How Task Representations Guide Attention: Further Evidence for the Shielding Function of Task Sets

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To pursue goal directed behavior, the cognitive system must be shielded against interference from irrelevant information. Aside from the online adjustment of cognitive control widely discussed in the literature, an additional mechanism of preventive goal shielding is suggested that circumvents irrelevant information from being processed in the first place. Participants had to react to 8 different words depicting clothing items that were presented in front of line drawings that could be either semantically related (clothes) or unrelated (animals with spatial orientation) to the target words. Participants either learned the stimulus–response (S–R) mappings by heart or used 1 task set (TS). In the S–R group, semantically related and unrelated distractors interfered with performance, whereas in the TS group, only semantically related distractors interfered, and unrelated distractors had no effect. It follows that task representations based on a general TS help to focus attention on relevant information, thereby preventing the processing of irrelevant information.

Keywords: goal shielding, distractor interference, conflict, task set, selective attention

In daily life, humans are constantly confronted with a lot of information from the environment, but only part of this information actually gains access to the cognitive system. And at least most of the time, it is relevant information that is attended to, whereas irrelevant information, ideally, can successfully be ignored. But who or what decides which information is relevant and thus gains access to further processing? Or, in other words, who or what decides which information is to be discarded as irrelevant? In this article we argue that task representations modulate which stimulus information is processed and which is not. More precisely, we assume that task representations that provide a general rule can reduce interference from stimulus features that are not part of the task representation by narrowing the focus of attention toward the response-discriminating stimulus features. That is, we propose a global shielding mechanism that prevents the occurrence of response conflicts because the presumably interfering information is not being processed in the first place.

Such a global shielding mechanism would perfectly add to the currently discussed conflict models of selective attention: In these models, it is suggested that the actual perception of a response conflict (due to distractor interference) triggers the mo-bilization of additional control, thereby increasing shielding against distraction, which, in turn, reduces response conflict (e.g., Botvinick, Carter, Braver, Barch, & Cohen, 2001; Botvinick, Cohen, & Carter, 2004; Gratton, Coles, & Donchin, 1992; Kerns et al., 2004; but see Mayr, Awh, & Laurey, 2003). This kind of context-sensitive adjustment has mostly been described by the sequential modulation of response conflicts (a conflict in Trial $N - 1$ reduces conflict in Trial N). That is, the already experienced conflict itself triggers the adjustment on the following trial. But there is also evidence that these control adjustments already act locally in response to experienced conflict on the current trial (Goschke & Dreisbach, 2008) or even globally on a whole block of trials (Dreisbach & Haider, 2006).

These latter findings are difficult to reconcile on the basis of conflict models of selective attention because these models represent a mechanism that is triggered only by an (already) experienced response conflict (ex post). We assume that an additional global shielding mechanism must exist, which shields the cognitive system against irrelevant information before it is even processed. A good candidate for such a global shielding mechanism might be the specific task representation a participant adopts to fulfill a given task. Specifically, we assume that a task representation that allows the focusing of attention on a common response-discriminating stimulus feature prevents other possibly interfering stimulus features from being processed in the first place. On the other hand, a task representation that does not allow for such information reduction will result in increased interference for any stimulus information.

Recently, we developed a paradigm (also used here) that allows the manipulation of this kind of task representation (Dreisbach, Goschke, & Haider, 2006, 2007; Dreisbach & Haider, 2008). In this paradigm, all participants react to an identical stimulus set with exactly the same responses. The critical manipulation is the instruction given to the participants. Participants have either to

learn the single stimulus–response (S–R) mappings by heart, or they receive one or even two task sets (TS; simple categorization rules) in order to answer the stimuli. The main difference between these kinds of task representations (TS vs. S–R rule) is that TSs provide a general rule that emphasizes the common stimulus feature associated with each response. The consequence is that, apart from the fact that the rule can be applied in principle to an infinite number of stimuli, it narrows the focus of attention directly toward the critical common (response discriminating) features of the stimuli. In contrast, with the S–R instruction, participants do not receive such a general rule. They are told only to respond to the stimulus with a prespecified response. This instruction does not emphasize specific stimulus dimensions and, thus, does not direct attention toward any specific features of the stimulus, as the TS instruction does. With the S–R representation, the entire stimulus is bound to the response rather than specific features of the stimulus. Consequently, the S–R-based task representation makes the system more susceptible to interference from any stimulus information (no narrowing of the focus of attention toward critical stimulus features).

Findings of a recent study (Dreisbach & Haider, 2008) have already provided first evidence for this assumption: Participants had to react to eight words, written in red and green with the color of the words being completely uncorrelated with the responses. However, participants who received the S–R instruction still processed the irrelevant color feature of the words, as was indicated by a significant interaction of Response × Color Switch (a typical measure of binding effects between stimulus features and response features). In contrast, with the TS instruction, this interaction was completely absent. These findings nicely fit our global shielding assumption: The irrelevant color feature was not processed in the TS condition, because the task-set allowed participants to focus their attention on the common response-discriminating stimulus features (as defined by the TS instruction) and consequently ignore irrelevant stimulus features. In the S–R condition, however, such information reduction was not possible due to the lack of a general task rule.

So far, we have shown that the specific task representation (S–R vs. TS) modulates binding processes between stimulus and response. In the current article we want to provide further evidence that task representations modulate processes of selective attention. More precisely, the goal of the current experiments was to investigate the assumption that response conflicts due to distractors are modulated by the specific kind of task representation. According to the assumed global shielding mechanism, we hypothesize that task representations in the form of generalizable task rules narrow the focus of attention toward common response discriminating stimulus features, thereby preventing interference by stimulus information that is not part of the current task representation. In contrast, task representations based on specific S–R mappings do not allow such an information reduction and, thus, should not prevent irrelevant stimulus features from being processed.

To test this assumption, we compared distractor interference (a) between groups with different task representations (S–R vs. TS), and (b) between distractors that were either semantically related or semantically unrelated to the task representation. To this end, we used compound word–picture stimuli with the words being the targets and the pictures being the distractors. The pictures (standardized line drawings; Snodgrass & Vanderwart, 1980) could represent either objects that were also presented as words (that is, semantically related objects) or objects from a completely different domain (semantically unrelated objects) but with a response-congruent or -incongruent spatial orientation. As stimuli we used eight different words depicting clothing items (boot, tie, blouse, coat, sweater, dress, vest, trousers) that were mapped to a left or a right response key. Participants in the S–R-instruction condition had to learn the S–R mappings by heart; in the TS condition participants had to decide whether the clothes covered part of the legs or not (we had to use a not too obvious TS to prevent participants in the S–R condition from guessing the TS). The manipulation of interference was realized by always presenting the stimuli in front of line drawings. The pictures depicted either these clothing items or spatially oriented animals. This made it possible to create compound word–picture stimuli that were either related (target words in front of clothing pictures) or unrelated (target words in front of spatially oriented animal pictures) to the task representation in both instruction conditions. The related compound stimuli could be either compatible (both mapped to the same response) or incompatible (both mapped to different responses). Accordingly, the unrelated compound stimuli also could be either compatible or incompatible, depending on the spatial orientation of the irrelevant animal drawing (word mapped to the left or right key and animal oriented to the left or right).

Ample evidence is available that endorses the finding that the orientation of even irrelevant objects provokes spatial compatibility effects. For example, Tucker and Ellis (1998) observed compatibility effects for left–right oriented objects, even if they were task irrelevant. Likewise, Rueda et al. (2004) adapted the Eriksen flanker task (Eriksen & Eriksen, 1974) for children, using pictures of left- versus right-oriented fishes and found corresponding compatibility effects.

If task representations actually guide attention, we should find differential compatibility effects in the different instruction conditions. In the TS condition, the instructed task rule allows a focusing of attention on the common response-discriminating stimulus features ("clothes cover part of the leg or not"). Therefore, we assume that the task representation based on a general TS will lead to compatibility effects only for the related clothing items (because the clothes are part of the task representation) but not to compatibility effects for the unrelated animal pictures. In contrast, in the S–R condition, the task representation does not allow a narrowing of the focus of attention as much as it does in the TS condition.[1] Because participants in this group have no general rule at hand telling them which stimulus features are more important than others, they will be less focused. This reduced focus of attention will make them more vulnerable for processing any stimulus information. Consequently, the task representation based on single S–R mappings should result in compatibility effects for both—related clothing pictures as well as unrelated animal pictures.

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[1] In the S–R condition, participants will of course also focus their attention. For example, they know that the stimulus will appear in the middle of the screen, and they know they have to react to the words. However, they do not have a rule that tells them which features of the stimuli are important. Or, one might even argue, they have the rule that any stimulus feature might be important.
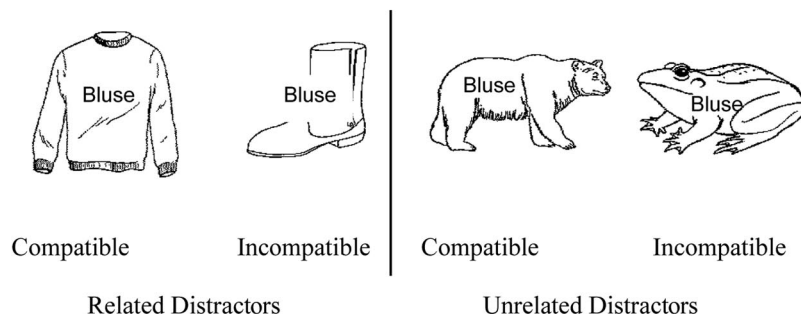
Experiment 1

Method

Participants. Forty undergraduate students (34 women) from the Technische Universität Dresden participated for partial course credit (age $M = 21.22$, $SD = 2.7$). Participants signed an informed consent form and were debriefed after the session. Twenty participants were assigned to the S–R instruction condition, and 20 participants were assigned to the TS condition. One participant in the S–R condition made up her own (visual) TS and was therefore excluded and replaced by another participant.

Stimuli and procedure. Eight German words depicting clothes served as target stimuli (dress, coat, boots, trousers, blouse, vest, pullover, tie) and were presented in front of standardized line drawings (Snodgrass & Vanderwart, 1980)—semantically related line drawings: dress, coat, boots, trousers, blouse, vest, pullover, tie; unrelated line drawings: animals with orientation: frog–left, fox–left, polar bear–right, rabbit–right; see Figure 1 for stimuli).

The words *dress, coat, boots,* and *trousers* were mapped to a left response key (*Y* key on a QWERTZ computer key board), and the other words were mapped to a right response key (the hyphen key). To prevent participants in the S–R condition from guessing the underlying TS ("covers part of the leg" vs. "does not cover part of the leg") if all eight stimuli had been presented at the same time, stimuli were introduced blockwise, starting with two stimuli in Block 1 and increasing by two until, in Block 4, all eight stimuli had been introduced. Additionally, with this stepwise procedure we made sure that participants in the S–R condition could memorize the eight different S–R mappings without searching actively for a categorization rule.

In the four practice blocks, each word was presented 10 times, resulting in a block length of 20, 40, 60, and 80, respectively. The first

A   Semantically related objects:
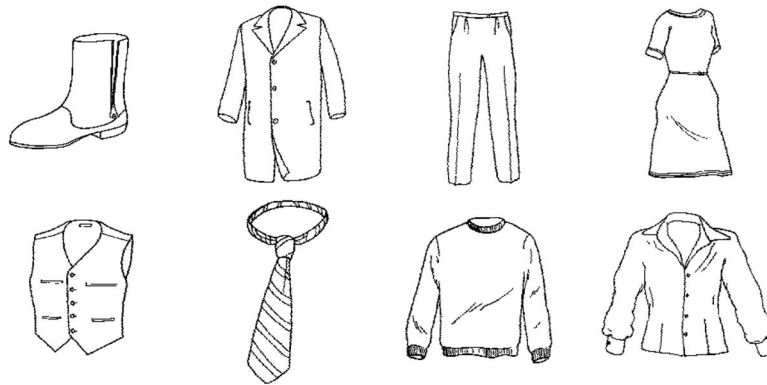
B   Semantically unrelated objects:

C   Compound word–picture stimuli:

Compatible   Incompatible   Compatible   Incompatible

Related Distractors   Unrelated Distractors

Figure 1. Line drawings (Snodgrass & Vanderwart, 1980) used as distractors. A: semantically related objects where the objects correspond to the eight target words. B: semantically unrelated objects with spatial orientation. C: examples of word–picture stimuli.

six stimuli of each block consisted of the two newly introduced words only (without distractors), and from Trial 7 on, the compound stimuli (word + distractor) were presented. In Blocks 1 and 2, six distractors were chosen randomly from the unrelated animal distractors. In Blocks 3 and 4, eight unrelated distractors were presented.

After the four practice blocks, three experimental blocks of 96 trials each were presented. Each of these blocks contained 64 trials with related distractors (8 words × 8 clothes distractors) and 32 trials with unrelated distractors (8 words × 4 animal distractors). This resulted in 32 response-compatible related trials,[2] (e.g., the word *tie* in front of the line drawing of a blouse), 32 incompatible related trials (e.g., the word *tie* in front of the line drawing of a boot), 16 compatible unrelated trials (e.g., the word *tie* in front of an animal oriented to the left), and 16 incompatible unrelated trials (e.g., the word *tie* in front of an animal oriented to the right). All trials were presented at random. Negative priming trials (distractor in trial $N - 1$ becomes the target in trial N) were allowed but excluded from all statistical analysis (overall about 20 trials per participant).

Each trial started with a fixation cross for 400 ms, followed by a blank screen for 400 ms. Then the compound stimulus appeared on the screen until a response was given. After 400 ms, the next trial started with the presentation of the fixation cross. Feedback was given for erroneous responses only, in which case the intertrial interval was extended to 2,000 ms.

The experiment started with written instructions on the computer screen. Participants in the S–R condition read that we were interested in how easily they assigned words to specific responses. Participants in the TS condition read that we were interested in how easily they assigned words to specific categories and were then told that they should decide for each clothes item whether it covers part of the leg or not. In both conditions, however, the stimuli were introduced stepwise with the correct mapping. After Block 4, participants were told that no additional words would appear from that moment. Subsequently, the three experimental blocks were presented. In both groups, the distractors were never mentioned in the instruction. After the third experimental block a short postexperiment interview followed. Participants in the TS condition were asked whether they found the task rule ("covers the leg") useful and, if not, whether they had used any other strategy. In the S–R condition, participants were asked whether they had used any memory aids to memorize the eight words. One participant in this condition reported having used a very sophisticated task rule whereby she mentally dressed a dummy with the clothes. This procedure, however, resulted in very slow reaction times (RTs) and a compatibility effect in the related compound stimuli that exceeded the overall mean compatibility effect by three times. Therefore, data of this participant were excluded and replaced by an additional participant.

Design. A 2 (instruction: S–R vs. TS) × 2 (compatibility: compatible vs. incompatible) × 2 (distractor relatedness: related vs. unrelated) mixed factors design was applied. Instruction was manipulated between participants; compatibility and distractor relatedness were repeated measures within participants.

Results

Incorrect responses were excluded from the analysis. Word repetitions ($M = 22$ per participant) and negative priming trials ($M = 20$ per participant) were also excluded. We present the data

only from the three experimental blocks where all eight words had already been introduced and learned. To control for RT outliers, we computed median RTs of each factor combination. Thus, we present mean RTs (means of the individual median RTs) for compatible and incompatible trials in the related and unrelated trials of each instruction group. In all analyses reported here, the adopted significance level is .05. For significant effects, individual *p* values are not reported.

RT data. Figure 2 depicts mean RTs as a function of instruction group, compatibility, and distractor relatedness. A 2 (instruction) × 2 (compatibility) × 2 (distractor relatedness) mixed factors analysis of variance (ANOVA) brought up a main effect of compatibility, $F(1, 38) = 49.68$, $MSE = 557.97$. Overall, compatible trials were answered faster than incompatible trials (609 ms vs. 635 ms). Instruction ($F < 1$, $p > .4$) as well as distractor relatedness, $F = 1.4$, $p > .2$, were not significant. The Distractor Relatedness × Compatibility interaction was significant, $F(1, 38) = 5.34$, $MSE = 802.08$, and was further qualified by the Instruction × Distractor Relatedness × Compatibility interaction, $F(1, 38) = 4.93$, $MSE = 802.08$. This latter interaction substantiates the observation readily apparent from visual inspection of Figure 2 that, as expected, compatibility interacted with distractor relatedness in the TS group, $F(1, 38) = 10.27$, $MSE = 802.07$, but not in the S–R group, $F = .003$, $p = .98$.

Planned comparisons further revealed significant compatibility effects in the S–R condition in related and unrelated trials, $F(1, 38) = 13.76$, $MSE = 479.66$; $F(1, 38) = 7.04$, $MSE = 880.37$, respectively. In the TS condition, however, a significant compatibility effect was present only in related trials, $F(1, 38) = 47.33$, $MSE = 479.67$, but was totally absent in the unrelated trials, $F < 1$, $p > .4$. Finally, trials in which word and picture were identical (e.g., the word *tie* on the line drawing of a tie) did not differ between groups: 612 ms in the S–R group versus 590 ms in the TS group, $F = .47$, $p = .49$.

Error rates. Error data are also presented in Figure 2, bottom. A 2 (instruction) × 2 (compatibility) × 2 (distractor relatedness) mixed-factors ANOVA with repeated measures on the last two factors reached significant main effects for distractor relatedness, $F(1, 38) = 11.17$, $MSE = 6.16$, and compatibility, $F(1, 38) = 20.30$, $MSE = 5.44$, and no effect of instruction ($F < 1$, $p > .6$). Related distractors were more error prone than were unrelated distractors (4.1% vs. 2.8%), and incompatible trials were more error prone than were compatible trials (4.2% vs. 2.6%). Furthermore, the Distractor Relatedness × Compatibility interaction proved reliable, $F(1, 38) = 15.13$, $MSE = 6.87$. That is, the compatibility effect was present for related trials (2.4% vs. 5.7%) but absent for unrelated trials (2.7% vs. 2.8%). All other interactions were not significant (all $F < 1.5$, all ps > .2). Finally, stimulus-compatible trials again did not differ between instruction conditions: 2.25% in the S–R group versus 1.75% in the TS group, $F = .22$, $p = .64$.

The results of Experiment 1 fully support our assumptions by revealing that our instruction-based manipulation of task representation substantially modulates which information gains access to

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[2] Of these 32 compatible related trials, 8 trials were *stimulus* compatible, that is, target word and distractor picture matched (e.g., the word *tie* presented on the line drawing of a tie). These trials were analyzed separately.
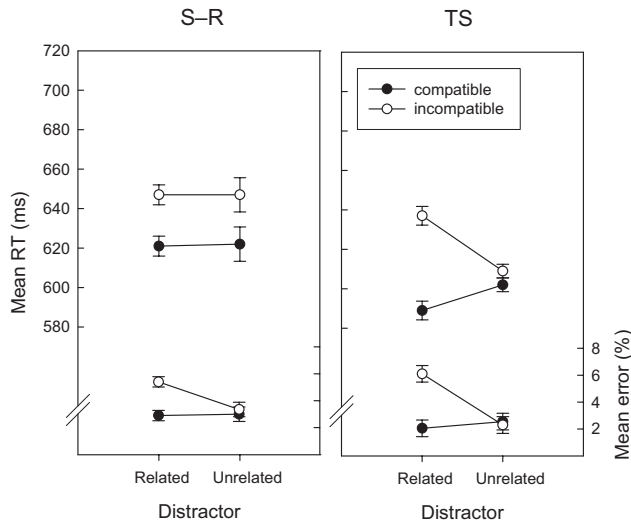
Figure 2. Mean response times (RTs, in ms) and error rates (%) in the two instruction conditions (left panel: stimulus–response [S–R]; right panel: task set [TS]) as a function of compatibility and distractor relatedness in Experiment 1. Error bars represent 95% within-participant confidence intervals based on the corresponding compatible versus incompatible comparison (Loftus & Masson, 1994).

further processing. The task representation based on a general task rule in the TS condition narrowed participants' focus of attention such that only TS-related information got processed (as indicated by the significant compatibility effect for the clothes pictures and the absence thereof for animal pictures). However, in the S–R condition without the opportunity for information reduction, participants were distracted even by distractor information that was not semantically related to the primary task (as indicated by the significant compatibility effects for both, clothes *and* animal distractors).

Before we further discuss these findings, we first want to make sure that the results were actually driven by the differential task representations induced by the TS and S–R instruction and not by the specific instructions per se. Therefore, in Experiment 2 we used a slightly different methodological approach. Instead of manipulating the task representation via explicit instructions, we solely used the S–R instruction but introduced all stimuli at once. With this method, we expected at least some participants to make up their own individual TS in order to be better able to memorize the eight S–R mappings. We hypothesized that those participants who generated a TS should show the same data pattern as the TS group in Experiment 1, whereas those who simply learned the S–R mappings by heart should resemble the former S–R condition. That is, a self-generated TS should just as well allow focusing on the particular common response-discriminating stimulus features. Such a result would further corroborate the assumption that task representations guide attention.

Experiment 2

The general logic of Experiment 2 was the same as in Experiment 1: Clothes distractors were again part of the task representation (because they are semantically related with the target words), whereas animal distractors were not part of the task

representation (irrespective of whether the particular task representation was based on single S–R mappings or a general task rule). Whether these unrelated distractor stimuli gain access to further processing should again depend on the particular kind of task representation a participant has generated while learning the S–R associations. We expect that those participants who create their own task rule in order to memorize the eight S–R mappings will focus their attention toward the one or the other response-discriminating stimulus feature and will thus be less vulnerable for distractor interference by unrelated distractors. In contrast, participants who do not use such a task rule but instead rely on the instructed S–R mappings will process the stimuli in a less focused way and will consequently be more sensitive to the distractor information (semantically related *and* semantically unrelated distractor information).

Method

Participants. Thirty-four undergraduate students (18 female) from the Technische Universität Dresden participated for partial course credit (age $M = 22.67$, $SD = 4.22$) or €3. Participants signed an informed consent form and were debriefed after the session. None of them had participated in Experiment 1.

Stimuli and procedure. The stimuli and procedure were exactly the same as in Experiment 1, except for the following changes. The eight word stimuli with the corresponding responses were introduced simultaneously on one instruction slide (without distractors). Participants then received one practice block consisting of 64 trials (48 trials with related and 16 trials with unrelated distractors.). Subsequently, four experimental blocks with 96 trials each were presented (see Method section in Experiment 1). After the experiment, all participants were asked about the strategy they had used to memorize the eight word stimuli.

*Design.* A 2 (distractor: related or unrelated) × 2 (compatibility) repeated measures design was used.

Results

The between-factor task representation (TS vs. S–R) this time was determined post hoc on the basis of the postexperiment interview. Sixteen participants reported having memorized the stimuli by heart, and 18 participants described some kind of categorization rule by which they had grouped the stimuli into those mapped either to the left or to the right response key (e.g., rather female vs. male clothes, top vs. bottom clothes [which is close to the original "covers part of the leg"-rule], visual image of two different dummies for left and right; clothes I like/dislike). Viewing time of the slide that informed about the eight different S–R mappings in the instruction did not differ between the S–R and (subjective) TS groups (45 s vs. 39 s, respectively; $F = 1.2$, $p = .25$). Obviously, the groups did not differ with respect to the time they had spent to memorize the stimuli.

The data analysis follows the logic of Experiment 1. Incorrect responses were excluded from the analysis, as were word repetitions ($M = 1.50\%$ per participant) and negative priming trials ($M = 3.02\%$ per participant). To control for RT outliers, median RTs of each factor combination collapsed over the four experimental blocks were computed separately for the S–R and subjective TS groups.

RT data. Figure 3 depicts mean RTs as a function of task representation (S–R vs. subjective TS), compatibility, and distractor relatedness. A 2 (memory strategy) × 2 (compatibility) × 2 (distractor relatedness) mixed factors ANOVA brought up a main effect of compatibility, $F(1, 32) = 19.83$, $MSE = 512.4$, and distractor relatedness, $F(1, 32) = 11.03$, $MSE = 1,148.30$. Overall, compatible trials were answered faster than incompatible trials (649 ms vs. 666 ms), and trials with animal distractors were answered faster than trials with clothes distractors (648 ms vs. 667 ms). Task representation was not significant ($F < 1$, $p = .45$). Again, as in Experiment 1, the interaction of Distractor Relatedness × Compatibility was significant, $F(1, 32) = 10.49$, $MSE = 590.62$, and was further qualified by the higher order interaction of Task Representation × Distractor Relatedness × Compatibility, $F(1, 32) = 6.39$, $MSE = 590.62$. This latter interaction replicates the results of Experiment 1 by showing that, as expected, compatibility interacts with distractor relatedness in the subjective TS group, $F(1, 32) = 17.62$, $MSE = 590.62$, but not so in the S–R group, $F < 1$, $p = .62$. Planned comparisons further revealed significant compatibility effects in the S–R group in semantically related and unrelated trials, $F(1, 32) = 9.82$, $MSE = 476.51$, and $F(1, 32) = 4.25$, $MSE = 626.51$, respectively. In the subjective TS condition, however, a significant compatibility effect was present only in semantically related trials, $F(1, 32) = 26.56$, $MSE = 476.51$, but was descriptively reversed in the unrelated trials, $F = 1.6$, $p = .21$. Finally, the stimulus compatible trials (e.g., the word *tie* on the line drawing of a tie) did not differ between groups: 625 ms in the S–R group versus 634 ms in the TS group, $F < 1$, $p > .8$.

Error rates. Error data are also presented in Figure 3, bottom, and perfectly mirror the RT data. Accordingly, the 2 (task representation) × 2 (compatibility) × 2 (distractor relatedness) mixed factors ANOVA with repeated measures on the last two factors reached significant main effects for the factors distractor relatedness, $F(1, 32) = 12.59$, $MSE = 6.05$, and compatibility, $F(1, 32) = 8.47$, $MSE = 13.13$, and no effect of task representation ($F < 1.3$, $p = .27$). Related distractors were more error prone than unrelated distractors (4.01% vs. 2.51%, respectively), and incompatible trials were more error prone than compatible trials (4.16% vs. 2.35%, respectively). Again, the Distractor Relatedness × Compatibility interaction proved reliable, $F(1, 32) = 20.03$, $MSE = 7.86$, which was further qualified by the higher order interaction of Task Representation × Distractor Relatedness × Compatibility, $F(1, 32) = 5.15$, $MSE = 7.86$. This latter interaction also mirrors the results of the RT data: Compatibility interacts with distractor relatedness in the subjective TS group, $F(1, 32) = 24.18$, $MSE = 7.86$, but not in the S–R group, $F = 2.29$, $p = .13$. Planned comparisons further revealed significant compatibility effects in the S–R group in related trials, $F(1, 32) = 5.63$, $MSE = 16.788$, and a marginally significant effect for unrelated trials, $F(1, 32) = 3.27$, $MSE = 4.20$, $p = .07$. In the TS condition, a significant compatibility effect was present in related trials, $F(1, 32) = 10.85$, $MSE = 16.788$, but was actually significantly reversed in the unrelated trials, $F(1, 32) = 8.55$, $MSE = 4.20$. Finally, the stimulus-compatible trials did not differ between groups: 1.8% in the S–R group versus 2.8% in the subjective TS group, $F < 1$, $p > .44$.
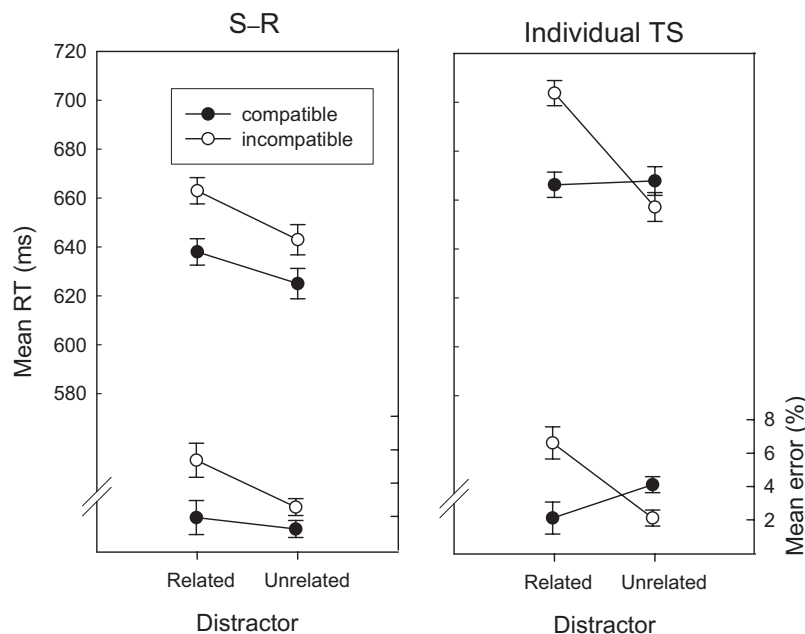
Figure 3. Mean response times (RTs, in ms) and error rates (%) as a function of compatibility and distractor relatedness in Experiment 2. Stimuli were introduced all at once, and all participants received the same stimulus–response [S–R] instructions. Sixteen participants reported having learned the S–R mappings by heart (left panel: S–R), and 18 participants reported having made up their own task rule (right panel: individual task set [TS]). Error bars represent 95% within-participant confidence intervals based on the corresponding compatible versus incompatible comparison (Loftus & Masson, 1994).

Data from Experiment 2 perfectly replicated our findings of Experiment 1, although participants in Experiment 2 in the subjective TS condition generated TSs by themselves. We can thus exclude that the results of Experiment 1 were driven by the specific task instructions. Rather, the results show that any task representation suited to group the stimulus set into response-discriminating subcategories helps to focus attention and thus shields against interference from unrelated distractors. In the absence of such a rule, attention is less focused, consequently leading to the observed interference effects for any distractor information.

Experiments 1 and 2 brought up ample evidence that a general task rule helps to narrow the attentional focus toward common response discriminating stimulus features, thereby preventing interference from unrelated distractor information. In addition, the results also showed that the application of single S–R mappings does not allow for such information reduction and consequently results in interference from any stimulus information. Against this latter conclusion one might argue, however, that the results of the S–R condition were not driven by less focused processing but follow from an increased susceptibility for spatial information in general. That is, the instruction of the single S–R mappings might have biased participants to categorize the items in those requiring a right response and those requiring a left response. This, in turn, might have emphasized left/right spatial information and, therefore, might have produced the compatibility effects for the spatially oriented animal distractors. However, we think this is rather unlikely for at least two reasons: First, Experiment 2 showed that at least the S–R instruction per se cannot account for the spatial compatibility effects, because here, all participants received exactly the same task instructions. Second, in another series of experiments (Metzker & Dreisbach, in press), we showed that the Simon effect (a spatial compatibility effect) vanished as soon as more than two S–R mappings were used.[3] This latter result obviously speaks against the assumption that the results presented here were driven by a processing advantage for spatial information in the S–R condition.

So far, we have argued that task representations guide attention in that the application of a task rule allows for an information reduction whereas single S–R rules do not. However, there are other ways to manipulate task representations, one of which is practice. There is plenty of evidence from research on skill acquisition that training not only strengthens S–R mappings (in the sense of automatization) but also leads participants to reduce task processing to only task-relevant information (e.g., Doane, Alderton, Sohn, & Pellegrino, 1996; Doane, Sohn, & Schreiber, 1999; Gibson & Gibson, 1955; Haider & Frensch, 1996; Schyns & Rodet, 1997). Likewise, the well-known blocking effect (e.g., Kamin, 1969) suggests that once participants have learned to react to a specific stimulus, they do not learn to attend to a new stimulus concurrently presented with the already learned stimulus (see also, Kruschke & Blair, 2000).

On the basis of these findings, one should expect that—like the general task rules—this training should lead to well established S–R representations and allow participants to narrow their attention toward the information that is relevant in order to generate a response for the stimulus at hand. Consequently, participants should no longer show the compatibility effects for unrelated distractors. If this turns out to be true, such a result would also provide even more evidence against the assumption of a spatial processing advantage for S–R-based processing.

Experiment 3

The procedure of Experiment 3 was identical to that of Experiment 2 with the exception that the eight word stimuli were introduced and trained in one practice block *without* any distractors (just the word stimuli). Afterward, participants received the same four experimental blocks as in Experiment 2 with animal and clothes distractors. We expected that participants would be able to build stable S–R mappings within the first practice block. In the upcoming blocks, these stable S–R representations should then allow participants to focus attention on task-relevant information while ignoring unrelated stimulus information.

Method

Participants. Twenty-six undergraduate students (15 female) from the Technische Universität Dresden participated for partial course credit (age $M = 23.19$, $SD = 4.42$) or €3. Participants signed an informed consent form and were debriefed after the session. None of them had participated in Experiment 1 or 2.

Stimuli and procedure. The stimuli and procedure were exactly the same as in Experiment 2, except for the first practice block. In this case, in the first practice block, the word stimuli were presented without any distractors and consisted of 128 trials (each of the eight word stimuli was thus presented 16 times). After that, four experimental blocks with 96 trials each were presented (see Method section in Experiment 1). Again, the experiment ended with the postexperiment interview.

Design. A 2 (distractor: related vs. unrelated) × 2 (compatibility) repeated measures design was used.

Results

As a first step, all participants who stated in the postexperiment interview that they generated a TS were excluded from further analyses. This was necessary because our hypothesis was that participants with training on the S–R mappings should not show any compatibility effect for the unrelated distractors. As already shown in Experiment 2, participants with self-generated TSs did not show any effect for the unrelated animal distractors. So, it should be trivial to find no effect for the unrelated distractors when including participants who had generated an individual TS during training. Overall, eight participants had made up their own TS and were therefore excluded (they consequently showed the same data pattern as participants in the subjective TS group in Experiment 2).

For the remaining 18 participants, incorrect responses were excluded from the analysis as well. Word repetitions ($M = 1.50\%$ per participant) and negative priming trials ($M = 3.02\%$ per participant) were also excluded. To control for RT outliers, median RTs of each factor combination collapsed over the four experimental blocks were computed.

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[3] The Simon effect also disappeared when more than two categorization rules were applied, showing that not the particular task representation but rather the number of stimuli or stimulus features associated with one particular spatial response decide whether the Simon effect occurred.

RT data. Figure 4, top panel, depicts mean RTs as a function of distractor relatedness and compatibility. The 2 (distractor relatedness) × 2 (compatibility) repeated measures ANOVA indicated that, overall, incompatible trials were answered more slowly than compatible trials, $F(1, 17) = 13.07$, $MSE = 653.12$, whereas distractor relatedness was not significant, $F < 1$, $p = .80$. And, most important, this time distractor relatedness interacted significantly with compatibility, $F(1, 17) = 4.89$, $MSE = 821.82$. Related distractors yielded a significant compatibility effect, $F(1, 17) = 24.52$, $MSE = 494.87$, whereas the unrelated animal distractors did not, $F < 1$, $p = .52$.

Error data. Error data are also presented in Figure 4, bottom panel. A 2 (distractor relatedness) × 2 (compatibility) repeated measures ANOVA revealed no main effects (both $F < 1$, both $p > .7$) but a significant interaction of both factors, $F(1, 17) = 11.22$, $MSE = 3.87$. Planned comparisons resulted in a significant compatibility effect for related distractors, $F(1, 17) = 6.75$, $MSE = 4.20$. The descriptively reversed compatibility effect for the unrelated distractors was not significant, $F = 2.9$, $p = .10$.

The results of Experiment 3 show that if participants have the chance to memorize the eight different S–R mappings in the absence of distractors, they are no longer susceptible to distractors that are semantically unrelated to their task representation. This finding rules out the alternative assumption that the S–R condition promotes processing of spatial information per se. Rather, and
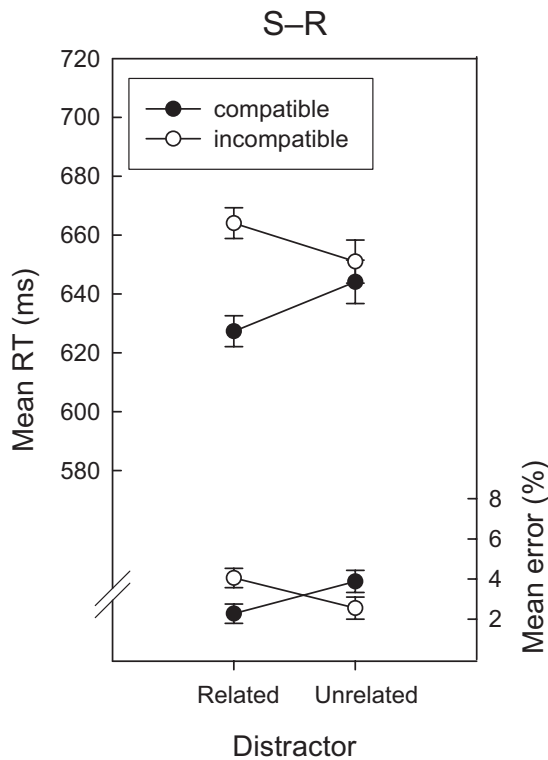

Figure 4. Mean response times (RTs, in ms) and error rates (%) as a function of compatibility and distractor relatedness in Experiment 3 (practice without distractor). Error bars represent 95% within-participant confidence intervals based on the corresponding compatible versus incompatible comparison (Loftus & Masson, 1994).

more important, the current findings support our assumption that if participants have the chance to establish stable S–R-mappings in the absence of any distractors, these stable S–R mappings then prevent interference from semantically unrelated information. This finding is in accordance not only with research on skill acquisition but also with research on associative learning (Kamin, 1969; Kruschke & Blair, 2000). From the blocking perspective, one could argue that due to the practice block, the newly introduced distractor stimuli did not acquire associative strength. From a skill acquisition perspective, one could conclude that increasing practice of the S–R rules had helped participants to generate a more specific task representation that allows focusing on relevant stimulus aspects. Whatever the exact underlying process might be, the results of Experiment 3 again support our assumption that the particular task representation (in this case the practiced S–R rules) modulates processes of selective attention.

General Discussion

The experiments presented in this article support our assumption that task representations crucially modulate processes of selective attention: Experiment 1 revealed that task representations based on a general task rule prevented participants from processing semantically unrelated distractors that were not part of the task representation. In contrast, task representations based on single S–R mappings made participants more susceptible to interference from related *and* unrelated distractors. Experiment 2 further corroborated this finding by showing that this effect was not due to the specific task instruction or categorization rule participants received in the TS condition. If participants did not receive an explicit TS but generated one themselves, the results revealed the same shielding effect against semantically unrelated animal distractors. And finally, Experiment 3 showed that susceptibility to interfering stimuli when using single S–R mappings depends on how well these S–R- representations are established. When participants were given the opportunity to practice the S–R mappings in the absence of any distractors, the compatibility effect for unrelated animal distractors disappeared. This latter result suggests that task representations based on stable S–R mappings are just as well suited as task rules to focus attention and prevent semantically unrelated distractors from being processed.

In sum, we replicated and extended previous findings: In our previous work where we first described the shielding function of TSs (Dreisbach & Haider, 2008), we had already shown that the specific task representation (S–R vs. TS) modulates binding processes between stimulus and response. Whereas an irrelevant stimulus feature (color) got bound to the response in the S–R condition, no such binding effect occurred in the TS condition. In the current article, we have provided even more direct evidence for this shielding function by showing that response conflicts are also modulated by the specific kind of task representation. More precisely, we have shown that task representations, either in the form of a general task rule or based on practice, narrow the focus of attention and thereby prevent the cognitive system from processing any information that is not part of this goal representation.

On a more theoretical level, the results presented here thus support the assumption of a global shielding mechanism. Whereas current conflict models of selective attention focus on sequential modulation of response conflicts, we have provided evidence for

the existence of an additional global shielding mechanism that prevents interfering information from being processed in the first place.

One critical objection to this interpretation might be that the conditions in our experiments differed with respect to different working memory load. In the S–R condition, the memory load is higher than in the TS condition, and, even in Experiment 3, one could argue that the practice block served to reduce working memory load. Lavie and colleagues (Lavie, 2005; Lavie, Hirst, de Fockert, & Viding, 2004), for example, argued that interference from irrelevant information depends on perceptual load and on working memory load: Increasing perceptual load leaves less capacity for processing (irrelevant) information, thereby reducing distractor interference. Increasing working memory load leaves less capacity for maintaining the relevant information for the current goal, thereby increasing distractor interference.

Applied to our paradigm, perceptual load did not differ between instruction conditions (all participants received exactly the same stimuli) but working memory load presumably did. That is, in the S–R condition where participants had to memorize all eight stimuli by heart, working memory load was probably higher than in the TS condition where participants had to memorize just one task rule. One might therefore argue that the higher working memory load in the S–R condition and not the availability of the response-discriminating task rule in the TS group impelled our results. However, what is difficult for this argument to reconcile is the differential effect for semantically related and unrelated distractors. In all three experiments, we found a reduced compatibility effect for semantically unrelated distractors but not for semantically related distractors when working memory load was reduced (which was the case in the TS condition in Experiments 1 and 2, and in the S–R condition in Experiment 3). If working memory load had actually caused our results, it should have reduced any distractor effects (semantically unrelated and semantically related distractors). We therefore conclude that the differences in working memory load between the TS and the S–R conditions—which indeed might exist—cannot explain our findings.[4] Rather, we assume that the task representations modulate the susceptibility to semantically related or unrelated distractors.

The results presented here also have implications for another field of research—namely, task switching (see Monsell, 2003, for a review). In the task-switching paradigm, participants typically have to switch between two or more simple categorization tasks. The main and very robust finding is that RTs increase whenever the task switches, compared with the repetition of the same task. This is especially so when bivalent stimuli (one stimulus set for both tasks) compared with univalent stimuli (different stimulus sets for both tasks) are used.

Our current findings further support the assumption that switch costs (or rather repetition benefits) result from a carryover effect from the previous task (Altmann, 2004; Dreisbach & Haider, 2006; Dreisbach, Haider, & Kluwe, 2002; Koch, 2001; Logan & Bundesen, 2003; Ruthruff, Remington, & Johnston, 2001; Sohn & Anderson, 2001; Wylie & Allport, 2000). Results suggest that this carryover effect stems from one of two not mutually exclusive mechanisms: (a) Especially with univalent stimuli and time to prepare, the implementation of the task rule (goal setting) narrows the focus of attention toward (task rule) relevant information and,

as a consequence, shields against any information that is not part of this task rule such that, as soon as the task changes, it takes longer to process the formerly ignored distractor information. (b) With bivalent stimuli, even though distractor information cannot be ignored per se, conflict triggered goal shielding steps in such that, as soon as the task changes, it takes longer until the formerly processed but then inhibited distractors are processed. The typically observed smaller switch costs, with univalent compared with bivalent stimuli, suggest that the global shielding due to goal setting is more effective than the locally acting conflict-triggered goal shielding (e.g., Dreisbach et al., 2002, Experiment 3; Ruthruff et al., 2001).

Finally, the results presented here need to be discussed in light of recent research by Gollwitzer and colleagues (Gollwitzer, 1993, 1999; Cohen, Bayer, Jaudas, & Gollwitzer, 2008). Gollwitzer stated that implementation intentions (i.e., an if–then plan) improve goal attainment by mentally linking an intention to an external cue that then, when perceived, automatically triggers the associated intention. As such, an implementation intention is a self-regulatory strategy that facilitates the accomplishment of resolved intentions (see also Altmann & Trafton, 2002, who proposed a goal-activation model of goal attainment). In a recently published article, Cohen et al. (2008) showed that such an implementation intention can actually facilitate task switching: Participants had to switch between a digit and a letter task (with bivalent compound stimuli consisting of a letter and a digit). One group additionally received an implementation intention in the form of one single S–R mapping. It turned out that switch costs in this group were smaller, especially for the critical S–R mapping. This result fits nicely with some of our previous work where we compared the S–R condition with a 2TS (task switching) condition and did not find any switch costs in the S–R group (Dreisbach, Goschke, & Haider, 2006, 2007). Also, in the current study, this intentional account might explain the fact that the compatibility effect for related distractors was smaller in the S–R group than in the TS group, presupposing that the S–R group can be seen as a group using eight different implementation intentions.

However, this account does not explain why we also found a compatibility effect for the semantically unrelated trials in the S–R conditions in Experiments 1 and 2. If S–R mappings have the function of implementation intentions, then one might have expected that the target word triggers the response before the animal distractor is even processed. Probably, only S–R mappings in the form of stable memory representations as in Experiment 3 serve the same function as implementation intentions. And of course, an alternative explanation would be that eight implementation intentions do not have the same effects as a single one. Maybe the effect decreases with increasing S–R mappings. Systematically varying the number of implementation intentions might shed some light in this interesting field of research.

In conclusion, the results presented in this article show that selective attention is facilitated by the specific task representation. Well-established task representations either in the form of a gen-

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[4] By this, we do not mean to imply that working memory load has no effect on compatibility effects whatsoever. We simply state that it cannot explain the specific data pattern and interaction found in the TS condition.

eral task rule or based on practice narrows the focus of attention and thereby prevents the cognitive system from processing any information that is not part of this goal representation. Together with conflict-triggered goal shielding, this process thus helps to guide attention toward relevant information, thereby shielding against irrelevant information.

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