta_p^2 = .53$. Pairwise comparisons revealed that movements were initiated later with negative

Table 1. *Mean ITs (in milliseconds), SAs (in degrees), MTs (in milliseconds) and areas under the curve (AUCs, in $10^3 px^2$) in Experiment 1 as a function of proportion congruency and valence (columns), and current spatial congruency (rows)*

		Proportion congruency					
		80% congruent blocks			20% congruent blocks		
		Valence			Valence		
Measure	Congruency	Negative	Neutral	Positive	Negative	Neutral	Positive
IT	Congruent	511	496	449	563	540	541
	Incongruent	522	515	516	556	536	537
SA	Congruent	12.7	13.3	12.9	6.6	7.1	6.4
	Incongruent	−2.4	−1.1	−2.7	5.9	6.4	6.0
MT	Congruent	578	560	566	617	591	610
	Incongruent	694	662	663	605	587	590
AUC	Congruent	13.7	12.6	13.2	35.7	29.4	32.3
	Incongruent	68.6	59.2	61.7	29.8	28.8	28.3

(539 ms) than with neutral (521 ms) pictures, $t(15) = 4.15$, $p = .001$, $d = 1.04$ or positive (522 ms) pictures, $t(15) = 4.85$, $p < .001$, $d = 1.21$, whereas ITs did not differ significantly between neutral and positive pictures, $t(15) = 0.95$, $p = .335$, $d = 0.24$. Moreover participants initiated movements later when the congruency proportion was low (545 ms) rather than high (507 ms), $F(1, 15) = 6.26$, $p = .024$, $\eta_p^2 = .30$. Finally, there was an interaction between spatial congruency and proportion congruency, $F(1, 15) = 8.17$, $p = .012$, $\eta_p^2 = .35$, with a strong congruency effect when the proportion of congruent trials was high ($\Delta = 21$ ms), $t(15) = 3.70$, $p = .002$, $d = 0.92$, and a descriptively reversed congruency effect when the congruency proportion was low ($\Delta = -5$ms), $t(15) = -1.05$, $p = .309$, $d = 0.26$ (Figure 2A). Most importantly, there was no interaction of proportion congruency and picture valence, $F(2, 14) = 1.17$, $p = .339$, $\eta_p^2 = .14$ (Figure 2B), nor any other effect ($Fs < 2.32$, $ps > .149$).

Starting angles. There was a significant effect of picture valence, $F(2, 14) = 5.14$, $p = .021$, $\eta_p^2 = .42$. Pairwise comparisons revealed that the initial movement trajectory was steeper with negative (8.07°) than with neutral (8.60°) pictures, $t(15) = 2.53$, $p = .023$, $d = 0.63$. Positive pictures (8.18°) differed from neither negative nor neutral pictures ($ps > .145$). Moreover participants' initial movement trajectory was more shallow in congruent (11.64°) than in incongruent (4.64°) trials, $F(1, 15) = 33.24$, $p < .001$, $\eta_p^2 = .69$. Finally, there was an interaction between spatial congruency and proportion congruency, $F(1, 15) = 54.85$, $p < .001$, $\eta_p^2 = .79$, with a strong congruency effect when the proportion of congruent trials was high ($\Delta = 15.01°$), $t(15) = 8.88$, $p < .001$, $d = 2.22$, resulting in initial movements to the opposite side in incongruent trials, and no congruency effect at all when the congruency proportion was low ($\Delta = 0.32°$), $t(15) = 0.21$, $p = .833$, $d = 0.05$ (Figure 2C). Most importantly, there was no interaction of proportion congruency and picture valence, $F(2, 14) = 0.31$, $p = .738$, $\eta_p^2 = .04$ (Figure 2D), nor any other effect ($Fs < 1.90$, $ps > .188$).

Response execution

Movement times. There was a significant effect of picture valence, $F(2, 14) = 14.10$, $p < .001$, $\eta_p^2 = .67$. Pairwise comparisons revealed that movements were executed slower with negative (603 ms) than with neutral (585 ms) pictures, $t(15) = 6.15$, $p < .001$, $d = 1.54$ or positive (590 ms) pictures, $t(15) = 4.36$, $p < .001$, $d = 1.21$ and MTs were also higher with positive than with neutral pictures, $t(15) = 2.48$, $p = .025$, $d = 0.62$. Moreover participants executed movements faster in congruent (577 ms) than in incongruent (610 ms) trials, $F(1, 15) = 22.78$, $p < .001$, $\eta_p^2 = .60$. Finally, there was an interaction between spatial congruency and proportion congruency, $F(1, 15) = 54.26$, $p < .001$, $\eta_p^2 = .78$, with a strong congruency effect when the proportion of congruent trials was high ($\Delta = 105$ ms), $t(15) = 7.61$, $p < .001$, $d = 1.90$, and a descriptively reversed congruency effect when the congruency proportion was low ($\Delta = -13$ ms), $t(15) = 1.37$, $p = .191$, $d = 0.34$ (Figure 3A). Most importantly, the interaction of proportion congruency and picture valence was not significant, $F(2, 14) = 1.39$, $p = .281$, $\eta_p^2 = .17$ (Figure 3B), nor was any of the remaining effects ($Fs < 3.17$, $ps > .095$).

Area under the curve. There was a significant effect of picture valence, $F(2, 14) = 4.92$, $p = .024$, $\eta_p^2 = .41$. Pairwise comparisons revealed that movements were marginally more contorted with negative (26703 px^2) than with neutral (24856 px^2) pictures, $t(15) = 2.05$, $p = .058$, $d = 0.51$. Positive pictures (25175 px^2) differed from negative, $t(15) = 2.54$, $p = .023$, $d = 0.64$, but not from neutral pictures, $t(15) = 0.44$, $p = .667$, $d = 0.11$. Moreover participants' movement execution was more shallow in congruent (16990 px^2) than in incongruent (35131 px^2) trials, $F(1, 15) = 40.14$, $p < .001$, $\eta_p^2 = .73$ and more convex in blocks with high proportion of incongruent trials (29269 px^2) than in blocks with high proportion of congruent trials (22704 px^2), $F(1, 15) = 9.60$, $p = .007$, $\eta_p^2 = .39$. Finally, there was an interaction between spatial congruency and proportion congruency, $F(1, 15) = 53.71$, $p < .001$, $\eta_p^2 = .78$, with a strong
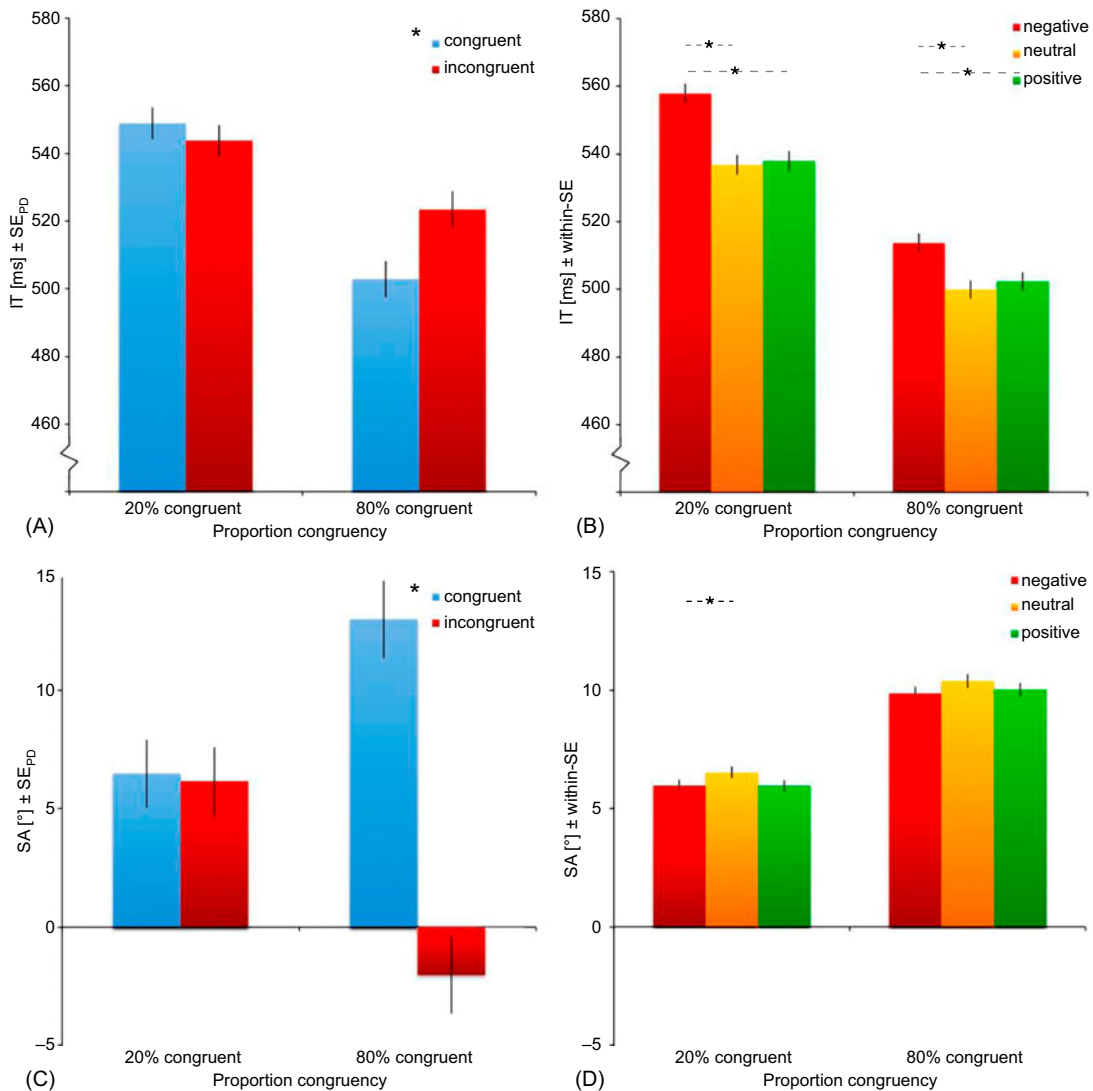
Figure 2. *Results for movement initiation of Experiment 1. Mean ITs (top row) and mean SAs (bottom row) as a function of current spatial congruency (left) and stimulus valence (right), each separately for low and high proportion congruency. Error bars represent standard errors of paired differences, calculated separately for each comparison of congruent and incongruent trials (left panels; Pfister & Janczyk, 2013) or within-subjects standard errors for each comparison of stimulus valences (right panels; Loftus & Masson, 1994).*

congruency effect when the proportion of congruent trials was high (Δ = 48665 px^2), $t(15)$ = 8.60, $p <$ .001, d = 2.15 and a descriptively reversed congruency effect when the congruency proportion was low (Δ = -3801 px^2), $t(15)$ = 0.99, p = .338, d = 0.25 (Figure 3C). Again, the interaction of proportion congruency and picture valence did not reach significance, $F(2, 14)$ = 0.38, p = .694, η_p^2 = .05

(Figure 3D), nor did any of the remaining effects (Fs < 3.03, ps > .081).

Error rates

As error rates were overall very low (1.4%); due to obvious floor effects, we chose not to analyse error rates further (see Dixon, 2008, for comments on floor and ceiling effects when analysing error data).
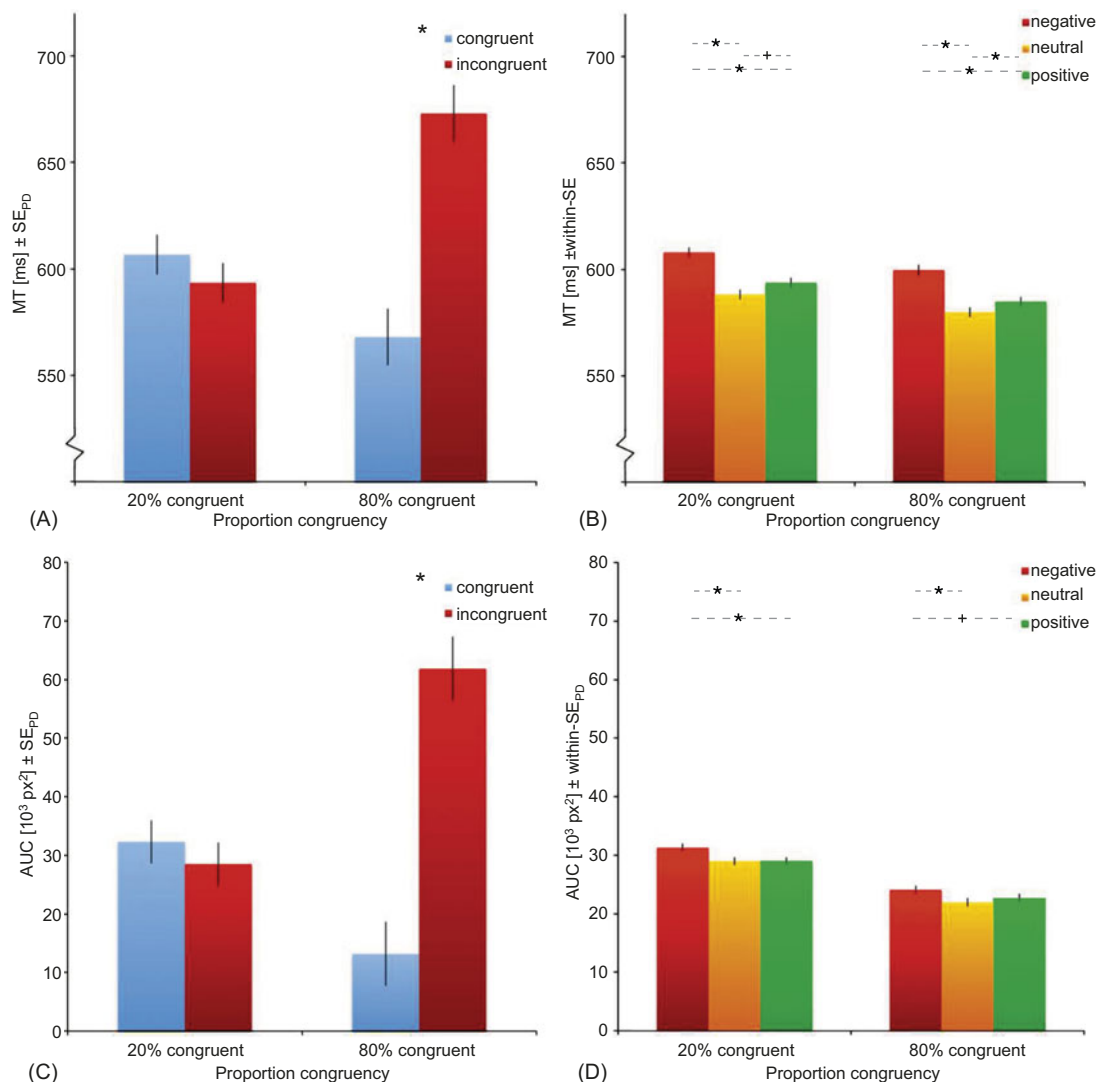
Figure 3. *Results for movement execution of Experiment 1. Mean MTs (top row) and mean areas under the curve (AUC; bottom row) as a function of current spatial congruency (left) and stimulus valence (right), each separately for low and high proportion congruency. Error bars represent standard errors of paired differences, calculated separately for each comparison of congruent and incongruent trials (left panels; Pfister & Janczyk, 2013) or within-subjects standard errors for each comparison of stimulus valences (right panels; Loftus & Masson, 1994).*

Follow-up analyses

To compare the impact of the proportion congruency manipulation, we computed separate ANOVAs on the individual sizes of cognitive disturbance effect (incongruent minus congruent) and affective disturbance effect (affective minus neutral) with proportion congruency (80% congruent blocks vs. 20% congruent blocks) and type of disturbance

(cognitive vs. affective) as within-subject factors for each of the four dependent variables.

Across all four dependent measures, we found main effects for proportion congruency (Fs > 8.16, ps < .012) and type of disturbance (Fs > 7.79, ps < .014). Moreover, there was a strong impact of proportion congruency on cognitive disturbance effects (IT: Δ = 20ms; SA: Δ = 14.44°;

MT: Δ = 117 ms; AUC: Δ = 53397 px^2; ts > 2.86, ps < .012) but not on affective disturbance effects (IT: Δ = 10 ms; SA: Δ = 0.50°; MT: Δ = −1 ms; AUC: Δ = 972 px^2; $|t|$s < 1.44, ps > .172) which led to significant interactions of proportion congruency and type of disturbance for SA, MT and AUC, Fs > 49.29, ps < .001, as well as a marginally significant interaction for IT, $F(1, 15)$ = 3.45, p = .083, η_p^2 = .19.

Analysis of JZS-Bayes-factors (Rouder, Speckman, Sun, Morey, & Iverson, 2009; http://pcl.missouri.edu/bayesfactor) for the cognitive disturbance effects revealed substantial evidence for an impact of proportion congruency for ITs, BF = 4.28, and decisive for the remaining three variables, BFs > 9386.59. For the affective disturbance effects, by contrast, this analysis did not favour any hypothesis for ITs, BF = 2.10, but showed substantial evidence in favour of a lack of an impact of proportion congruency for the remaining three variables, BFs > 3.90.

Discussion

In Experiment 1, we tested whether sustained adaptation to a high or low frequency of stimuli that were spatially incongruent with the required response, would modulate the impact of affective task disturbances by valent target pictures. While congruency effects diminished in high-conflict environments, indicating a strong modulation of the cognitive task, the size of the valence-based interruption was not affected. This pattern of results speaks against a shared control mechanism, because such a shared mechanism would render both types of disturbance similarly sensitive to modulation. Before drawing any further conclusions, we tested a possible transfer in the opposite direction. Experiment 2 therefore probed for modulation of the cognitive task under conditions of sustained adaptation to the affective task.

EXPERIMENT 2

In Experiment 2, we applied the same approach as in Experiment 1, but instead of manipulating the proportion of congruent trials to create high- and low-interfering settings, we now varied the proportion of negative pictures. This resulted in conditions that called for sustained adaptation to the proportion of interfering events. This allowed us to test whether valence-based interruptions can be modulated by sustained control processes at all and whether this adaptation does transfer to the impact of cognitive task disturbances.

Method

Participants

A new set of 16 participants from the University of Würzburg were recruited and received either course credit or €5 monetary compensation (mean age = 20.6 years, SD = 1.7, 2 male, all right-handed). All participants gave informed consent, were naive to the purpose of the experiment and were debriefed after the session.

Stimuli and procedure

Apparatus, stimuli and procedure were practically identical to Experiment 1, but we omitted all positive pictures, leaving 20 negative and 20 neutral pictures, with each 10 human and 10 non-human pictures. As interruption effects were almost exclusively driven by negative pictures in Experiment 1, high- and low-interfering conditions could be more easily implemented by varying the proportion of negative vs. neutral pictures. Moreover this procedure matched more closely the manipulation of high- and low-spatial interference in Experiment 1, where spatial congruency had two levels as well. In one half of the experiment there was a high proportion of negative pictures (80% negative), whereas there was a low proportion negative pictures (20%) in the other half. The order of valence proportions was counterbalanced across participants. Participants completed 20 blocks of 48 trials, with each of the 20 IAPS pictures of the frequent block-valence and 4 pictures of the infrequent block-valence each presented twice per block. Picture content and picture position was counterbalanced across blocks, so that every picture appeared equally often in the

experiment, both on the left and on the right side of the screen.

Results

Data selection and analyses

Data were processed exactly as in Experiment 1. For the following analyses, we omitted trials in which participants ended their movement on the wrong target-area (errors; 1.4%) or failed to hit any of the two target-areas at all (omissions; 8.2%). Trials were discarded as outliers if any of the measures (IT, MT, SA, AUC) deviated more than 2.5 standard deviations from their respective cell mean (6.6%). The four measures were then analysed in separate $2 \times 2 \times 2$ ANOVAs with picture valence (negative vs. neutral), spatial congruency (congruent vs. incongruent) and proportion negative (80% negative blocks vs. 20% negative blocks) as within-subjects factors (see Table 2 for condition means).

Response initiation

Initiation times. There was a significant effect of spatial congruency, $F(1, 15) = 6.97$, $p = .019$, $\eta_p^2 = .32$, with spatially congruent responses (549 ms) initiated faster than incongruent responses (555 ms). Moreover there was an interaction between the picture valence and proportion negative, $F(1, 15) =$

10.00, $p = .006$, $\eta_p^2 = .40$, with a significant interruption of negative pictures when the proportion of negative pictures was low ($\Delta = 17$ ms), $t(15) = 2.22$, $p = .042$, $d = 0.55$ and a descriptively reversed effect when the proportion of negative pictures was high ($\Delta = -10$ ms), $t(15) = -1.16$, $p = .263$, $d = 0.29$ (Figure 4B). Similarly, there was an interaction between spatial congruency and proportion negative, $F(1, 15) = 4.77$, $p = .045$, $\eta_p^2 = .24$, with a significant congruency effect when the proportion of negative pictures was low ($\Delta = 14$ ms), $t(15) = 2.85$, $p = .012$, $d = 0.71$, and a descriptively reversed congruency effect when the proportion of negative pictures was high ($\Delta = -5$ ms), $t(15) = -1.00$, $p = .334$, $d = 0.24$ (Figure 4A). No other effects reached significance (Fs < 2.66, ps $> .124$).

Starting angles. There was a significant effect of spatial congruency, $F(1, 15) = 19.77$, $p < .001$, $\eta_p^2 = .57$, with spatially incongruent responses (3.79°) initiated steeper than congruent responses (10.41°). Moreover there was an interaction between picture valence and proportion negative, $F(1, 15) = 15.91$, $p = .001$, $\eta_p^2 = .52$, with a strong interruption of negative pictures when the proportion of negative pictures was low ($\Delta = 2.29°$), $t(15) = 4.32$, $p = .001$, $d = 1.09$ and a reversed effect when the proportion of negative pictures was high

Table 2. *Mean ITs (in milliseconds), SAs (in degrees), MTs (in milliseconds) and areas under the curve (AUCs, in $10^3 px^2$) in Experiment 2 as a function of proportion negative and current valence (columns), and spatial congruency (rows)*

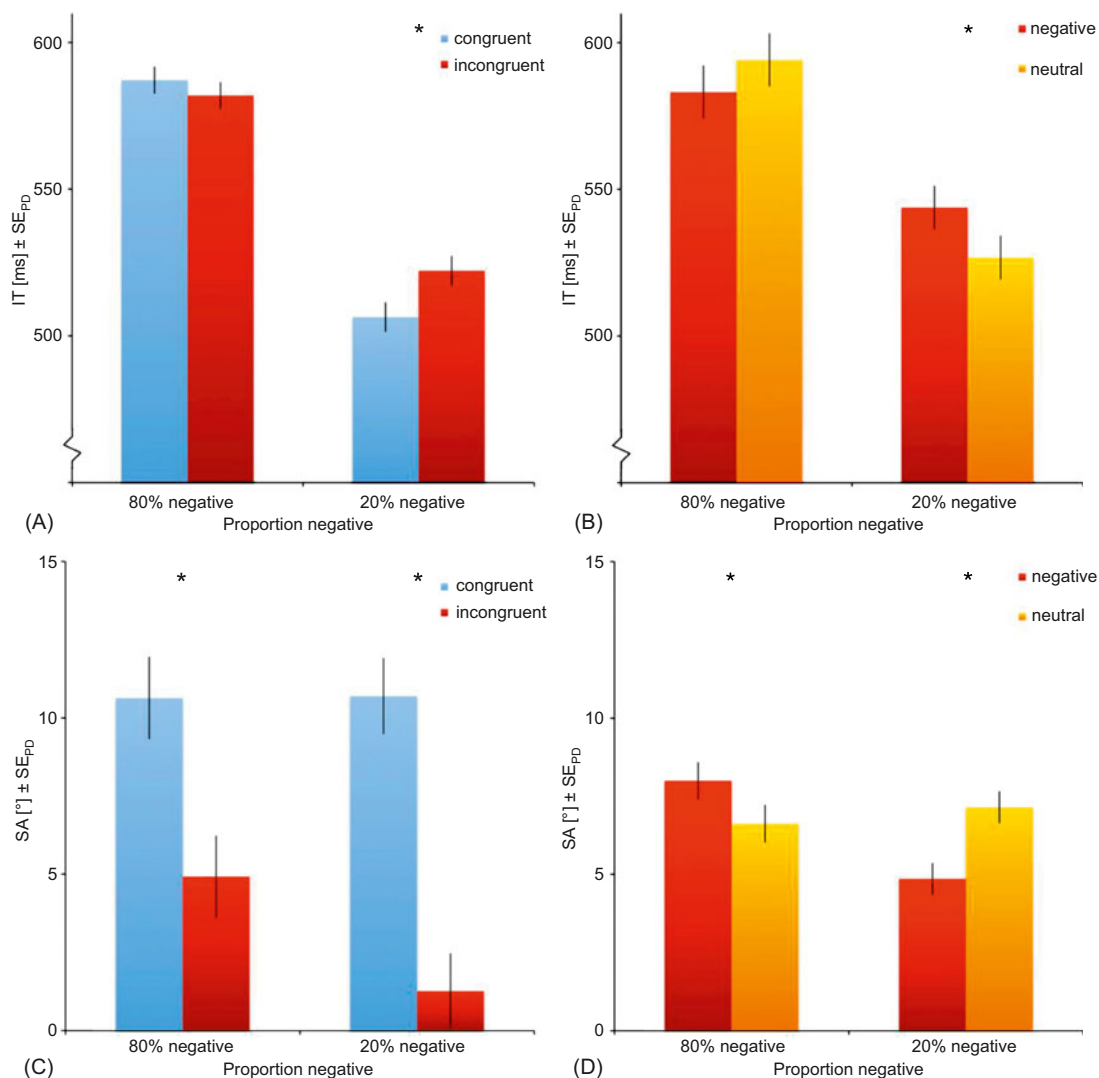| | | Proportion negative | | | |
| | | 80% negative blocks | | 20% negative blocks | |
| | | Valence | | Valence | |
Measure	Congruency	Negative	Neutral	Negative	Neutral
IT	Congruent	588	593	536	520
	Incongruent	581	597	551	553
SA	Congruent	11.0	8.6	8.8	10.9
	Incongruent	5.1	4.4	1.6	3.3
MT	Congruent	617	621	614	608
	Incongruent	643	665	683	651
AUC	Congruent	18.2	19.8	26.1	17.1
	Incongruent	32.3	33.3	45.8	37.1

Figure 4. *Results for movement initiation of Experiment 2. Mean ITs (top row) and mean SAs (bottom row) as a function of spatial congruency (left) and current stimulus valence (right), each separately for low and high proportion negative blocks. Error bars represent standard errors of paired differences (Pfister & Janczyk, 2013), calculated separately for each comparison of congruent and incongruent trials (left panels) or each comparison of negative and neutral trials (right panels).*

($\Delta = -1.38°$), $t(15) = -2.19$, $p = .044$, $d = 0.55$ (Figure 4D). Similarly, there was an interaction between spatial congruency and proportion negative, $F(1, 15) = 5.00$, $p = .041$, $\eta_p^2 = .25$, with a strong congruency effect when the proportion of negative pictures was low ($\Delta = 7.52°$), $t(15) = 5.53$, $p < .001$, $d = 1.37$, and a smaller congruency effect when the proportion of negative pictures was high

($\Delta = 5.71°$), $t(15) = 4.56$, $p < .001$, $d = 1.14$ (Figure 4C). No other effects reached significance ($Fs < 2.00$, $ps > .177$).

Response execution

Movement times. There was a significant effect of spatial congruency, $F(1, 15) = 22.38$, $p < .001$, $\eta_p^2 = .60$, with spatially congruent responses

(623 ms) being executed faster than incongruent responses (660 ms). Moreover there was an interaction between picture valence and proportion negative, $F(1, 15) = 62.56$, $p < .001$, $\eta_p^2 = .81$, with a strong interruption of negative pictures when the proportion of negative pictures was low ($\Delta = 33$ ms),

$t(15) = 6.19$, $p < .001$, $d = 1.55$, and a descriptively reversed effect when the proportion of negative pictures was high ($\Delta = -9$ ms), $t(15) = -1.72$, $p = .107$, $d = 0.43$ (Figure 5B). The interaction between spatial congruency and proportion negative was not significant, $F(1, 15) = 2.00$, $p = .178$, $\eta_p^2 = .12$
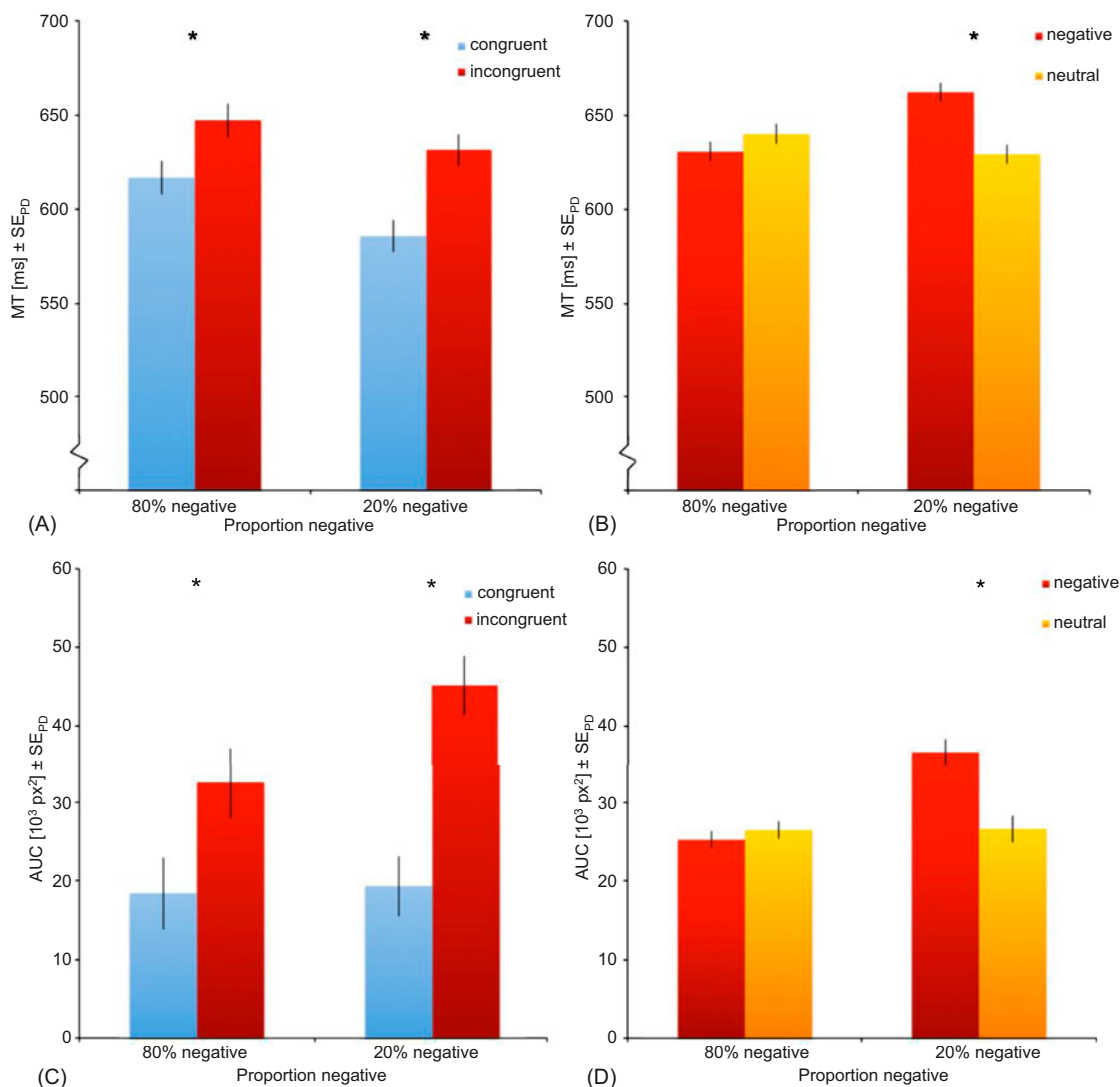

Figure 5. *Results for movement execution of Experiment 2. Mean MTs (top row) and mean areas under the curve (AUC; bottom row) as a function of current spatial congruency (left) and stimulus valence (right), each separately for low and high proportion negative. Error bars represent standard errors of paired differences (Pfister & Janczyk, 2013), calculated separately for each comparison of congruent and incongruent trials (left panels) or each comparison of negative and neutral trials (right panels).*

(Figure 5A). No other effects reached significance (Fs < 3.82, ps > .070).

Area under the curve. There was a significant effect of proportion negative, $F(1, 15) = 4.68$, $p = .047$, $\eta_p^2 = .29$, with responses overall less contorted if the proportion of negative pictures was high (25454 px^2) compared to low (28499 px^2). Similarly, there was an effect of picture valence, $F(1, 15) = 14.25$, $p = .002$, $\eta_p^2 = .49$, with movement trajectories less contorted with negative (26856 px^2) than with neutral pictures (27525 px^2). An effect of spatial congruency emerged, $F(1, 15) = 17.33$, $p = .001$, $\eta_p^2 = .54$, with spatially incongruent responses (35875 px^2) more contorted than congruent responses (18680 px^2). Moreover there was an interaction between the picture valence and proportion negative, $F(1, 15) = 32.30$, $p < .001$, $\eta_p^2 = .68$, with a strong interruption of negative pictures when the proportion of negative pictures was low ($\Delta = 9742$ px^2), $t(15) = 5.53$, $p < .001$, $d = 1.38$ and a descriptively reversed effect when the proportion of negative pictures was high ($\Delta = -1245$ px^2), $t(15) = -1.08$, $p = .297$, $d = 0.27$ (Figure 5D). Similarly, there was an interaction between spatial congruency and proportion negative, $F(1, 15) = 7.50$, $p = .015$, $\eta_p^2 = .33$, with a strong congruency effect when the proportion of negative pictures was low ($\Delta = 20123$ px^2), $t(15) = 4.26$, $p = .001$, $d = 1.06$ and a smaller congruency effect when the proportion of negative pictures was high ($\Delta = 14157$ px^2), $t(15) = 3.63$, $p = .002$, $d = 0.91$ (Figure 5C). No other effects reached significance (Fs < 0.04, ps > .845).

Error rates

Again, error rates were overall very low (1.4%) and we chose not to analyse them further due to floor effects.

Follow-up analyses

To compare the impact of the proportion negative manipulation on both types of disturbances, we computed separate ANOVAs on the individual sizes of cognitive disturbance effect (incongruent minus congruent) and affective disturbance effect (negative minus neutral) with proportion negative (80% negative blocks vs. 20% negative blocks) and type of disturbance (cognitive vs. affective) as within-subjects factors for each of the four dependent variables.

For the variables that mirror response execution (MT, AUC), we found main effects for proportion negative (Fs > 4.50, ps < .053). Equally, there were significant effects of type of disturbance (Fs > 18.07, ps < .001) for SA, MT and AUC. There was a strong impact of proportion negative on the valence disturbance effects (IT: $\Delta = 28$ ms; SA: $\Delta = 3.63°$; MT: $\Delta = 43$ ms; AUC: $\Delta = 10988$ px^2; ts > 3.49, ps < .003) and a smaller, but significant impact on cognitive disturbance effects (IT: $\Delta = 18$ ms; SA: $\Delta = 1.81°$; MT: $\Delta = 12$ ms; AUC: $\Delta = 5966$ px^2; ts > 2.33, ps < .035) which led to significant interactions of proportion negative and type of disturbance for all variables, Fs > 12.36, ps < .003.

Analysis of JZS-Bayes-factors (Rouder et al., 2009) for the cognitive disturbance effects revealed weak to substantial evidence for an impact of proportion negative, $2.00 < BFs < 6.10$. For the affective disturbance effects, this analysis yielded strong evidence for an impact of proportion negative on ITs, $BF = 13.80$, and decisive evidence for the remaining three variables, $BFs > 137.25$.

Discussion

In Experiment 2, we tested whether sustained adaptation to a high or low frequency of interrupting stimuli would modulate the impact of cognitive task disturbance. First, we found a strong modulation of the interruption effect by the proportion of negative pictures. In blocks with a high frequency of negative target pictures, the interruption effect disappeared and descriptively even reversed: now neutral pictures seemed to constitute the events that distracted participants. The classical view that attributes the performance reduction with negative pictures to their automatic capture of attention (Pratto & John, 1991) cannot explain why in a high-interrupting environment, the effect suddenly reverses, because it ascribes attentional capture to the negative property of the stimulus. It would

simply assume that valent information is suppressed and any differences between the valent- and the non-valent condition vanish. The descriptively reversed effect in the mainly negative condition might therefore reflect not influences of the picture valence, but rather influences due to the rareness, i.e., unexpectedness, of neutral stimuli (Melcher & Gruber, 2006; Notebaert et al., 2009; Sutton, Braren, Zubin, & John, 1965). When negative target pictures are presented frequently, the rareness of neutral stimuli reinforces the expectation of negative instead of neutral pictures. In trials with a neutral target, this expectation is violated, provoking an orienting reaction and attention capture that seems to override the vigilance associated with valent stimuli.

Contrary to the lack of transfer from adaptation to spatial interference to the impact of affective disturbances (Experiment 1), we found a modulation of the spatial interference effect by the frequency of negative stimuli (Experiment 2): Spatial congruency effects were reduced in blocks with a high proportion of negative targets. In other words, adaptation to a high frequency of negative pictures did indeed influence the size of the Simon effect. While Experiment 1 suggested separate task adaptations for cognitive and affective task disturbances, Experiment 2 shows that there is at least some interplay.

GENERAL DISCUSSION

In the present experiments, we set out to explore the mutual interplay between sustained task adaptations triggered by cognitive and affective task disturbances and their transfer from the cognitive to the affective (Experiment 1) and from the affective to the cognitive domain (Experiment 2). To this end, we used an integrated design, which featured both, cognitive and affective task disturbances. By varying the proportion of cognitive task disturbances (incongruent Simon trials), we created high- and low-conflict environments, calling for high- and low amounts of sustained cognitive control and by varying the proportion of negative pictures, we created high- and low-interrupting environments.

We investigated the impact of these proportion manipulations by means of measures taken from continuous finger movements of the participants.

In Experiment 1, we found adjustments of the Simon effect according to the amount of sustained cognitive control that had to be exercised, with a strong impact of the irrelevant stimulus dimension if the frequency of conflicting events was low, and a weaker impact if the frequency of conflicting events was high (cf. Crump & Milliken, 2009; Funes et al., 2010; Logan & Zbrodoff, 1979; Lowe & Mitterer, 1982; West & Baylis, 1998). This was true for both, the time-related measures that describe how long these processes take (IT, MT), and the trajectory-related measures that depict spatial characteristics of the response (SA, AUC). It is important to note that these results show that our experimental setting is sensitive towards cognitive conflict and can not only measure the Simon interference as the extra amount of time that it takes to complete incongruent trials, but also as distinct spatial distortions of these responses. Additionally, we found an effect of picture valence throughout the experiment, with pictures of high stimulus valence disrupting performance more than neutral pictures (Kunde & Mauer, 2008; Augst et al., 2014; Kunde et al., 2012). This shows that our approach is also sensitive towards valence-based interruption effects. The most interesting question, however, was whether the frequency of conflicting events would also trigger adjustments in the impact of valence-based task interruptions. Our results show that there is no adjustment of the processing of the valent information according to the frequency of conflicting events in the cognitive domain; the size of the valence-based interruption effect did not vary with the frequency of incongruent trials. In neither measure did we find an interaction between the valence of the target picture and the proportion of trials in which the picture location is corresponding to the response that was called for. The lack of transfer in Experiment 1 therefore suggests that despite the negative valence of response conflict, a high frequency of conflict does not seem to trigger adaptations that are accessible to both domains of task disturbance.

In Experiment 2, we varied the proportion of negative pictures and found adjustments of the interruption effect according to the frequency of negative pictures: valence-based interruptions were smaller and spatially less affected in high-interrupting settings compared to low-interrupting settings. This shows that our proportion negative manipulation was successful in creating conditions that called for a sustained adaptation to the frequency of interrupting events. More importantly, we also found evidence that suggests at least some transfer between the two domains of task disturbance: the size of the Simon effect did vary with the frequency of negative pictures, with smaller disturbances under sustained adaptation to a highly interrupting setting.

These results show that there seems to be an asymmetry in whether adaptation to one source of task disturbance can transfer to another domain (Kunde & Wühr, 2006). While both, cognitive and affective conflicts seem to be registered as aversive signals (Dreisbach & Fischer, 2012; Fritz & Dreisbach, 2013, 2014; Schouppe, De Houwer, Richard Ridderinkhof, & Notebaert, 2012; Schouppe et al., 2014), the adaptation processes that these signals trigger seem to be less universal. If this were so, then the system should adapt to all kinds of negative affect, be it induced by cognitive conflict or other sorts of negative stimulation in the same manner, namely by a reduced impact of task-irrelevant stimulation. The lack of such general adaptation in Experiment 1 therefore calls for further research on the interplay of negative affect and cognitive conflict.

Possibly, the observed asymmetric transfer arises from different strength of disturbance. Specifically negative pictures might yield stronger disturbances than response-incongruent stimulus locations. Such asymmetry might arise from the rather extreme averseness of the chosen pictures which could hardly be ignored. These pictures signalled potential threat and might induce stress and fear beyond negative affect with specific consequences for information processing (Shackman, Maxwell, McMenamin, Greischar, & Davidson, 2011). If this was so, less aversive pictures should be more prone to adaptations to spatial interference.

Next to distinctions in robustness or strength of the task disturbances, which assume a common

adaptation mechanism and try to explain the observed asymmetry as quantitative differences, one could, however, also assume qualitative differences in the individual adaptation processes. And indeed, such qualitative differences suggest themselves at closer inspection of the mechanisms that might account for the individual adaptation effects, and we will discuss three potential mechanisms in the following.

For one, the high frequency of negative pictures in the high-interrupting environment could induce negative mood, which has been shown to promote conflict adaptation processes (van Steenbergen, Band, & Hommel, 2009, 2010). In this view, the modulation of cognitive interference according to the interrupting environment would be driven not by a direct transfer, but by an indirect influence of the global mood that the negative pictures provoke. This mechanism accounts for the observed transfer not as a direct influence of control adaptation, but introduces the participant's mood as a mediating variable that allows for an indirect transfer.

For another, participants might react with different kinds of strategic adjustments to the proportion manipulations. Whereas a possible strategic approach to high proportions of incongruent Simon trials would be to respond to the opposite of the stimulus location by default, such a strategy is certainly not viable in response to a high proportion of negative trials. Rather, participants might adopt a generally more cautious strategy in the high-interrupting setting. This adjustment in overall response time could account for the reduced Simon effect in these conditions, as the Simon interference usually diminishes for long responses (De Jong, Liang, & Lauber, 1994; Hommel, 1993; Vallesi, Mapelli, Schiff, Amodio, & Umiltà, 2005). Even though the corresponding main effect of proportion negative failed to reach significance in Experiment 2, such indirect effects due to global adjustments of response caution might partly have taken place which would (at least partly) also explain the asymmetric transfer.

A third and final hypothesis on qualitative differences between both adaptation effects is based on previous reports of feature-specific adaptation effects for the Simon effect. More precisely, if Simon and SNARC tasks were tested

for across-task adaptation effects (Verguts & Notebaert, 2009), such effects only emerged when the task-relevant features of both tasks overlapped whereas there was no transfer if the two tasks relied on different features. Therefore, adaptation to Simon-like interference might thus mainly be based on a rather specific strengthening or weakening of different feature representations (such as stimulus location, for a strong version of feature-based adaptation effects, see Hommel, Proctor, & Vu, 2004). Such feature-specific mechanisms seem to be well in line with the lack of transfer observed in Experiment 1.

The alternative explanations presented above are certainly not exclusive and each might have a share in accounting for the observed results. At any rate, it seems as if there are distinct accounts for the adaptation to affective and cognitive task disturbances with the possibility of an asymmetrical transfer. In this view, adaptations to conflict might best be characterised as operating mainly separately, with adaptation to affective disturbances being able to transfer to the cognitive domain, possibly by influencing global parameters, whereas adaptation to cognitive disturbances seems to be specific to its own domain and does not transfer to the processing of affective interruptions.

Disclosure statement

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APPENDIX

Table A1. *Pictures used in the experiments. Numbers represent picture codes from the IAPS database* (Lang et al. 1999).

Negative		Neutral		Positive	
Human	Non-human	Human	Non-human	Human	Non-human
3000	9570	2038	5471	2057	1440
3005	7380	2102	7000	2070	1441
3053	9140	2191	7034	2091	1460
3063	9290	2214	7052	2165	1610
3064	9301	2372	7055	2332	1710
3069	9320	2397	7090	2340	1750
3150	9340	2579	7100	2530	1920
3261	9571	2745	7161	2540	5760
9040	9600	2850	7242	2550	5833
9405	9902	7493	7547	4626	7200