

The impact of stimulus-specific practice and task instructions on response congruency effects between tasks

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Abstract In task switching experiments participants have to respond to the same set of stimuli while task instructions vary (e.g., digit stimuli are assigned to left- or right-sided key presses by means of magnitude vs. parity classification). Response congruency effects denote worse performance for a stimulus, which is associated with different responses in the two tasks as compared to a stimulus, which is associated with the same response. Previous research suggests that such effects reflect direct links between stimuli and responses acquired in the course of experimental practice. In the current study we investigated the impact of stimulus-specific practice and task instruction by reversing the S–R mapping of one task (Experiment 1) or replacing one task with a new one (Experiment 2) in the second half of an experimental session. Consistent with the direct link account, S–R links practiced during the first half of the experiment largely determined congruency effects despite altered task instructions. Furthermore, the results suggest that previously practiced S–R links (a) can be relatively quickly overwritten by practicing a novel S–R mapping, and (b) are subject to passive decay when no longer in use.

Introduction

Task switching paradigms (Allport, Styles, & Hsieh, 1994; Fagot, 1994; Meiran, 1996; Rogers & Monsell, 1995) allow the assignment of a set of stimuli to a set of responses under frequently varying categorization rules or S–R mappings. For instance, participants may have to respond to a stimulus digit with a left-sided key press if it is smaller than 5 and with a right-sided key press if it is larger than 5 in one condition (magnitude task), whereas in another condition they may have to respond with a left-sided key press if it is odd and with a right-sided key press if it is even (parity task). A typical finding in such situations is that responding is faster and often more accurate for stimuli associated with the same response in both tasks (henceforth response *congruent*, e.g., in the above example, the numbers 1, 3, 6, and 8) than for stimuli associated with different responses (henceforth response *incongruent*, e.g., in the above example, the numbers 2, 4, 7, and 9).

Previous research demonstrated that the magnitude of response congruency effects (i.e., the performance difference between incongruent and congruent trials) is mediated by *stimulus-specific practice*. Specifically, Kiesel, Wendt, and Peters (2007) found in a given task, the parity task, for example, larger congruency effects for stimuli which were frequently presented in the magnitude task compared to stimuli which never occurred in the magnitude task. This finding suggests that response congruency effects between tasks are brought about by direct links relating specific stimuli to responses, which should increase in strength as a result of experimental practice when a stimulus is repeatedly processed for *the other task*. However, congruency effects—albeit smaller—were also obtained for stimuli, which were uniquely presented

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in one of the tasks (see Koch & Allport, 2006, for a similar finding). These effects may reflect a different mechanism (i.e., concurrent application of the S–R instruction of the competitor task).

The current study was designed to contrast stimulus-specific practice and task instructions as determinants of congruency effects between tasks. To this end, participants switched between a magnitude and a parity task during the first half of an experimental session. In the second half of the experiment, either the parity task was instructed with reversed S–R mapping and half of the stimuli were no longer presented, or the parity task was replaced by a third task which was associated with an orthogonal S–R mapping as regards the two tasks practiced during the first half. This procedure enabled us to compare congruency effects in the magnitude task for stimuli whose S–R mapping was reversed under the new task's instructions (henceforth *response reversal stimuli*), with stimuli whose S–R mapping was no longer practiced (henceforth *no longer presented stimuli*, Experiment 1) and with stimuli which maintained their S–R mapping throughout the experiment (henceforth *response maintenance stimuli*, Experiment 2). Given that response congruency effects result, at least in large parts, from practice-related S–R links, we predict (for the second half of the experiments) marked differences between the congruency effects for response reversal stimuli, on the one hand, and the congruency effects for the stimuli which were no longer practiced or maintained their S–R mapping, on the other hand, *despite equivalently altered task instructions*. Specifically, congruency effects for response reversal stimuli should decrease and reverse throughout the course of practice of the second half of an experimental session, whereas no such reversal should occur for stimuli, which receive no practice as regards a reversed response assignment. Rather, initially acquired S–R links no longer in use may decay passively, thus resulting in gradual decline of the congruency effect for these stimuli. Stimuli, which maintain their response assignment after task replacement, in turn, should be associated with qualitatively the same kind of congruency effects as in the initial part of the experiment. To determine how congruency effects develop throughout the course of practice with an altered task instruction, we analyzed our data as a function of the experimental block.

Reversing the S–R mapping after a practice period has previously been shown to be associated with substantial negative transfer or proactive interference. For instance, Pashler and Baylis (1991) had participants categorize three different types of stimuli—letters, digits, and symbols (for example, &, #)—by pressing arbitrarily assigned response keys over 15 blocks of 50 trials each, before another five blocks were administered in which

the category-response assignment was shuffled. This manipulation resulted in a dramatic performance decrement which was, however, less pronounced for novel stimuli, which had not occurred previously, than for previously used stimuli—thus suggesting that at least part of the performance decrement resulted from stimulus–response links acquired during the initial 15 blocks. In line with these findings—and more closely related to the current study—Koch and Allport (2006) had participants switch between magnitude and parity classifications of stimulus digits for four blocks of 96 trials, with each digit occurring uniquely in one of the tasks. In a final block the stimulus-to-task assignment for all stimuli was reversed (i.e., if the digit 1 occurred in the magnitude task during the practice phase, it was presented in the parity task in the final block). Because magnitude and parity decisions involved the same pair of response keys, this manipulation resulted in reversal of the *S–R mapping* for half of the stimuli (i.e., the incongruent digits) while the other half of the stimuli maintained their S–R mapping (i.e., the congruent digits). Although performance was overall impaired in the final block, this impairment was larger for the incongruent digits than for the congruent digits (albeit the effect reached significance only in the errors).

While such findings demonstrate that *task-relevant* processing (i.e., selecting a response according to the S–R rules of the currently relevant task) suffers from previous incompatible S–R practice, it is a different question whether or not *irrelevant* processing (i.e., response activation according to the S–R rules of a currently irrelevant task) is similarly affected. After all, certain dissociations between intentional responding to task-relevant information and interference from processing the same information, when it is irrelevant for a current task, have been observed. For instance, in studies investigating the perception of global and local stimulus features, certain manipulations result in slowing of responses to the global level without a corresponding decrease in interference of global information on responses to the local level (e.g., Hübner, 1997; Lamb & Yund, 1993).

Experiment 1

Experiment 1 was designed to investigate overwriting and passive decay of previously established S–R links. This was done by reversing the S–R mapping of the parity task for the second half of an experimental session and comparing—in the non-altered magnitude task—congruency effects for stimuli which were no longer presented in the parity task with stimuli which still occurred in the (reversed) parity task.

In as much as response congruency effects go back to stimulus-specific practice, we predict (a) overwriting of previous S–R links by practicing a new S–R mapping, which should result in reversal of the congruency effects for response reversal stimuli, and (b) decay of S–R links no longer used, which should result in gradual reduction of congruency effects for no longer presented stimuli. This prediction contrasts with the view that congruency effects arise from the application of the current competitor task's S–R rules. Specifically, reversal of congruency effects for no longer presented stimuli would demonstrate that such task instruction-dependent processing outweighs previously established S–R links.

Method

Participants

Participants were 16 students of psychology at the University of Wuerzburg who took part in the experiment in partial fulfillment of a course requirement. They ranged in age from 20 to 40 years. Each participant attended a single experimental session lasting approximately 50 min.

Apparatus and stimuli

An IBM compatible computer equipped with a 17 inch VGA-display and the software package E-Prime (Schneider, Eschman, & Zuccolotto, 2002) was used for stimulus presentation and response sampling. Tasks were instructed by the German words for smaller–larger (“kleiner–größer”) and odd–even (“gerade–ungerade”). The order of the task categories matched the S–R mapping. Stimuli were the digits 1–9 excluding 5. The task cues extended approximately 6.5×0.7 cm, the stimuli 0.4×0.7 cm. Task cues were presented 1 cm above the digit stimuli, which were presented in the center of the screen. Task cue and stimulus remained on screen until a response was given. Responses were collected with an external keyboard with a distance of 2.5 cm between left and right response keys. Participants pressed the keys with the left and the right index finger, respectively.

Procedure

Each trial started with the presentation of the task cue. On each trial, the task was chosen randomly. 200 ms after the cue onset the stimulus was presented. Response times (RTs) were recorded from the onset of the target until the onset of the response. The next trial started 1,500 ms after response onset. Errors were indicated by the German word “Fehler” presented in red together with a beep tone.

The experiment consisted of two parts. In the first part, participants performed five blocks with 96 trials per block. In each block, each stimulus was presented six times for each task. In the second part of the experiment, the S–R mapping for the parity task was reversed, that is if participants had to press a left key for odd and a right key for even numbers in the first part, they were then instructed to press a right key for odd and a left key for even numbers. The second part also consisted of five blocks with 96 trials per block. In each block all 8 digits were presented six times for the magnitude task. For the parity task only 4 digits (either the digits 1, 4, 6, 7, or the digits 2, 3, 8, 9, counterbalanced over participants) were presented 12 times per block. We confined reversal of the S–R mapping to the parity task because interpretation of S–R reversal in the magnitude task is complicated due to the fact that responding to small digits is faster with a left-sided movement and responding to larger digits is faster with a right-sided movement, compared to the reversed mapping. This is the so-called spatial–numerical association of response codes (SNARC) effect (Dehaene, Bossini, & Giraux, 1993). The S–R mapping for both tasks was counterbalanced over participants.

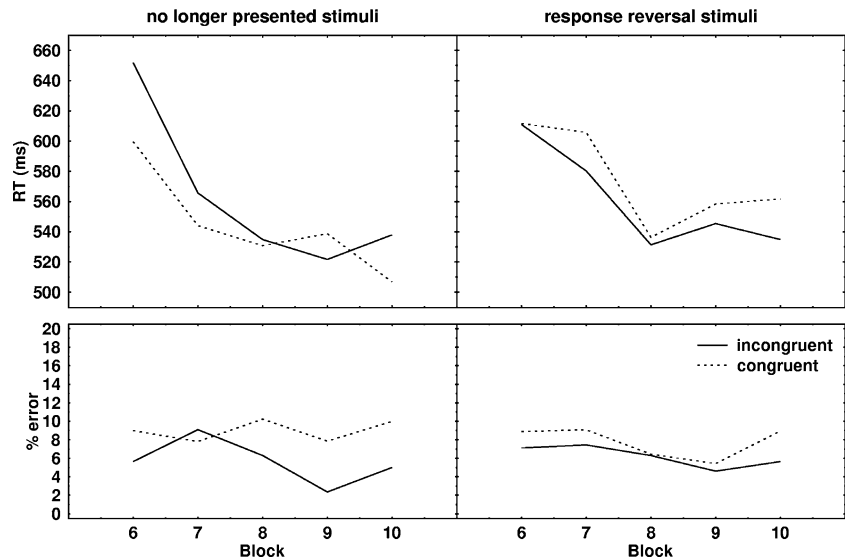
Results

The first trial of each block, trials following an error (8.7%), and trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant in each condition (1.5%) were excluded from the analysis. Furthermore, only the magnitude task was considered for the analysis. The first and the second part of the experiment were analysed separately. For the first part, mean RTs for correct trials and mean percentages of error (PEs) were computed for each participant separately for congruent and incongruent stimuli. For the second part, mean RTs and PEs were computed for each participant for each combination of the factors block (6–10), congruency (incongruent vs. congruent), and stimulus class (no longer presented vs. response reversal). Averaged data across all participants for the second part are presented in Fig. 1. Please note, that the factor congruency was always coded according to the S–R mapping of the first part of the experiment. As the S–R mapping for the parity task was reversed in the second part of the experiment, the congruency relations were also reversed.

In the first part of the experiment, participants responded more slowly to incongruent (667 ms) than to congruent stimuli [634 ms, $t(15) = 2.49$, $p < .05$]. The conditions did not significantly differ regarding error rates (7.9 vs. 6.6%, $t(15) = .89$, $p = .39$).

For the second part, an ANOVA with the within-subject factors block, congruency and stimulus class revealed a

Fig. 1 Mean RTs (*upper panels*) and error proportions (*lower panels*) in Experiment 1 displayed separately for the two stimulus classes (no longer presented stimuli, response reversal stimuli) as a function of block (6–10) and congruency (congruent, incongruent)



significant main effect of block, $F(4,60) = 6.75$, $p < .001$, $MSE = 84,895.4$, a marginally significant effect of stimulus class, $F(1,15) = 3.22$, $p < .10$, $MSE = 16,705.7$, and a significant interaction between the factors, congruency, and stimulus class, $F(1,15) = 9.41$, $p < .01$, $MSE = 21,287.1$. As can be seen in Fig. 1, participants responded more slowly in block 6 (619 ms) and block 7 (574 ms) than in the final blocks (block 8: 533 ms, 9: 541 ms, 10: 535 ms). In general, they responded somewhat more slowly to response reversal stimuli (568 ms) than to no longer presented stimuli (553 ms). Most importantly, however, participants responded more slowly to incongruent (562 ms) compared to congruent (544 ms) stimuli if the stimuli were not presented in the (reversed) parity task (i.e., no longer presented stimuli). In contrast, the congruency effect was reversed for stimuli that were presented in the parity task (i.e., response reversal stimuli). For these stimuli, participants responded faster to incongruent (561 ms) than to congruent stimuli (575 ms). All other effects were not significant (p 's $> .39$).

The same analysis on error rates revealed only a main effect of congruency, $F(1,15) = 5.32$, $p < .05$, $MSE = 466.0$. Participants made more errors to congruent (8.4%) compared to incongruent stimuli (6.0%), thus the new S–R mapping determined error rates not only for the response reversal but also for the no longer presented stimuli. All other effects were not significant (p 's $> .26$).

Discussion

Experiment 1 demonstrates that S–R links acquired in a previous experimental phase can determine response congruency effects between tasks, thereby corroborating previous demonstrations of the importance of stimulus-

specific practice (Kiesel et al., 2007). Specifically, despite reversal of the S–R mapping in the parity task, stimuli which were not presented in the reversed task still yielded congruency effects according to the previously practiced S–R mapping, as regards RTs. These congruency effects mainly arise in block 6 and 7 and they disappear in the following blocks, thus suggesting gradual decay of S–R links no longer in use. However, as regards PEs, no longer presented stimuli were associated with a significant reversal of congruency effect, thus displaying congruency effects according to S–R links which had never been practiced. That is, some generalization of the novel S–R mapping to non-presented stimuli occurred. As regards the response reversal stimuli, the pattern of results was clearly different. A clear-cut reversal of congruency effects occurred, visible from block 7 on in RT and from block 6 on in PE. This pattern of results is consistent with the idea of relatively fast overwriting of previous S–R links. To summarize, while the maintenance of initial congruency effects for the no longer presented stimuli demonstrates that previously practiced S–R links determine congruency effects despite a contradictory S–R instruction, the different patterns of congruency effects for no longer presented stimuli and response reversal stimuli are consistent with the notions of fast overwriting of previous S–R links and slower passive decay of S–R links no longer in use.

Experiment 2

A problem as regards the interpretation of the pattern of congruency effects for no longer presented stimuli refers to the fact that it is unclear whether these stimuli—which never occurred in the reversed parity task—actually

became part of the mental representation (i.e., the task-set) of the reversed parity task. That is, it is unclear if the pattern of congruency effects obtained for the no longer presented stimuli reflects a pure aftermath of previous practice or the outcome of a competition between this aftermath and the reversed S–R mapping instruction (although the reversal of congruency effects in error rates suggests some application of the novel task instruction to the no longer presented stimuli). It is therefore conceivable that the reversal of the congruency effect (for the response reversal stimuli) obtained in Experiment 1 was brought about by the altered task instruction rather than by the practice-related overwriting of the initially acquired S–R links and that we did not observe such reversal for the no longer presented stimuli, because the novel task instructions were not applied to them.

In response to this possibility, we conducted a second experiment in which we compared congruency effects for stimuli which were, and stimuli which were not, associated with reversal of the instructed S–R mapping, thereby making sure that both kinds of stimuli were part of the mental representation of the novel task. This was achieved by replacing the parity task with a “center–periphery” task—which assigned numbers of medium magnitude (regarding the set of stimuli used) to one response, and more extreme (i.e., small or large) numbers to the other response—after the first half of the experiment. As illustrated in Fig. 2, with this manipulation, half of the stimuli, which were congruent before task replacement kept their level of congruency. The other half of the stimuli, which were congruent before task replacement, were, however, incongruent after task replacement and an analogous reasoning applies to incongruent stimuli. Again, we refer to stimuli with reversed S–R mapping as response reversal stimuli, whereas stimuli, which keep their S–R mapping after task replacement are denoted as response maintenance stimuli.

Assuming that the magnitude and direction of congruency effects is primarily determined by stimulus-specific practice, response reversal stimuli and response maintenance stimuli should be associated with different congruency effects in the magnitude task of the second half of the experiment, although these stimuli do not differ with regard to the S–R mappings in the new task. Whereas response maintenance stimuli—for which the same S–R mapping is practiced in both the parity and the center–periphery task—should yield qualitatively the same kind of congruency effects in both halves of the experiment, congruency effects for response reversal stimuli should disappear and reverse during the course of the second half of the experimental session, because for these stimuli practice in the parity task of the first half of the experiment works in the opposite direction as practice in the center–periphery task of the second half.

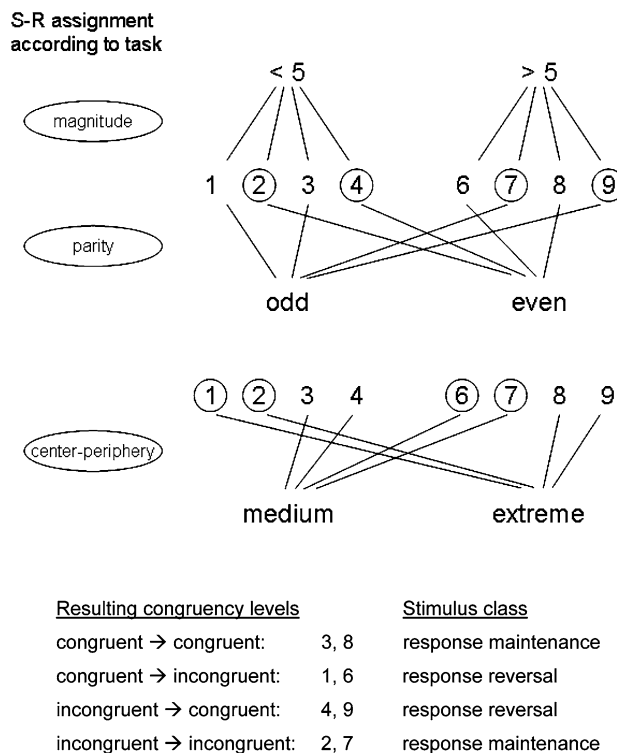


Fig. 2 Example of the stimulus–response mapping regarding the three tasks used and the resulting congruency levels in Experiment 2. Incongruent stimuli regarding the parity and the “center–periphery” task are surrounded by a circle. For the analysis, the factor congruency is coded according to the S–R mapping of the first part of the experiment, i.e., the parity task. The factor stimulus class specifies whether congruency levels in the first and second part of the experiment repeat (response maintenance) or switch (response reversal)

Method

Participants

Participants were 32 students at the University of Wuerzburg who took part in the experiment either in partial fulfillment of a course requirement or were paid 6 Euro. They ranged in age from 19 to 27 years. Each participant attended a single experimental session lasting approximately 55 min. None of the participants had participated in Experiment 1.

Apparatus and stimuli

Apparatus and stimuli were the same as in Experiment 1. To instruct the center–periphery task, the German words for inside and outside (“innen–außen”) were used.

Procedure

The procedure was similar to Experiment 1. In the first part of the experiment, participants performed five blocks of 96

trials each. In these blocks each stimulus was presented six times in the magnitude and the parity task. In the second part of the experiment, the parity task was replaced by the center–periphery task. Again each combination of stimulus and task was required six times per block and five blocks were performed. The S–R mappings for all three tasks were counterbalanced over participants.

Results

The first trial of each block, trials following an error (7.1%), and trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant in each condition (2.5%) were excluded from the analysis. Only the magnitude task was considered for the analysis. The first and the second part of the experiment were analysed separately.

For the first part, mean RTs for correct trials and mean PEs were computed for each participant separately for congruent and incongruent targets. For the second part, mean RTs and PEs were computed for each participant for each combination of the factors block (6–10), congruency (incongruent vs. congruent) and stimulus class (response maintenance vs. response reversal, see Fig. 3). Again, the factor congruency is coded according to the S–R mapping of the first part of the experiment.

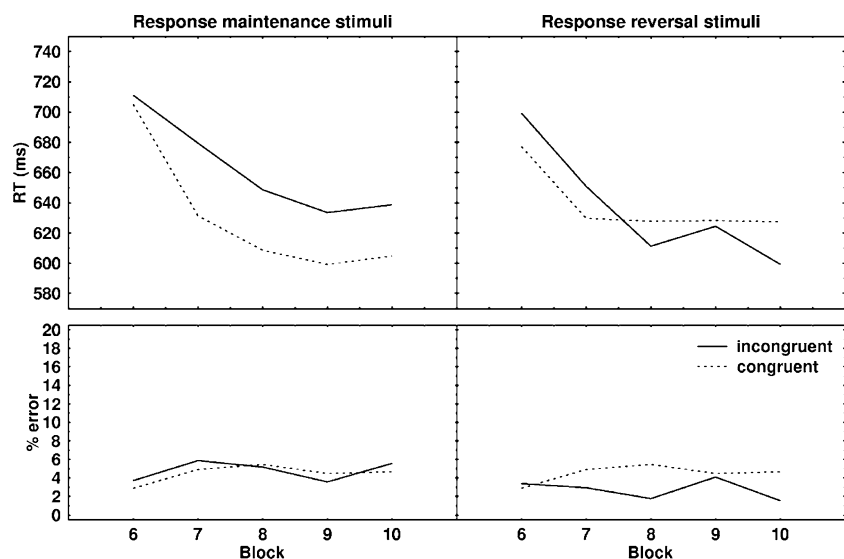
In the first part of the experiment, participants responded more slowly and made more errors to incongruent (719 ms, 9.5%) than to congruent stimuli (671 ms, 3.6%), $t(31) = 4.91$, $p < .001$ for RTs, $t(31) = 5.01$, $p < .001$ for PEs.

For the second part, an ANOVA with the within-subject factors, block, congruency, and stimulus class was com-

puted. The ANOVA revealed significant main effects of the factors block, $F(4,124) = 10.48$, $p < .001$, $MSE = 145,390.6$, and congruency, $F(1,31) = 7.08$, $p < .05$, $MSE = 39,631.3$, and a significant interaction between the factors, congruency and stimulus class, $F(1,31) = 5.03$, $p < .05$, $MSE = 44,846.3$. Participants responded more slowly in block 6 (698 ms) and 7 (648 ms) than in the following blocks (block 8: 624 ms, 9: 621 ms, 10: 618 ms). In general, they responded more slowly to incongruent (650 ms) compared to congruent (634 ms) stimuli, but this congruency effect was modulated by the factor stimulus class. If the S–R mapping for the stimuli was maintained in the second part of the experiment, participants responded more slowly to incongruent (662 ms) compared to congruent (630 ms) stimuli. But the congruency effect vanished for stimuli with reversed S–R mapping. For these stimuli, RTs for incongruent (637 ms) and congruent stimuli (638 ms) did not differ significantly. All other effects were not significant (p 's $> .13$).

The same analysis on error rates revealed no main effects but a significant interaction between the factors congruency and stimulus class, $F(1,31) = 9.33$, $p < .01$, $MSE = 568.2$. Participants made more errors for incongruent (4.8%) compared to congruent stimuli (2.7%), if the S–R mapping remained the same. They also made more errors for congruent (4.5%) than incongruent stimuli (2.7%), for stimuli in which the S–R mapping was reversed. The three-way interaction between all factors just missed significance, $F(4,124) = 2.21$, $p < .10$, $MSE = 77.4$, probably because the reversed congruency effect for response reversal stimuli started just from block 7 on (see Fig. 3). All other effects were not significant (p 's $> .67$).

Fig. 3 Mean RTs (*upper panels*) and error proportions (*lower panels*) in Experiment 1 displayed separately for the two stimulus classes (response maintenance stimuli, response reversal stimuli) as a function of block (6–10) and congruency (congruent, incongruent)



Discussion

Congruency effects in the magnitude task of the second half of the experimental session were clearly different for response maintenance and response reversal stimuli, thereby demonstrating the influence of S–R links practiced in the parity tasks of the first half of the experiment. Specifically, whereas congruency effects for response reversal stimuli disappeared (in RT) and reversed (in PE) during the second half, response maintenance stimuli yielded qualitatively similar congruency effects as in the first half of the experiment. This pattern of results is consistent with the notion that congruency effects in the second half of the experiment were determined by stimulus-specific practice during both parts of the experiment (i.e., in the center–periphery and the parity task) rather than by an abstract representation of the competitor task of the second half of the experiment (i.e., center–periphery task).

Contrasting with Experiment 1, as regards RTs, response reversal stimuli were associated with elimination rather than reversal of the original congruency effect. Inspection of Fig. 3 suggests, however, that this elimination reflects a congruency effect reversal over time (i.e., whereas in blocks 6 and 7 the original congruency effect was maintained, it was numerically reversed in blocks 8–10). Because in Experiment 2 all stimuli were presented in the center–periphery task, response reversal stimuli received only half as much practice with the reversed S–R mapping as in Experiment 1 (in which only response reversal stimuli were presented in the second half). Obtaining reversal of congruency effects at a later stage under these conditions is thus fully consistent with the notion of stimulus-specific practice as the underlying mechanism.

General discussion

The results of the current study corroborate and extend previous demonstrations that stimulus-specific practice is an important source of response congruency effects between tasks (Kiesel et al., 2007). Specifically, in Experiment 1, we obtained different patterns of congruency effects under conditions of an instructed reversal of the S–R mapping depending on whether stimuli did or did not receive practice with the reversed S–R mapping. Stimuli, which were not presented after the S–R mapping reversal (at least as regards RTs) yielded congruency effect according to the initially practiced S–R links which seemed, however, to decay with time. Contrarily, quick reversal of congruency effects was observed for the stimuli

which received practice with the reversed S–R mapping. Similarly, in Experiment 2 stimuli which were consistently practiced with the same S–R mapping yielded congruency effects according to the S–R instruction of the novel competitor task, whereas stimuli which were previously practiced with a reversed S–R mapping were associated with elimination (as regards RT) and reversal (as regards PE) of the congruency effect. Thus, the current study demonstrates that response congruency effects between tasks are primarily determined by stimulus-specific practice rather than by the S–R instruction of the current competitor task.

On the other hand, although stimulus-specific practice clearly dominated abstract S–R instructions, stimulus-unspecific effects, such as the congruency effect for stimuli which are consistently presented in only one task (e.g., Kiesel et al., 2007; Koch & Allport, 2006; see also Wenke, Gaschler, & Nattkemper, 2007) or the congruency effect reversal in error proportions for the no longer presented stimuli in Experiment 1 of the current study need clarification. That is, it has to be determined under what conditions stimuli are processed according to an irrelevant abstract task-set. Viewed from a broader perspective, the current findings add to a growing body of evidence demonstrating the stimulus-specific nature of “classical” effects in task switching paradigms, which were originally assumed to be related to abstract task-sets (Allport et al., 1994; Fagot, 1994; Meiran, 2000; Rogers & Monsell, 1995; Rubinstein, Meyer, & Evans, 2001). Most notably in this regard, Allport and co-workers (e.g., Allport & Wylie, 2000; Koch & Allport, 2006; Waszak, Hommel, & Allport, 2003) showed that at least large parts of so-called task switch cost (i.e., performance decrement on task alternation trials as compared to task repetition trials) are brought about by stimulus-specific bindings acquired during performance of the competitor task, which increase in strength with the frequency of presentation. Likewise, focusing on recency rather than frequency of stimulus occurrence, Hübner, Kluwe, Luna-Rodriguez, and Peters (2004) found overestimation of the task switch cost when including trial-to-trial repetitions of stimulus attributes (for similar suggestions see Hoffmann, Kiesel, & Sebald, 2003). Finally, Lien, Ruthruff, Remington, and Johnston (2005) recently demonstrated that beneficial effects of increased preparation time for an upcoming task are bound to specific stimuli. Given this development, an important endeavour of future research will consist in pinpointing the (residual) role of abstract task-sets.

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