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Automatic activation of task-related representations in task shifting

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Stimulus displays consisting of a target and a distractor can produce task conflicts when target and distractor are associated with different tasks. The present study examined whether these stimulus-induced task conflicts are affected by priming the irrelevant task or by increasing the salience of the distractor. In a series of three experiments, we employed a task-shifting paradigm in which subjects had to apply one of two judgments to either the global or the local level of a hierarchical stimulus. In each block, the target level and the judgment were either constant or mixed. Stimulus-induced judgment conflicts were measured by comparing performance for stimuli associated with two judgments and stimuli associated with only one. It turned out that only mixing the target level and not mixing the judgment increased the conflicts. These findings indicate that only the salience of the distractor modulates stimulus-induced conflicts.

It is a well-known phenomenon that stimuli can automatically activate associated responses. Consequently, when a stimulus display is associated with more than one response, response conflicts can emerge, as has been shown in several experimental paradigms, including the Stroop paradigm (Stroop, 1935) and the Eriksen flanker task (Eriksen & Eriksen, 1974). Furthermore, recent studies have provided some evidence that stimuli can even activate mental structures that are not directly related to a specific response. For instance, it has been hypothesized that stimuli can activate whole tasks (Monsell, Taylor, & Murphy, 2001; Rogers & Monsell, 1995; Waszak, Hommel, & Allport, 2003), producing conflicts whenever the stimuli in a display are linked to more than one task. However, although response conflicts are well examined, less is known about the conditions under which stimulus-induced task conflicts can emerge, or about how the cognitive system is able to resolve these conflicts.

A viable method for examining these questions is the task-shifting paradigm, in which subjects alternate between two or more choice tasks in either a random or fixed order (see, e.g., Allport, Styles, & Hsieh, 1994; Meiran, 1996; Rogers & Monsell, 1995). So far, research on this paradigm has focused mainly on the so-called *shift cost*, which refers to the impaired performance in trials in which the task is shifted (*task shift trials*) rather than repeated (*task repetition trials*). The tasks used in this paradigm usually share the same stimulus materials and physical responses. Often, subjects must apply a given task (e.g., a consonant/vowel judgment) to a target stimulus (e.g., a letter) while ignoring a distractor (e.g., a digit) linked to an irrelevant task (e.g., an odd/even judgment). Accordingly, stimulus-induced task conflicts can emerge because stimulus presentation leads to the activation of multiple tasks.

The present study addressed the question of the conditions under which a distractor stimulus can trigger stimulus-induced task conflicts. We started with an observation frequently made in task-shifting paradigms, that stimulus-induced task conflicts increase on task shift relative to task repetition trials (Rogers & Monsell, 1995; Waszak et al., 2003; Waszak, Hommel, & Allport, 2005). This finding has been taken as evidence that a stimulus can activate an irrelevant task more strongly when this task was primed on the previous trial (Waszak et al., 2003, 2005). However, we will show that such a conclusion is not justified, but rather that a second variable could be more important than priming per se. We suggest that the amount of task conflict induced by a stimulus display depends on the salience of the distractor that is linked to the irrelevant task. More specifically, salience should determine the extent to which a distractor can capture attention and affect further processing. High distractor salience can result, for instance, when the stimulus category of the distractor is primed. This account points to an aspect of executive control that is often ignored. If the strength of task conflicts depends on distractor salience, then the resolution of these conflicts already starts at the level of target selection. Accordingly, visual selective attention might play a crucial role in the coordination of tasks (see, e.g., Logan & Gordon, 2001; Phaf, Van der Heijden, & Hudson, 1990).

In the following sections, we first consider in detail two studies in which stimulus-induced task conflicts in task-shifting conditions were examined. Then, we report three new experiments in which the contributions of task- and stimulus-related aspects of stimulus-induced

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task conflicts were examined. Finally, we outline a theory of conflict resolution under task-shifting conditions that integrates the finding of multiple levels of conflicts and conflict resolution.

Evidence for Stimulus-Induced Task Conflicts in Task Shifting

An important issue concerns the measurement of stimulus-induced task conflicts. Response conflicts, for instance, are often examined by comparing stimulus displays associated with only one response (*congruent* displays) with others associated with two responses (*incongruent* displays). Impaired performance for the latter displays should reflect the conflict resulting from the activation of more than one response. A similar contrast can be computed for measuring task conflicts. This is achieved by comparing stimulus displays associated with one task (*univalent* displays) with others associated with two tasks (*bivalent* displays). Since task conflicts can be induced only by the bivalent display, this comparison should be a measure of the strength of such conflict. However, a problem emerges when response conflicts and task conflicts are confounded. Such a confound results whenever a stimulus display associated with two tasks is also associated with different responses. One solution to this problem would be, when analyzing task conflicts, to exclusively use stimulus displays in which both tasks lead to the same response (i.e., *bivalent congruent* displays). Because only two studies have employed such a method, they are described in more detail below.

The first of these is the influential study of Rogers and Monsell (1995). In their tasks, subjects had to decide either whether a letter was a consonant or a vowel or whether a digit was odd or even. The categories of both tasks were mapped on the same set of responses (e.g., left key = odd or consonant). The order of tasks was fixed by using a so-called *alternate-runs* schedule (e.g., AABBAABB . . .), and the stimulus displays consisted of a character pair containing a target and a distractor. Which stimulus was the target depended on the task in a given trial. For measuring response conflicts, Rogers and Monsell subtracted the performance measures for bivalent congruent displays (e.g., "3M," based on the key mapping described earlier) from those for bivalent incongruent displays (e.g., "A5"). In contrast, task conflicts were estimated according to the impairment of performance for bivalent congruent displays relative to that for univalent displays, in which the distractor was a neutral symbol (e.g., "2%"). Both conflict types occurred on task shift trials as well as on task repetition trials. However, the conflicts were more pronounced on task shift trials.

A different approach for examining task conflicts was used by Waszak et al. (2003). In their study, subjects had to shift between a word naming and a picture naming task. They exclusively used bivalent stimulus displays that contained a word as well as a picture. In contrast to Rogers and Monsell (1995), they manipulated task conflicts by varying the amount of the subjects' practice with the specific stimulus displays. In an initial phase, one portion of the stimulus displays was practiced with both tasks. According to Waszak et al. (2003), this should lead to an association of those displays with both tasks. A further portion of the stimulus displays was presented exclusively with one of the tasks. Consequently, these displays became associated more strongly with either the word or the picture naming task. When the whole set of stimulus displays was used in a later phase, those displays that were associated with both tasks elicited impaired performance, a result that was interpreted as the effect of a stimulus-induced task conflict. Furthermore, this effect was observed only on task shift trials, at least for the word naming task. In further experiments, Waszak et al. (2003) showed that the extent of this effect varied with the frequency that the stimuli were presented together with one or both tasks. This was taken as evidence that the amount of task conflict depends on the strength of learned stimulus–task associations. Moreover, by analyzing only congruent stimuli, they could distinguish between task conflicts and response conflicts.

Determinants of Stimulus-Induced Task Conflicts

The results of both studies reveal a similar picture. Performance is impaired if a stimulus is associated with multiple tasks. In addition, the cost of this stimulus-induced task conflict seems to contribute to the shift cost, since it either increased on task shift trials (Rogers & Monsell, 1995) or was present only following a task shift (Waszak et al., 2003). But how can this pattern be explained? Why is a distractor stimulus more capable of activating an irrelevant task when the task is shifted? Any explanation must take into account the fact that repeating the task does not imply a stimulus repetition. Accordingly, the strengthening of a specific stimulus–task association on the previous trial cannot cause the effect.

An answer can be found in theories of the shift cost—that is, of the impaired performance on task shift trials. A popular account explains this cost by a mechanism called *task set inertia* (Allport et al., 1994). It is assumed that during the execution of a task, that task becomes activated while the alternative task is inhibited (see also Mayr, 2002; Mayr & Keele, 2000). If the next trial requires the same task, then this task is primed, which improves performance. However, if the task is shifted, then the upcoming task is in an inhibited state, which impairs performance. Thus, this account suggests that the shift cost is caused by a task conflict resulting from positive and negative priming of tasks (Allport & Wylie, 1999). As a consequence, it seems that task conflicts can emerge from two sources: sequential task priming and stimulus-driven activation of tasks.

If this assumption is valid, it would be plausible that both sources of task conflicts could interact in some way. For instance, if a given task is preactivated from the previous trial, this should increase the capability of a stimulus to further activate this task. In the same way, if a task is in an inhibited state, this should decrease the ability of a stimulus to activate the task. Because the irrelevant task is activated while the relevant task is inhibited in a task shift, the task conflict induced by the stimulus should be enhanced on these trials, and explanations of this type have indeed been suggested in the literature (Allport & Wylie, 1999, 2000; Waszak et al., 2003). Such a mechanism also has implications for the question of how stimulus-induced task conflicts are controlled. From this perspective, the same control process—for instance, the inhibition of tasks—could serve to suppress sequentially induced as well as stimulus-induced conflicts.

However, a closer look at the experiments described above reveals a second account that could also explain the data. In the paradigms of Rogers and Monsell (1995) and Waszak et al. (2003), the relevant task had to be applied to a target stimulus, while a distractor associated with the irrelevant task had to be ignored. The target and the distractor were taken from different categories: letters and digits for Rogers and Monsell, and words and pictures for Waszak et al. Most importantly, even if the stimulus did not repeat, a task repetition always implied a repetition of the target category, and a task shift always implied a shift of the target category.

This reasoning leads to a further hypothesis: The increased task conflict on shift trials could be due to the increased salience of the distractor. On task shift trials, the stimulus category that currently defines the distractor defined the target on the previous trial. As a consequence, the distractor category is primed, which enhances the capability of the distractor to capture attention and to affect further processing. This explanation differs from the task-priming hypothesis in one important respect: It implies that the increased stimulus-induced task conflicts on task shift trials are not necessarily a general phenomenon, but rather a consequence of the fact that subjects have to select a target and ignore a distractor. Under these conditions, stimulus-induced task conflicts should be increased whenever the target category is shifted.

Such an explanation is consistent with recent research showing that stimulus-related processes such as selecting the target stimulus contribute substantially to the shift cost (Sohn & Anderson, 2003). Moreover, this theory implies that a type of control other than mere task inhibition could be effective for minimizing stimulus-induced task conflicts. Given that these conflicts are triggered by a distractor, they could be suppressed by the mechanisms of visual selective attention. More specifically, attention to the target should reduce the influence of the distractor on further processing and, accordingly, reduce its ability to cause a task conflict. Indeed, the role of visual attention in task coordination and control has also been discussed in terms of other theories related to task shifting (see, e.g., Logan & Gordon, 2001) and to conflicting tasks (e.g., Phaf et al., 1990).

However, the hypotheses described above are not mutually exclusive. It is conceivable that task-related as well as stimulus-related mechanisms could be effective. The following experiments were designed to examine the extent to which each variable modulates task conflicts during task shifting. More specifically, we tested whether the specific shifting of the task or of the target category enhances conflict.

Experimental Approach

In the present experiments, we applied a paradigm in which two task components, judgment type and level of the target stimulus, varied independently (Hübner, Futterer, & Steinhauser, 2001; Steinhauser & Hübner, 2005). Subjects had to switch between two judgment types—for instance, between a letter judgment (vowel/consonant) and a parity judgment (odd/even). The stimulus categories for both judgment types were mapped onto a common set of responses (e.g., both "vowel" and "even" required a left response). Furthermore, the stimuli had two components, a target (e.g., a digit) and a distractor (e.g., a letter), that were part of the same hierarchical stimulus (Navon, 1977).[1] This hierarchical stimulus consisted of a global symbol that was composed of several local symbols (examples are presented in Figure 1). On each trial, subjects had to apply a prespecified judgment to the target—that is, to the symbol at a prespecified level (e.g., local). Both the judgment and the target level were indicated by a cue preceding the stimulus; the cue's duration was determined by the subject in order to allow for sufficient preparation (Hübner et al., 2001).

To measure stimulus-induced conflicts, we constructed different types of stimuli, which are described in detail in their respective experimental sections. Two of these stimulus types were most important. For one type, the symbols at the target and distractor levels were associated with different judgments. Therefore, stimuli of this type were bivalent and could either be congruent or incongruent. For example, a global letter *A* consisting of local 3s was incongruent, because "vowel" and "odd" required different responses. In contrast, a global *H* made up of 3s was congruent, because "consonant" and "odd" required the same response. In either case, such a stimulus should activate both tasks and, consequently, induce a judgment conflict. For the other stimulus type, only the symbol at the target level was linked to a judgment, while the symbol at the distractor level was neutral. Thus, this stimulus type (e.g., an hourglass made up of 3s) was univalent and could activate only the relevant judgment type.

By comparing the performance for bivalent congruent stimuli with that for univalent stimuli, we could determine the effects of the conflict between the judgments activated by the bivalent stimulus. In the following discussion, we refer to a conflict that is reflected by impaired performance for bivalent relative to univalent stimuli as a *judgment conflict*. The fact that we define task conflicts as conflicts between judgments has some implications, which are discussed at the end of this article. Our main goal in the present study was to examine whether these judgment conflicts were enhanced by increased distractor salience, by increased judgment priming, or by both. Within our paradigm, this issue could in principle be investigated using two methods, a sequential method and a block method.

The first method corresponds to that used by Rogers and Monsell (1995) and Waszak et al. (2003). They compared the effects of task conflicts on trials in which the task repeated and in which it shifted. In the same manner, we could compare the judgment conflict on level repeti-

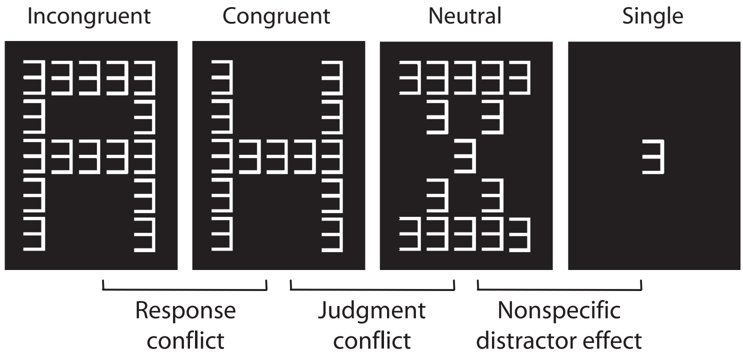

Figure 1. Experiment 1: Examples of the four stimulus types, which differ with respect to which types of conflict are triggered by the distractor level (here: global). Single stimuli contain no distractor level at all. Neutral stimuli have a distractor level that is meaningless with respect to the judgments. For congruent stimuli, the distractor level is linked to an alternative judgment but to the same response as the target level. Incongruent stimuli consist of a target and a distractor level that are associated with different judgments and different responses. Accordingly, by contrasting performance on pairs of these stimulus types, the performance decrements caused by different types of conflict can be estimated. The amount of response conflict results from subtracting performance on congruent stimuli from that on incongruent stimuli. Judgment conflicts can be measured by subtracting performance on neutral stimuli from that on congruent stimuli. Finally, a nonspecific distractor effect can be estimated by subtracting performance on single stimuli from that on neutral stimuli.

tion trials with that on level shift trials, as well as comparing the judgment conflict on judgment repetition trials with that on judgment shift trials. In the latter case, we assumed that on judgment shift trials the judgment associated with the distractor was primed. Accordingly, increased judgment conflict on judgment shift trials indicates that the conflict was enhanced by judgment priming. In contrast, for level shift trials we assumed that the salience of the distractor was increased. Since the target level on the previous trial (e.g., global) became the distractor level on the current trial, the distractor level was primed, increasing its capability to affect processing (for an overview of the sources of level repetition effects with hierarchical stimuli, see Hübner, 2000). Thus, increased judgment conflict after a level shift indicates that the salience of the distractor modulated the conflict.

However, there is one problem with this method. Whereas Rogers and Monsell (1995), as well as Waszak et al. (2003), used an alternate-runs paradigm, with the tasks alternating across trials, our two-component paradigm required that judgments and levels be randomized. This randomization was necessary so that level and judgment could shift independently. However, it is known that the shift cost differs between these two paradigms. With randomized tasks, the shift cost is smaller and dissipates over the course of several consecutive repetition trials (Tornay & Milán, 2001). Moreover, the performance on shift trials in the alternate-runs paradigm seems to reflect additional cue-related processes (Altmann, 2004), which could affect task activation and, consequently, modulate the stimulus-induced task conflict. These results suggest that repetition trials and shift trials in a paradigm with randomized tasks do not differ to the same extent as in the alternate-runs paradigm. If this reasoning is valid, then comparing shift and repetition trials in a randomized-task design might not be sensitive enough to detect different levels of stimulus-induced conflict. Nevertheless, we applied this method to make our results comparable to those of the mentioned studies. However, we also used a second method.

The second method was to compare judgment conflicts between blocks in which the task components were either constant or randomized. More specifically, in one condition, both target level and judgment were held constant. In two further conditions, only one of these task components varied randomly. In a fourth condition, both target level and judgment were randomized independently. In this case, the effect of judgment priming on the judgment conflict could be measured by comparing constant- and mixed-judgment blocks. Analogously, the effect of distractor salience could be assessed by comparing conflict in blocks with a constant level with conflict in blocks with mixed levels. These comparisons should be more sensitive for differences in judgment conflicts than comparisons of repetition and shift trials. In a block with a constant judgment, there is never any priming of the irrelevant judgment, and activation of the judgment linked to the distractor should thus be very low. Similarly, the distractor at the irrelevant stimulus level should have a small influence if this level is never used in a block and, thus, the distractor level is never primed (for such a result, see Hübner, 1997).

EXPERIMENT 1

In Experiment 1, we used the same judgments (consonant/vowel and odd/even) and symbol types (letters and digits) as Rogers and Monsell (1995) within our two-component paradigm. Although our main goal was to investigate conflicts between the two judgments, we also examined further effects of the distractor on performance. First, we looked at the response conflicts that could be measured by comparing the performance for congruent and incongruent stimuli—that is, stimuli in which the two levels led to the same or to different responses. Second, we examined whether the pure presence of a distractor had an effect. This was accomplished by comparing the performance for stimuli without any distractor with performance for stimuli in which the distractor was not associated with any judgment. Both effects provide additional information on how a distractor can cause conflicts during task performance.

Four stimulus types were used (see Figure 1). Incongruent stimuli consisted of a digit and a letter. Moreover, the two symbols were also linked to different responses, according to their associated judgments. Congruent stimuli also consisted of a digit and a letter, but both symbols were linked to the same response. In neutral stimuli, only the target level contained a symbol for the relevant judgment, and the distractor level included a neutral symbol (e.g., an hourglass or a triangle). A fourth stimulus type, called single stimuli, consisted only of a target symbol without any distractor. These stimuli were simple digits or letters whose size was comparable to the size of the global or local level of the hierarchical stimuli, depending on the target level.

Judgment conflicts were measured by comparing the performance for congruent and neutral stimuli (see Figure 1). Congruent stimuli are bivalent—that is, both judgments are applicable. They should produce high judgment conflict, although both judgments would lead to the same response. Neutral stimuli, however, are univalent, since only one judgment is applicable. They should produce no judgment conflict at all. In addition, we measured response conflicts by comparing incongruent and congruent stimuli. By comparing neutral and single stimuli, we obtained a nonspecific distractor effect that represents the effect of the mere presence of a distractor.

Our main question, however, was whether the strength of the judgment conflict depends on the shifting of the judgments, the shifting of the target level, or both. As we have already described, this question was analyzed in two ways. On the one hand, we compared the judgment conflicts on trials in which the target level or judgment shifted with those on trials in which the relevant component repeated. On the other hand, we compared blocks in which levels or judgments were mixed with those in which they were constant. In both types of analysis, we focused on the effect of the stimulus type within the different shift conditions and mixing conditions. In addition, we also examined the main effect of the shift conditions (i.e., the shift cost) and the mixing conditions (i.e., the mixing cost). However, a more detailed discussion of these effects in the present paradigm can be found in Hübner et al. (2001) and Steinhauser and Hübner (2005).

Method

Subjects

Twelve subjects (8 female, 4 male) between 19 and 28 years of age (mean 23.1 years) with normal or corrected-to-normal vision participated in the study. These subjects were recruited at the Universität Konstanz and were paid €5/h.

Apparatus

The stimuli were presented on a 21-in. color monitor. An IBM-compatible PC controlled stimulus presentation and response registration.

Stimuli

We used hierarchical stimuli (Navon, 1977) whose global shapes were constructed from a 5 × 5 grid of local symbols, resulting in a global and a local stimulus level. At a viewing distance of 127 cm, the global symbol extended 1.71º of visual angle horizontally and 2.34º vertically, and the local symbols extended 0.23º × 0.34º. The stimuli were white (82 cd/m^2) on a black (0.314 cd/m^2) background.

On each trial, the target level could either contain one of the digits 1, 3, 6, or 8 or one of the letters *A*, *H*, *U*, or *T*, depending on the indicated judgment. The distractor level could contain either one of these task-relevant symbols (bivalent stimulus), a neutral symbol (neutral stimulus), or nothing (single stimulus). Task-relevant symbols at the distractor level were always drawn from the stimulus category opposite the symbols at the target level—that is, if a letter constituted the target level, a digit appeared at the distractor level. Neutral symbols were drawn from a set of four symbols: a triangle pointing up, a triangle pointing down, two triangles forming a vertical hourglass, and two triangles forming a horizontal hourglass. If a stimulus included no irrelevant level, a single symbol that was similar to either a local or a global symbol in size was presented in the center of the screen. All together, this design resulted in 32 bivalent stimuli, 64 neutral stimuli, and 16 single stimuli.

Procedure

On each trial, subjects had to categorize the symbol at a given level with respect to a given judgment. The judgment was to decide either whether a letter was a vowel or a consonant or whether a digit was odd or even. Both judgments were mapped onto the same responses. Subjects had to press a button with the index finger ("consonant," "even") or middle finger ("vowel," "odd") of the right hand.

Each trial started with the appearance of a cue, which was centered on the screen and could have one of two forms and one of two sizes. The odd/even judgment was indicated by an ellipse, and the consonant/vowel judgment by a square, whereas the target level was indicated by the size of the cue, which corresponded to the size either of the global stimulus shape or of one local element. For instance, a small ellipse indicated that the odd/even judgment had to be performed with the symbol at the local level. After the subjects started the trial by pressing a start key with the left hand, a blank screen appeared for 400–500 msec, followed by the stimulus, which was centered on the screen for 133 msec. The cue for the next trial appeared 1,000 msec after the response and remained on the screen until the subject pressed the start key again. Errors were signaled by a tone.

Each subject worked through 16 blocks with 64 trials per block, resulting in 1,024 experimental trials. Four mixing conditions were realized: (1) *Constant level/constant judgment*. The target level as well as the relevant judgment was constant throughout the block. One block was constructed for each combination of level and judgment. (2) *Constant level/mixed judgment*. The target level was constant but the judgment changed randomly. Two blocks were constructed for each of the two target levels. (3) *Mixed level/constant judgment*. The relevant judgment was always the same, but the target level changed randomly. Two blocks were constructed for each of the two judgments. (4) *Mixed level/mixed judgment*. The target level as well as the relevant judgment changed randomly. Four blocks were constructed for this condition.

For each block and each combination of target level and judgment, four trial types appeared with equal frequency: (1) *Incongruent*. A bivalent stimulus was presented. The symbol at the distractor level was associated with a response different from the one at the target level. (2) *Congruent*. A bivalent stimulus was presented. The symbol at the distractor level was associated with the same response as at the target level. (3) *Neutral*. A stimulus with a neutral symbol at the irrelevant level was presented. (4) *Single*. A single stimulus the size of the indicated level was presented—that is, no distractor level existed.

The 16 blocks were distributed over two 1-h sessions. Each half of a session contained one block in each mixing condition. The order of mixing conditions within each half session was randomized for each subject. The frequency of level/judgment combinations within each half session was counterbalanced. In a preliminary training session, subjects worked through nine blocks: four constant level/constant judgment blocks, two constant level/mixed judgment blocks, two mixed judgment/constant level blocks, and one mixed level/mixed judgment block. At the beginning of each block, subjects were instructed about the level/judgment combinations that could occur in the block.

Data Analysis

Latencies of correct responses and error rates were analyzed. ANOVAs with repeated measures on each variable were applied. Outliers were eliminated by excluding trials with response times larger than 3 sec. Less than 1% of trials were excluded in this way.

Results and Discussion

We applied the following strategy for analyzing the data in this and the further experiments. Our main goal was to examine the magnitude of judgment conflict within the different conditions. However, we included several further analyses, which we organized in the following way. Each Results and Discussion section consists of two sets of analyses. In the first set, the influence of the mixing conditions (the four combinations of constant vs. mixed level and judgment) on performance is reported, whereas in the second set we focus on the effect of the different shift types within these mixing conditions (level/judgment repetition vs. shift). Within each set, we applied the same analysis to four dependent variables: (1) The absolute response times and error rates, collapsed across all stimulus types, were analyzed to determine the main effects of our mixing and shift manipulations on performance (i.e., the mixing cost and the shift cost). (2) Response conflict was computed by subtracting the performance for congruent stimuli from that for incongruent stimuli. (3) Judgment conflict was computed by subtracting the performance for neutral stimuli from that for congruent stimuli. (4) The nonspecific distractor effect was computed by subtracting the performance for single stimuli from that for neutral stimuli. All analyses were conducted for response times as well as for error rates. In the following, we report the data for our distractor effects only in terms of these dependent variables.

Mixing Conditions

The mean response time in this experiment was 552 msec, and the mean error rate was 6.1%. We began by analyzing the influence of the four mixing conditions on our dependent variables. The data for each dependent variable were entered into a two-way ANOVA with the variables level mode (constant, mixed) and judgment mode (constant, mixed).

Absolute performance. The mean response times and error rates for each mixing condition can be found in Table 1. For response times, both main effects were significant, revealing substantial costs of judgment mixing as well as level mixing. Mean response times were higher in the mixed-level blocks (602 msec) than in the constant-level blocks (502 msec) [$F(1,11) = 12.8$, $MS_e = 9{,}493$, $p < .01$], and they were also higher in the mixed-judgment blocks (583 msec) than in the constant-judgment blocks (521 msec) [$F(1,11) = 10.0$, $MS_e = 4{,}524$, $p < .01$]. There was no significant interaction. For error rates, no significant effects were observed.

Response conflict. Mean response conflict scores are shown in the right part of Figure 2. Neither level mode nor judgment mode had a significant effect on the response time scores. The mean response conflict score for response times was 9 msec, which was not significantly different from zero. The same analysis for error rates revealed increased response conflict in blocks with mixed levels (3.9%) relative to blocks with a constant level (1.5%) [$F(1,11) = 5.41$, $MS_e = 13.1$, $p < .05$]. No further effects were significant.

Judgment conflict. Mean judgment conflict scores are shown in the middle panel of Figure 2. For the response time scores, a significant main effect of level mode showed that increased judgment conflict was observed in mixed-level blocks (46 msec) relative to constant-level blocks, where judgment conflict was nearly absent (2 msec) [$F(1,11) = 5.99$, $MS_e = 3{,}813$, $p < .05$]. A planned-contrast analysis using a *t* test showed that only the former value was reliably greater than zero [$t(11) = 2.79$, $p < .05$]. Neither the effect of judgment mode nor the interaction was significant. The same analysis for error rates revealed a nonsignificant judgment conflict of 0.5% and no further significant effects.

Table 1
Experiment 1: Absolute Response Times (RTs, in Milliseconds) and Error Rates Collapsed Across All Stimulus Types

	RT		% Error	
	M	*SEM*	*M*	*SEM*
Constant Level/Constant Judgment	*475*	*11.3*	*5.1*	*0.6*
Mixed Level/Constant Judgment	*568*	*21.6*	*5.7*	*0.6*
Level repetition	544	17.8	5.0	0.7
Level shift	589	25.3	6.4	0.9
Constant Level/Mixed Judgment	*529*	*17.3*	*6.2*	*0.7*
Judgment repetition	514	14.5	5.0	0.8
Judgment shift	545	21.1	7.5	1.0
Mixed Level/Mixed Judgment	*637*	*34.6*	*7.3*	*0.9*
Double repetition	596	26.2	6.7	1.2
Only level shift	657	40.2	6.8	1.1
Only judgment shift	634	35.5	8.0	1.2
Double shift	661	41.4	7.0	1.2

Note—For each mixing condition, the mean performance is given (in italics), as well as the performance for the possible repetition and shift types within the condition.

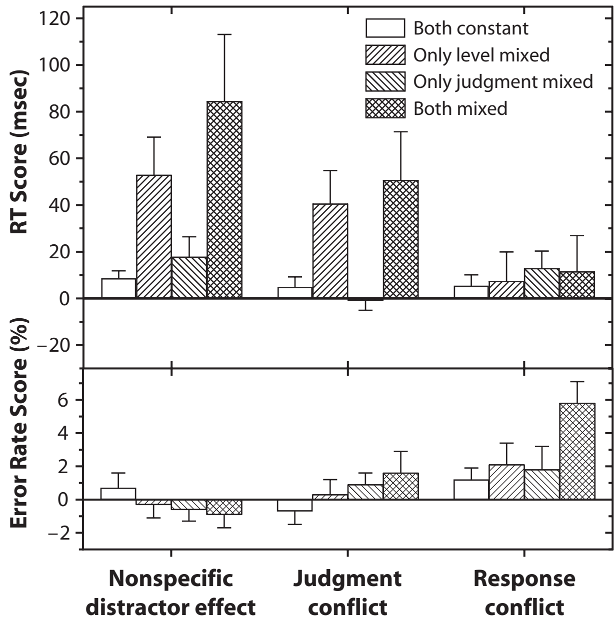

Figure 2. Experiment 1: Distractor effects in the response times and error rates, separately for the four mixing conditions. Each value represents the performance difference between two stimulus types (response conflict, incongruent minus congruent; judgment conflict, congruent minus neutral; nonspecific effect, neutral minus single). Error bars represent standard errors of the mean.

Nonspecific distractor effect. Mean scores for the nonspecific distractor effect are shown in the left part of Figure 2. For the response time scores, there were significant main effects of level mode and judgment mode. The nonspecific distractor effect was increased in mixed-level blocks (68 msec) relative to constant-level blocks (13 msec) [$F(1,11) = 5.93$, $MS_e = 6{,}226$, $p < .05$], and it was increased in mixed-judgment blocks (51 msec) relative to constant-judgment blocks (31 msec) [$F(1,11) = 6.90$, $MS_e = 722$, $p < .05$]. The interaction did not reach significance. For error rates, no significant effects were obtained; the mean nonspecific distractor effect was −0.3%, which was not significantly different from zero.

Summary. The results of this first part of analyses can be summarized in the following way. First, level mixing as well as judgment mixing had an effect on general performance. Moreover, the effects of both mixing types were additive. This finding is consistent with our former results (Hübner et al., 2001; Steinhauser & Hübner, 2005). We will discuss the implications of this result at the end of this study.

Second, our data provide evidence for three types of conflicts. Performance for neutral stimuli was impaired relative to that for single stimuli. This nonspecific distractor effect indicates that the mere presence of a distractor seems to impair performance. This effect could be an indicator of a conflict during target selection. When a second stimulus level (e.g., local) is present, target selection is impaired, even if this level contains a neutral symbol. Furthermore, performance for congruent stimuli was impaired relative to that for neutral stimuli. Whereas the former contained symbols to which both judgments could be applied, the latter consisted of only one task-relevant symbol and a neutral distractor. Accordingly, this effect is indicative of a judgment conflict. Finally, performance for incongruent stimuli was impaired relative to that for congruent stimuli. This effect represents a response conflict because the stimuli only differed with respect to whether the same or different responses are activated by the target and distractor levels.

Third, the amount of conflict induced by the distractor was modulated by our mixing manipulations. Each distractor effect was amplified by mixing the level. The judgment conflict even disappeared with a constant level. This indicates that the effect the distractor symbol has on performance is strongly influenced by the salience of the distractor level. In contrast, mixing the judgment had no effect on either the judgment conflict or the response conflict. Only the nonspecific distractor effect was slightly increased with a mixed judgment. As a consequence, with respect to our main question, we can conclude that judgment conflict is not amplified by priming the irrelevant judgment per se, but rather by increasing the salience of the irrelevant level.

In the preceding analyses, we examined the influence of the blockwise mixing conditions because we hypothesized that such an analysis should be most sensitive for revealing the effects of distractor salience and judgment priming on our conflict measures. However, we can also look at the influence of trial-by-trial effects, as in the studies of Rogers and Monsell (1995) and Waszak et al. (2003). Thus, in further analyses, we investigated the extent to which the different shift types within our mixing conditions modulated the distractor effects.

Shift Conditions

We analyzed the different types of shift cost (level shift cost and judgment shift cost) as well as the distractor effects on these shift and repetition trials. This analysis was done separately for the three mixing conditions in which one or two of the task components were variable. For each mixing condition, we will first provide an analysis of the shift cost averaged across all stimulus types, which are reported in Table 1. Then, we will test whether our distractor effects are different on shift and repetition trials. The corresponding data are presented in Table 2.

Mixed level/constant judgment. A one-way ANOVA with the variable level transition (repetition, shift) on the absolute response times indicated a significant level shift cost of 45 msec [$F(1,11) = 10.5$, $MS_e = 39{,}962$, $p < .01$]. The same type of ANOVA was applied to each of our three distractor effects. Table 2 shows that each of our distractor effects was increased on level shift trials relative to level repetition trials. However, this trend reached significance for neither response nor judgment conflict. Only the nonspecific distractor effect was higher on level shift trials (71 msec) than on level repetition trials (29 msec) [$F(1,11) = 6.21$, $MS_e = 1{,}688$, $p < .05$]. No significant effects were observed in the error rates.

Constant level/mixed judgment. A similar analysis was conducted for the constant level/mixed judgment

Table 2
Experiment 1: Distractor Effects Separately for the Different Shift Types Within Conditions in Which One or Both Task Components Were Mixed

	Response Conflict				Judgment Conflict				Nonspecific Effect			
	RT		% Error		RT		% Error		RT		% Error	
	M	*SEM*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*
Mixed Level/Constant Judgment												
Level repetition	2.6	15.1	1.2	1.1	30.4	12.1	1.3	1.0	28.9	13.0	−2.6	1.4
Level shift	17.1	13.8	3.5	2.3	50.4	17.0	−0.9	1.8	70.7	21.6	1.4	1.7
Constant Level/Mixed Judgment												
Judgment repetition	16.0	9.3	2.1	1.5	10.2	11.3	0.8	0.6	6.3	15.5	−1.6	1.7
Judgment shift	11.8	13.0	2.3	2.5	−8.4	9.2	1.1	1.3	24.7	9.2	−0.1	1.3
Mixed Level/Mixed Judgment												
Double repetition	33.5	32.8	2.7	3.5	50.7	20.2	1.5	2.3	60.1	34.3	−1.5	2.1
Only level shift	18.4	29.1	6.4	2.7	54.3	32.9	1.1	2.4	118.0	46.0	−0.6	1.8
Only judgment shift	34.6	35.4	6.7	2.7	32.2	17.9	2.1	2.1	81.6	37.9	−2.7	3.3
Double shift	−39.3	37.1	6.3	3.6	83.1	43.0	0.5	3.9	80.9	24.2	−0.1	2.5

Note—Each value represents the performance difference between two stimulus types (response conflict, incongruent minus congruent; judgment conflict, congruent minus neutral; nonspecific effect, neutral minus single). RT, mean response time in milliseconds.

blocks, using four one-way ANOVAs with the variable judgment transition (repetition, shift). The analysis of absolute response times revealed a marginally significant judgment shift cost of 31 msec [$F(1,11) = 4.10$, $MS_e = 1{,}375$, $p = .07$]. In contrast, the same analysis applied to the three distractor effects showed that none of them was different for judgment shifts or for judgment repetitions. Similarly, no significant effects in the error rates were obtained.

Mixed level/mixed judgment. For the mixed level/mixed judgment blocks, we first analyzed level and judgment shifts in a two-way ANOVA with repeated measures on the variables level transition (repetition, shift) and judgment transition (repetition, shift). The main effects of level transition and judgment transition were not significant, but there was a trend toward an underadditive interaction for both variables. When the level repeated, the cost of a judgment shift was 38 msec. In contrast, when the level shifted, the judgment shift cost was only 4 msec. However, this interaction also failed to reach significance. In this condition, we compared only the distractor effects on trials with a double shift and those on trials in which both task components repeated. Accordingly, three one-way ANOVAs with the transition variable (double repetition, double shift) were conducted. However, our distractor effects were not significantly different between the trial types. Again, no significant effect was obtained for the error rates.

Summary. The analysis of level and judgment transitions showed a pattern of shift costs comparable to that reported in previous studies (Hübner et al., 2001; Steinhauser & Hübner, 2005). We observed a level as well as a judgment shift cost, which were subadditive in the blocks in which both shift types could occur. We discuss this pattern in Steinhauser and Hübner (2005). More important, however, were the distractor effects for the respective trial types. There was a consistent trend toward increased conflicts on level shift trials. This effect did not reach significance, indicating that even on level repetitions in mixed-level blocks, the distractor produced considerable conflicts. Initially, we speculated that repetition and shift trials are rather similar with respect to stimulus-induced conflicts when the tasks are randomized. Indeed, this theory receives support from the present results.

Conclusions

Taken together, the results of Experiment 1 mainly address the question of whether judgment conflicts are modulated by shifting the judgment or by shifting the target level. As our results show, substantial judgment conflicts were present, but only in blocks in which the target level varied, whereas there was no effect when the target level was constant. We take this as evidence that judgment conflicts are increased when the salience of the distractor is high, which was obtained in our case by mixing the target level. In contrast, the judgment conflict was similar in blocks in which the judgment varied and blocks in which the judgment was constant. Obviously, a variable judgment seems not to increase the capability of the distractor to activate the irrelevant judgment.

For these conclusions to be valid, however, one must assume that the comparison of neutral stimuli and congruent stimuli actually reflects a stimulus-induced conflict between judgments. Unfortunately, there is also an alternative interpretation: The effect could also reflect a conflict during target selection. This interpretation is supported by the following arguments. Normally, subjects are instructed to select the target at the level at which it occurs. But given the structure of our neutral stimuli, the target symbol could also be determined without knowing at which level it occurs. This results from the fact that our neutral stimuli contained only symbols from one category (e.g., a letter) linked to a relevant judgment. Because of this, the subjects might have been tempted to ignore the redundant level information and select the target based on its symbol category.

In this case, however, the duration of target selection should depend on the number of task-relevant symbol categories activated by the stimulus. Because bivalent stimuli consist of a letter and a digit, they activate both symbol categories. In contrast, neutral stimuli activate only one symbol category. Thus, what we have interpreted as a judgment conflict could reflect a conflict between symbol categories used for selecting the target. The following two experiments were conducted to exclude this alternative interpretation. Experiment 2 is a replication of Experiment 1. However, instead of letters and digits, only digits were used for both judgments. In Experiment 3, we tested a prediction that can be derived only from the assumption that the measured conflicts were judgment conflicts.

EXPERIMENT 2

In this experiment, we examined judgment conflicts under conditions in which targets and distractors were from the same symbol category. The task-relevant symbols were digits, and the judgments were a magnitude judgment (less than 6, greater than 5) and a parity judgment (odd, even). Because both judgments could now be applied to each digit, we could not construct univalent stimuli. As a consequence, as in the method of Waszak et al. (2003), we manipulated the degree of judgment conflicts by varying the associative strength between specific digits and judgments. Observing judgment conflicts under these conditions would strongly support our hypothesis that the effects in Experiment 1 were due to the automatic activation of acquired stimulus–judgment associations.

The following method was applied. We constructed two disjunctive sets of digits: {2, 3, 6, 7} and {4, 5, 8, 9}. During the whole experiment, the digits of one of these sets were exclusively presented together with the parity judgment, and the other set was only presented together with the magnitude judgment. The assignment of the two sets to the two judgments was counterbalanced across subjects. Again, we constructed four types of stimuli. Congruent as well as incongruent stimuli consisted of a digit at the local level taken from one set and a digit at the global level taken from the other set. For instance, if the digit at the global level should be classified according to the parity judgment, the global digit was taken from the parity number set and the local digit was taken from the magnitude number set. Neutral and single stimuli were constructed in a way similar to that in the first experiment.

One important note has to be made with respect to the congruency effects. In Experiment 1, a stimulus was considered congruent when the distractor was linked to the same response required for the target. Otherwise, the stimulus was defined as incongruent. In the present experiment, however, the distractor was linked to two responses: one for the relevant judgment and one for the irrelevant judgment. Accordingly, two types of congruency could be defined.[2] First, the distractor could be congruent or incongruent with respect to the relevant judgment. Second, the distractor could also be congruent or incongruent with respect to the irrelevant judgment. For instance, if the parity judgment was relevant and the target digit was 3 (odd = right), a digit 8 at the distractor level would be incongruent with respect to the relevant judgment (even = left) but congruent with respect to the irrelevant judgment (greater than 5 = right). We expected a more pronounced effect of the latter type of congruency on performance, because the distractor was always taken from the set of digits that was applied to the irrelevant judgment. As a consequence, the distractor digit should be associated more strongly with the response of the irrelevant judgment. Nevertheless, we examined both types of congruency and chose the stimuli used for computing the judgment conflict on the basis of the outcome of these analyses.

Assuming that the unequivocal assignment of each digit to one of the judgments results in a strengthening of only one stimulus–judgment association, we should observe the following results. A congruent stimulus should produce high judgment conflict, since the target digit strongly activates the relevant judgment but the distractor digit activates the irrelevant judgment. In contrast, a neutral stimulus should induce little judgment conflict, because it contains only one digit, strongly associated with one judgment. Accordingly, we would expect impaired performance for congruent stimuli relative to neutral stimuli. Note that such a result could not be explained by a conflict between symbol categories, because symbols of the same category, digits, were used for targets and distractors in both congruent and incongruent stimuli. This manipulation also forced the subjects to use the indicated level for target selection.

Method

Twelve subjects (8 female, 4 male) between 19 and 28 years of age (mean 23.5 years) with normal or corrected-to-normal vision participated in the study. Subjects were recruited at the Universität Konstanz and were paid €5/h. The stimuli, tasks, and procedure of this experiment were similar to those in Experiment 1, with the following exceptions. Judgments were now a parity judgment (odd/even) and a magnitude judgment (less than 6/greater than 5). The stimulus categories of these judgments were mapped to the same response set: the index finger (even, less than 6) and middle finger (odd, greater than 5) of the right hand. Again, we used hierarchical stimuli, but now only digits (2–9) were used as task-relevant symbols. The digits were distributed in two sets: {2, 3, 6, 7} and {4, 5, 8, 9}. One set of digits was only classified with respect to the parity judgment, and the remaining digits only appeared as targets for the magnitude task. Half of the subjects performed the parity judgment on the first set, whereas the remaining half performed the parity judgment on the second set. In congruent and incongruent stimuli, the distractor symbol was always taken from the set of the irrelevant judgment.

Results and Discussion

The mean response time and mean error rate in this experiment were 603 msec and 3.6%, respectively. Analyses similar to those in Experiment 1 were computed. In a first part of the analysis, we examined the influence of level mixing and judgment mixing on absolute performance and the distractor effects.

Mixing Conditions

Absolute performance. The absolute response times and error rates, averaged across all stimulus types, are shown in Table 3. These data were entered into a two-way ANOVA with repeated measures on the variables level mode (constant, mixed) and judgment mode (constant, mixed). For the response times, we obtained significant effects of level mode and judgment mode. The mean response time was increased in mixed-level blocks (663 msec) relative to constant-level blocks (544 msec) [$F(1,11) = 30.2$, $MS_e = 5{,}643$, $p < .001$]. Moreover, it was also increased in mixed-judgment blocks (648 msec) relative to constant-judgment blocks (559 msec) [$F(1,11) = 28.6$, $MS_e = 3{,}350$, $p < .001$]. Again, the two mixing effects did not interact significantly. For the error rates, only the level mode variable reached significance. More errors were committed in mixed-level blocks (4.8%) than in constant-level blocks (2.4%) [$F(1,11) = 16.8$, $MS_e = 4.2$, $p < .01$].

Response conflicts. Because of our stimuli, two types of response conflict could be distinguished. The distractor could be congruent or incongruent with respect to the relevant or the irrelevant judgment. To test whether both types of congruency have an effect, we conducted separate analyses for each of them. First, we computed the response conflict scores with respect to the relevant judgment. For response times, neither level mixing nor judgment mixing had an effect on this variable. The mean score was 9 msec, which was not significantly different from zero. Moreover, no significant effect in error rates was observed. Second, the same analysis was applied to response conflict for the irrelevant judgment. The corresponding scores are shown in the right part of Figure 3. For response times, this measure was increased in blocks with mixed judgments (35 msec) in comparison with blocks with a constant judgment (3 msec) [$F(1,11) = 8.13$, $MS_e = 1{,}534$, $p < .05$]. For error rates, the response conflict score was increased in mixed-level blocks (4.3%) in comparison with constant-level blocks (0.4%) [$F(1,11) = 7.62$, $MS_e = 24.1$, $p < .05$]. No further interactions were significant.

Judgment conflict. The judgment conflict scores were computed by subtracting performance for neutral stimuli from that for congruent stimuli. In response to the results of the previous analysis, the latter were defined with respect to the irrelevant judgment. The corresponding judgment conflict scores are shown in the middle panel of Figure 3. For response times, judgment conflict was increased in mixed-level blocks (46 msec) relative to constant-level blocks (−2 msec) [$F(1,11) = 11.18$, $MS_e = 2{,}469$, $p < .01$]. A planned-contrast analysis showed that only the former result was significantly different from zero [$t(11) = 3.67$, $p < .01$]. Furthermore, judgment mode had no significant effect, and no significant interaction was obtained. In the error rates, no significant effect was obtained. However, the mean judgment conflict score was 1.2%, which was reliably greater than zero [$t(11) = 3.24$, $p < .01$].

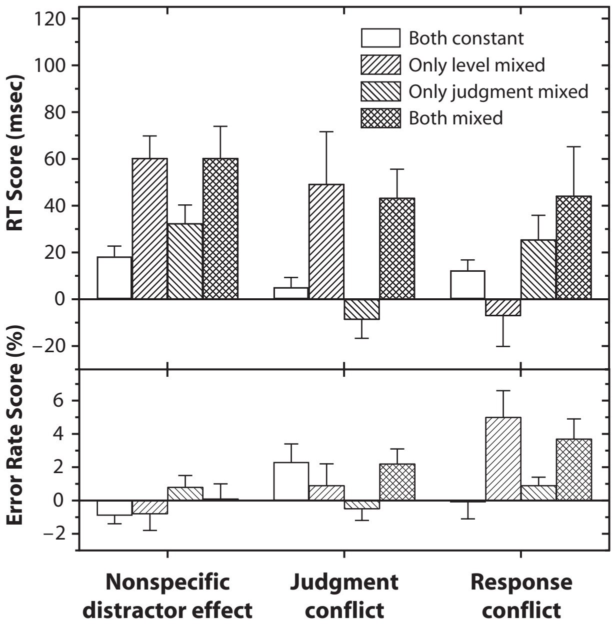

Figure 3. Experiment 2: Distractor effects in the response times and error rates, separately for the four mixing conditions. Each value represents the performance difference between two stimulus types (response conflict, incongruent minus congruent; judgment conflict, congruent minus neutral; nonspecific effect, neutral minus single). Error bars represent standard errors of the mean. Note that congruency was defined with respect to the irrelevant judgment (see text for details).

Nonspecific distractor effect. Finally, a nonspecific distractor effect was computed by subtracting performance for single stimuli from that for neutral stimuli. These scores are presented in the left part of Figure 3. Again, the response time scores for this measure were increased in mixed-level blocks (60 msec) in comparison with constant-level blocks (25 msec) [$F(1,11) = 12.4$, $MS_e = 1{,}179$, $p < .01$]. This time, no effect of judgment mode was obtained. In the error rates, no significant effects were obtained, and the overall score was not significantly different from zero (−0.2%).

Summary. The analyses of the distractor effects within the different mixing conditions replicated the effects observed in Experiment 1 to a large extent. We found a substantial judgment conflict that was only present when the level was mixed. In contrast, no effect of judgment mixing on this variable was obtained. Moreover, we observed a

Table 3
Experiment 2: Absolute Response Times (RTs, in Milliseconds) and Error Rates Collapsed Across All Stimulus Types

	RT		% Error	
	M	*SEM*	*M*	*SEM*
Constant Level/Constant Judgment	*499*	*5.9*	*2.0*	*0.4*
Mixed Level/Constant Judgment	*619*	*15.5*	*4.5*	*0.7*
Level repetition	599	15.1	3.7	0.6
Level shift	641	17.2	5.2	0.9
Constant Level/Mixed Judgment	*589*	*13.6*	*2.8*	*0.4*
Judgment repetition	565	11.3	1.9	0.4
Judgment shift	612	17.1	3.5	0.5
Mixed Level/Mixed Judgment	*707*	*21.4*	*5.1*	*0.7*
Double repetition	652	19.5	2.5	0.6
Only level shift	717	22.3	6.5	1.2
Only judgment shift	734	25.8	5.6	1.3
Double shift	736	26.1	5.7	0.9

Note—For each mixing condition, the mean performance is given (in italics), as well as the performance of the possible repetition and shift types within each condition.

nonspecific distractor effect that was also affected by level mixing but not, this time, by judgment mixing. Finally, response conflict was observed only when it was defined with respect to the irrelevant judgment, confirming our prediction. The distractor level contained exclusively digits to which the irrelevant judgment was applied, and accordingly, these stimuli activated mainly the response associated with this irrelevant judgment. Interestingly, in this experiment, response conflict was markedly increased with a mixed judgment.

Shift Conditions

As in Experiment 1, we also examined how distractor effects were affected by the shift conditions. Each mixing condition in which one or two task components varied was analyzed in two stages. First, the shift cost was analyzed by collapsing absolute response times and error rates across all stimulus types (see Table 3). Then each distractor effect was examined separately (see Table 4).

Mixed level/constant judgment. For the mixed level/constant judgment blocks, a one-way ANOVA on absolute response times with the variable level transition (repetition, shift) indicated a significant level shift cost of 42 msec [$F(1,11) = 17.5$, $MS_e = 604$, $p < .01$]. However, the same ANOVAs on our distractor effects revealed no significant effect, although Table 4 shows a trend toward higher judgment conflict on level shift trials (61 msec) than on level repetition trials (35 msec). No effects reached significance in the error rates.

Constant level/mixed judgment. For the constant level/mixed judgment blocks, a one-way ANOVA with the variable judgment transition (repetition, shift) on absolute response times revealed a significant judgment shift cost of 47 msec [$F(1,11) = 7.71$, $MS_e = 1{,}723$, $p < .05$]. Again, none of the ANOVAs involving the distractor effects detected a significant effect of judgment transition. A similar picture was obtained for the error rates, in which only a significant judgment shift cost of 1.5% was observed [$F(1,11) = 5.48$, $MS_e = 2.6$, $p < .05$].

Mixed level/mixed judgment. For the mixed level/mixed judgment blocks, we analyzed level and judgment shifts in a two-way ANOVA with the variables level transition (repetition, shift) and judgment transition (repetition, shift). A significant underadditive interaction for both variables was observed in the response times [$F(1,11) = 9.65$, $MS_e = 1{,}265$, $p < .05$]. When the level repeated, the cost of a judgment shift was 82 msec. On level shift trials, the judgment shift cost decreased to 19 msec. Again, we compared the distractor effects on trials with a double shift with those on trials in which both task components repeated, in one-way ANOVAs with the variable transition (double repetition, double shift). However, no significant effect was obtained. In the error rates, only a significant level shift cost of 1.1% was observed [$F(1,11) = 7.66$, $MS_e = 6.8$, $p < .05$].

Summary. The comparison of the distractor effects for the different shift and repetition conditions revealed the same picture as in Experiment 1. We observed a trend toward higher judgment conflict only on level shifts relative to level repetitions. However, none of these effects reached significance. This result supports our conjecture that the comparison of mixing conditions is more sensitive for detecting differences in stimulus-induced conflicts than is the comparison of shift conditions, at least in the present paradigm.

Conclusions

Taken together, the results of Experiment 2 were comparable to those of the previous experiment. Congruent stimuli substantially increased response times relative to neutral stimuli. This clearly indicates the presence of a judgment conflict. Again, this effect was observed for a mixed but not for a constant target level. Moreover, the degree of judgment conflict was independent of whether the judgment varied or not, and conflict also did not increase significantly on shift trials relative to repetition trials, irrespective of whether the level or the judgment shifted. However, again there was a trend toward increased

Table 4
Experiment 2: Distractor Effects Separately for the Different Shift Types Within Conditions in Which One or Both Task Components Were Mixed

	Response Conflict				Judgment Conflict				Nonspecific Effect			
	RT		% Error		RT		% Error		RT		% Error	
	M	*SEM*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*
Mixed Level/Constant Judgment												
Level repetition	9.0	15.4	3.9	1.4	34.8	18.0	−0.6	1.3	65.2	10.7	−0.9	0.9
Level shift	−18.5	19.1	6.3	2.2	61.0	32.7	2.1	1.9	53.7	17.2	−0.7	1.4
Constant Level/Mixed Judgment												
Judgment repetition	24.4	12.0	0.2	0.8	−16.2	11.4	0.9	0.4	29.8	12.7	−0.5	0.8
Judgment shift	34.9	14.9	1.3	1.0	−11.6	16.3	−1.4	1.1	34.8	13.1	1.7	1.1
Mixed Level/Mixed Judgment												
Double repetition	−17.8	36.7	2.6	1.7	71.9	32.4	−0.4	1.2	53.2	16.8	0.2	1.5
Only level shift	54.3	33.9	3.7	3.2	52.0	24.3	5.0	2.8	65.3	46.7	1.0	1.9
Only judgment shift	45.6	45.7	4.3	2.2	47.5	31.8	4.2	1.8	33.0	23.3	−2.6	2.8
Double shift	60.3	36.8	3.1	2.2	5.2	24.7	−0.6	2.3	82.8	31.4	2.8	1.6

Note—Each value represents the performance difference between two stimulus types (response conflict, incongruent minus congruent; judgment conflict, congruent minus neutral; nonspecific effect, neutral minus single). Note that congruency was defined with respect to the irrelevant judgment (see text for details). RT, mean response time in milliseconds.

judgment conflict on level shift trials. Together, the present data lead to the conclusion that judgment conflicts are mainly amplified by salient distractors. Moreover, this experiment showed that judgment conflicts are not caused by conflicting symbol categories. This hypothesis can be excluded because both judgments were applied here to the same type of stimuli.

However, before we can conclude that we actually observed a conflict between judgments, we have to consider a further interpretation: The conflict could have also emerged from competition between single symbols during target selection. To understand this theory, assume that each digit, target as well as distractor, first activates a representation of its identity (e.g., "8"). At a first processing stage, the mental system selects the representation of the target and inhibits that of the distractor. Steinhauser and Hübner (2005) considered this process to be responsible for the cost of level mixing—that is, the increased response times when the target level varies. The observed conflict could reflect an increased competition between target and distractor representations within the target selection stage. For congruent stimuli, two digits compete for being selected, whereas for neutral stimuli, the target digit competes only with a neutral symbol that never had been selected and, therefore, is less capable of activating its representation. This alternative explanation has to be excluded before we can finally conclude that our results reflect a judgment conflict.

EXPERIMENT 3

In this experiment, we used the same stimuli and judgments as in the preceding experiment. The only difference was that now each judgment was applied to each digit. This should mean that congruent as well as neutral stimuli should result in the same amount of judgment conflict. If each digit has to be classified according to both judgments, then each digit should develop the capability of activating both judgments to the same degree, regardless of whether it is presented as a target or as a distractor. As a consequence, the target digit should produce the same judgment conflict with congruent as with neutral stimuli. Moreover, for the congruent stimuli, the distractor digit should also activate both judgments. However, this should not increase judgment conflict, because the relative activation of both judgments would remain the same.

Thus, if the conflicts we have observed actually indicate a conflict between judgments, we should obtain the same performance for congruent and neutral stimuli in the present experiment. If, however, our results reflect a conflict between target and distractor at the target selection stage, we should expect the same results as in the preceding experiment—that is, congruent stimuli should produce impaired performance relative to neutral stimuli. This result would hold because applying each judgment to each digit should not affect the way each digit could activate its identity representation and, accordingly, cause a target selection conflict.

Method

Twelve subjects (9 female, 3 male) between 19 and 31 years of age (mean 22.4 years), with normal or corrected-to-normal vision, participated in the study. The subjects were recruited at the Universität Konstanz and were paid €5/h. The stimuli and procedure were the same as in Experiment 2, with one exception: Each judgment was applied to each of the digits. The congruent and incongruent stimuli could consist of each possible pair of the digits 2–9. Although this manipulation increased the set of possible stimuli (32 congruent and 32 incongruent), the proportions of the four stimulus types were kept the same as in the preceding experiments.

Results and Discussion

The mean response time in this experiment was 541 msec, the mean error rate 4.8%. The rationale of the analyses is the same as in the preceding experiments. Again, we applied the same analyses on four types of dependent variables: absolute performance and the three distractor effects.

Mixing Conditions

Absolute performance. Table 5 contains the absolute response times and error rates for each mixing condition. A two-way ANOVA on the absolute response times with the variables level mode (constant, mixed) and judgment mode (constant, mixed) revealed significant main effects of both variables. Response times were increased in mixed-level blocks (570 msec) relative to constant-level blocks (512 msec) [$F(1,11) = 57.9$, $MS_e = 697$, $p < .001$], and they were also increased in mixed-judgment blocks (554 msec) relative to constant-judgment blocks (527 msec) [$F(1,11) = 17.0$, $MS_e = 521$, $p < .01$]. No significant interaction was observed. A similar result was obtained for error rates. The error rate was higher in mixed-level blocks (5.4%) than in constant-level blocks (4.2%) [$F(1,11) = 14.1$, $MS_e = 1.2$, $p < .01$], and also in mixed-judgment blocks (4.2%) than in constant-judgment blocks (4.2%) [$F(1,11) = 7.8$, $MS_e = 2.3$, $p < .05$].

Table 5
Experiment 3: Absolute Response Times (RTs, in Milliseconds) and Error Rates, Collapsed Across All Stimulus Types

	RT		% Error	
	M	*SEM*	*M*	*SEM*
Constant Level/Constant Judgment	*496*	*5.9*	*3.6*	*0.4*
Mixed Level/Constant Judgment	*558*	*7.8*	*4.7*	*0.6*
Level repetition	543	10.8	3.3	0.5
Level shift	568	10.3	5.9	0.9
Constant Level/Mixed Judgment	*527*	*6.8*	*4.8*	*0.5*
Judgment repetition	518	8.6	4.1	0.6
Judgment shift	532	10.1	5.3	0.5
Mixed Level/Mixed Judgment	*581*	*9.4*	*6.0*	*0.6*
Double repetition	610	13.9	4.1	0.8
Only level shift	639	15.2	4.9	1.0
Only judgment shift	632	15.0	7.2	0.9
Double shift	647	17.9	7.7	1.2

Note—For each mixing condition, the mean performance is given (in italics), as well as the performance of the possible repetition and shift types within each condition.

The same two-way ANOVAs were applied to the distractor effects. Again, each distractor effect was computed as the performance difference between one pair of stimuli and was entered as a dependent variable into the analyses.

Response conflict. As in the preceding experiment, we had to examine two types of response conflict. The mean scores for response conflict defined with respect to the relevant judgment are shown in the right part of Figure 4. For the response time scores, a marginally significant effect of level mode indicated that response conflict was larger in mixed-level blocks (38 msec) than in constant-level blocks (16 msec) [$F(1,11) = 3.60$, $MS_e = 1{,}621$, $p = .08$]. No effect of judgment mode was observed. A similar pattern was obtained for the error rates, with increased response conflict in mixed-level blocks (4.7%) relative to constant-level blocks (0.8%) [$F(1,11) = 10.8$, $MS_e = 16.9$, $p < .01$]. In contrast, when we defined response conflict with respect to the irrelevant judgment, no significant effect was obtained. The overall values for the latter effect were 3 msec for the response times and 0.1% in the error rates. Both were not reliably different from zero.

Judgment conflict. Again, the effect of judgment conflict was computed by subtracting performance on neutral stimuli from that on congruent stimuli. In response to the results of the preceding analysis, congruent stimuli were defined with respect to the relevant judgment. Mean judgment conflict scores are shown in the middle part of Figure 4. For response times, there was a significant effect of the variable level mode [$F(1,11) = 9.78$, $MS_e = 91.1$, $p < .01$]. Judgment conflict was slightly positive (1 msec) in constant-level blocks, whereas it was negative (−8 msec) in mixed-level blocks. A planned-contrast analysis revealed that none of these values was significantly different from zero. No further significant effects were obtained. Furthermore, the analysis of the error rates revealed no significant effects.

Nonspecific distractor effect. The scores for the nonspecific distractor effect are shown in the left part of Figure 4. For response times, the analysis revealed only a significant effect of level mode. The score was larger in mixed-level blocks (47 msec) than in constant-level blocks (24 msec) [$F(1,11) = 38.4$, $MS_e = 142$, $p < .001$]. For error rates, the nonspecific distractor effect was increased on mixed-judgment blocks (2.0%) relative to constant-judgment blocks (−0.2%) [$F(1,11) = 8.61$, $MS_e = 6.5$, $p < .05$]. No further effects were significant.

Cross-experiment comparison. The main result of this first part of the analyses is the pattern observed for judgment conflict. In contrast to the preceding experiments, there was little evidence of a performance difference between congruent and neutral stimuli. For the mixed-level blocks, the judgment conflict value even became negative, indicating that performance with congruent stimuli was even better than that with neutral stimuli. To test whether the differences between this experiment and Experiment 2 were statistically significant, we entered the difference scores representing judgment conflict from both experiments in a three-way ANOVA with the within-subjects variables level mode (constant, mixed) and judgment mode (constant, mixed) and with the between-subjects variable experiment (2, 3). Indeed, the main effect of experiment [$F(1,22) = 4.55$, $MS_e = 1{,}353$, $p < .05$], as well as the interaction between experiment and level mode [$F(1,22) = 5.35$, $MS_e = 1{,}386$, $p < .05$], reached significance. Thus, the difference in outcomes between this experiment and the previous one is substantial.

Summary. In this experiment, we wanted to test whether the performance difference between congruent and neutral stimuli reflects either a conflict between two judgments or a conflict between the target and the distractor. The only difference between the present and the previous experiment was that here both judgments were applied to all digits. If the effects represented a conflict between the distractor and the target, the same results as in Experiment 2 would be expected—that is, neutral stimuli should lead to a better performance than congruent stimuli. If, however, a stimulus-induced judgment conflict caused our previous results, in this experiment we would observe approximately the same performance for both stimuli, since the target levels in both stimulus types should cause similar judgment conflicts by activating both judgments. The distractor level in the congruent stimulus, however, should not alter this conflict, because it also activates both

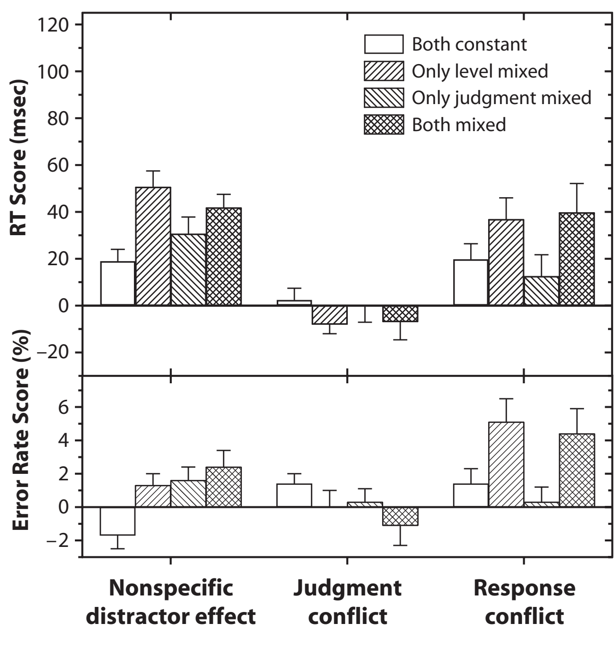

Figure 4. Experiment 3: Distractor effects in the response times and error rates, separately for the four mixing conditions. Each value represents the performance difference between two stimulus types (response conflict, incongruent minus congruent; judgment conflict, congruent minus neutral; nonspecific effect, neutral minus single). Error bars represent standard errors of the mean. Note that congruency was defined with respect to the relevant judgment (see text for details).

judgments, which should not change the relative activation of both judgments. Our results clearly confirm the latter prediction: Congruent and neutral stimuli produced nearly the same performance. Moreover, a comparison between Experiments 2 and 3 revealed that the reduction of this performance difference was also significant. Taken together, these results support our hypothesis that the comparison of these two stimulus types reflects a conflict between judgments.

However, there is one result that could compromise our conclusions. In the present experiment, the effect of response conflict was also increased. This does not only imply that the performance for congruent stimuli was impaired. It can also imply that the performance for congruent stimuli was facilitated. This could have led to the reduction of the judgment conflict effect in this experiment, because this effect is measured by the subtraction of the performance for neutral stimuli from that for congruent stimuli. This is also illustrated by the observation that performance on congruent stimuli was even slightly better than that on neutral stimuli in the mixed-level blocks in which the response conflict effect was increased.[3]

To test such a possibility, we reanalyzed the data from Experiments 2 and 3 by using an alternative method of computing the judgment conflict effect. This time, we compared the performance for neutral stimuli with the mean performance for congruent and incongruent stimuli. This method has two consequences: On the one hand, facilitative effects of response congruency should be eliminated from the judgment conflict contrast. On the other hand, eliminating these effects implies that the effect of judgment conflict is overestimated, because the effect of facilitation is typically smaller than the effect of interference in conflict tasks (see, e.g., MacLeod, 1991). The reanalysis revealed the same pattern of significant effects as had the original analysis, with one exception: We now obtained a rather small (10 msec) but significant judgment conflict even for Experiment 3 [$F(1,11) = 6.55$, $MS_e = 425$, $p < .05$], which did not interact with further variables. Most importantly, when we analyzed the data from both experiments together, there was a significant interaction between experiment and level mode [$F(1,22) = 5.27$, $MS_e = 1,055$, $p < .05$], indicating reduced judgment conflict in Experiment 3, even with this method of computing judgment conflict. This result suggests that the reduced judgment conflict in Experiment 3 is not an artifact resulting from increased response conflict.

In addition, there was an unexpected result concerning response conflicts. As already discussed, there were two types of congruency in these two experiments; the distractor can be congruent or incongruent with respect to the relevant judgment as well as with respect to the irrelevant judgment. In Experiment 2, we observed only an effect of congruency with respect to the irrelevant judgment. This was not surprising, since the distractor digits were always taken from the set of digits that was linked to the irrelevant judgment. In Experiment 3, however, each digit was presented in connection with both judgments. Nevertheless, we observed only an effect of congruency with respect to the relevant judgment. How can this be explained? Possibly, it is a consequence of the stronger activation of the relevant judgment than of the irrelevant one, which could mean that the stimulus–response associations of the relevant judgment inhibited those of the irrelevant judgment. Because of this, the contribution of the irrelevant judgment to the congruency effect was decreased or even eliminated. In Experiment 2, however, the stimulus–response associations between the distractor digits and the relevant judgment were not acquired, which prevented this kind of inhibition.

Shift Conditions

For completeness, we also conducted analyses of shift effects, as in the previous experiments. The mean response times and error rates of our shift conditions are included in Table 5, whereas the distractor effects within these conditions are presented in Table 6.

Mixed level/constant judgment. For the mixed level/constant judgment blocks, a one-way ANOVA with the variable level transition (repetition, shift) on absolute re-

Table 6
Experiment 3: Distractor Effects Separately for the Different Shift Types Within Conditions in Which One or Both Task Components Were Mixed

	Response Conflict				Judgment Conflict				Nonspecific Effect			
	RT		% Error		RT		% Error		RT		% Error	
	M	*SEM*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*
Mixed Level/Constant Judgment												
Level repetition	28.9	13.9	2.3	1.6	−11.7	7.1	−0.3	1.4	51.6	11.0	−0.1	1.1
Level shift	45.4	12.2	7.9	2.2	−11.3	6.4	0.2	1.4	41.8	8.2	2.7	1.2
Constant Level/Mixed Judgment												
Judgment repetition	17.4	10.2	−1.9	1.5	−8.3	9.6	1.9	1.2	35.0	8.5	0.1	1.7
Judgment shift	10.8	10.7	1.8	1.6	16.3	10.1	−0.6	1.1	12.1	10.6	2.5	1.2
Mixed Level/Mixed Judgment												
Double repetition	24.2	22.9	1.0	2.4	1.5	16.8	−1.2	2.2	33.0	12.7	−1.8	2.4
Only level shift	40.0	21.8	5.6	3.5	2.1	22.3	−1.6	2.2	37.3	19.1	3.6	2.0
Only judgment shift	14.5	17.7	5.3	2.1	−36.7	19.2	−1.7	2.0	79.8	23.6	2.7	2.5
Double shift	21.5	14.5	6.0	4.4	−18.7	18.2	−0.1	2.1	67.1	19.8	4.6	2.0

Note—Each value represents the performance difference between two stimulus types (response conflict, incongruent minus congruent; judgment conflict, congruent minus neutral; nonspecific effect, neutral minus single). Note that congruency was defined with respect to the relevant judgment (see text for details). RT, mean response time in milliseconds.

sponse times collapsed across all stimulus types showed a significant level shift cost of 25 msec [$F(1,11) = 27.9$, $MS_e = 131$, $p < .001$]. The same analysis on distractor effects revealed no significant effect. In the error rates, the same analyses revealed only a significant level shift cost of 2.6% [$F(1,11) = 20.3$, $MS_e = 2.02$, $p < .001$].

Constant level/mixed judgment. The same results hold for the constant level/mixed judgment blocks. A one-way ANOVA with the variable judgment transition (repetition, shift) on absolute response times showed a significant judgment shift cost of 14 msec [$F(1,11) = 5.78$, $MS_e = 229$, $p < .05$], whereas no effect was obtained for distractor effects. No effects were obtained for error rates.

Mixed level/mixed judgment. For the mixed level/mixed judgment blocks, a two-way ANOVA with the variables level transition (repetition, shift) and judgment transition (repetition, shift) was computed. For absolute response times, the level shift cost (22 msec) and the judgment shift cost (16 msec) were marginally significant [$F(1,11) = 4.67$, $MS_e = 1{,}230$, $p = .05$, and $F(1,11) = 3.97$, $MS_e = 719$, $p = .07$, respectively]. Although we obtained an underadditive pattern similar to the one in the preceding experiments, the interaction of the variables did not reach significance. When the level was repeated, the cost of a judgment shift was 22 msec. On level shift trials, the judgment shift cost decreased to 8 msec. For error rates, only a significant judgment shift cost of 3.0% was observed [$F(1,11) = 11.4$, $MS_e = 9.1$, $p < .01$]. Again, the three distractor effects were compared between trials with a double shift and the trials in which both task components repeated. No significant effect was observed for response times. In the error rates, the effect of transition was significant for the nonspecific distractor effect. This effect was present only when both task components shifted (4.6%), not when they repeated (−1.8%) [$F(1,11) = 6.97$, $MS_e = 35.7$, $p < .05$]. Overall, we again obtained no substantial difference in the distractor effects on repetition and shift trials, confirming the results of our preceding experiments.

GENERAL DISCUSSION

It has been shown that stimulus displays containing a target and a distractor can induce task conflicts, given that target and distractor are associated with different tasks (Rogers & Monsell, 1995; Waszak et al., 2003). However, it remained unclear which variables modulated these conflicts. Although previous studies provided evidence that stimulus-induced task conflicts are increased following a task shift, this result could be explained by priming of the irrelevant task as well as by increased distractor salience. The present study reports a series of three experiments that determined the contribution of each mechanism.

We used a paradigm in which the target level in a hierarchical stimulus and the relevant judgment varied independently. Task conflict was defined as conflict between the two judgments and measured by the impairment of performance for stimuli associated with two judgments relative to those associated with one judgment. Judgment shifting and level shifting were manipulated in a blockwise (pure vs. mixed level and/or judgment) as well as in a sequential manner (level and/or judgment repetitions vs. shifts). If judgment priming amplifies the stimulus-induced judgment conflict, one would expect increased conflict after the judgment was shifted, or generally when judgments are mixed in a block. In contrast, if the salience of distractors modulates the conflict, shifting the target level should instead affect the judgment conflict.

As our experiments revealed, substantial judgment conflicts occurred only in blocks in which the target level was mixed. This indicates that these conflicts are increased by the increased salience of the distractors in mixed-level blocks relative to that in blocks with a constant level. Surprisingly, we did not find an analogous increase in judgment conflict from mixing the judgments. Thus, increased activation of the irrelevant judgment does not seem to increase the capability of the distractor to activate this judgment. Interestingly, we also did not observe a significant increase of judgment conflicts after level or judgment shifts. The absence of any (significant) influence of these shift conditions on the stimulus-induced judgment conflicts is not consistent with the results of the earlier studies (Rogers & Monsell, 1995; Waszak et al., 2003) and will be discussed later.

Furthermore, we could exclude that judgment conflicts were due to a conflict during target selection. Although such an explanation could account for the results of Experiment 1, where the two judgments were linked to different symbol types (letters and digits), it cannot explain the combined results of Experiments 2 and 3. In Experiment 2, congruent stimuli consisted of two digits associated with different judgments, but neutral stimuli contained only one digit associated with a unique judgment. Accordingly, the result that response times were increased for congruent stimuli relative to neutral ones clearly indicates a judgment conflict. In Experiment 3, similar stimuli were used. However, congruent as well as neutral stimuli were associated with both judgments. As expected, in this case both stimulus types led to similar performance. Taken together, our results demonstrate that the number of judgments linked to the stimuli is the crucial factor for determining the degree of judgment conflict.

The results of Experiment 3 also exclude a further interpretation. Instead of a conflict between judgments, one could assume that our results reflect a conflict between integrated task sets—that is, between combinations of a certain level and a certain judgment. Consider, for instance, a neutral stimulus in Experiment 2, with a digit at the global level and a neutral symbol at the local level. This stimulus is associated with a single level/judgment combination, such as global/parity. A congruent stimulus with two digits, however, can activate two level/judgment combinations—for instance, local/magnitude and global/parity. Accordingly, a performance difference between these two stimulus types could be explained by a conflict between these level/judgment combinations. However, if this interpretation were valid, we should have observed the same result in Experiment 3. In this experiment, the neutral stimuli were also linked to two combinations (global/magnitude, global/parity), whereas the corresponding congruent stimuli were associated with all four possible combinations (local/magnitude, local/parity, global/magnitude, global/parity). As a consequence, one would expect a performance reduction for the congruent stimuli, because they can activate more level/judgment combinations and, accordingly, cause a stronger conflict than the neutral stimuli. This, however, was not the case, which clearly supports the hypothesis that our effects are due to a judgment conflict.

In addition to judgment conflict, we examined further effects of the distractor in each of our three experiments. On the one hand, we observed response conflicts by comparing congruent and incongruent stimuli. As shown in Experiment 2, these response conflicts mainly reflected associations between stimuli and responses that were acquired during the experiment. Furthermore, we observed a nonspecific distractor effect in which performance was impaired for stimuli with a distractor present, even if this distractor was not associated with any judgment or response. In contrast to the judgment conflict, this effect could represent a conflict within the stage of target selection—that is, the mere existence of a distractor impaired the selection of the target.

Interestingly, these distractor effects were not affected in the same way by level mixing and judgment mixing as was the judgment conflict. For instance, response conflicts were increased in blocks with a mixed judgment relative to blocks with a constant judgment, at least in Experiment 2, in which the associative strength between stimuli and judgments was manipulated. Moreover, the nonspecific distractor effect was increased by judgment mixing in both Experiment 1 (in response times) and Experiment 3 (in error rates). The latter result is especially hard to interpret. However, this pattern demonstrates that it is necessary to distinguish carefully between the different conflict types. Confounding, for instance, response conflicts and judgment conflicts can lead to misleading results and wrong conclusions. Further research will be necessary to investigate the different mechanisms (e.g., stimulus–response associations vs. stimulus–task associations) underlying these conflict types.

What Causes Increased Task Conflicts After a Task Shift?

An important question is how the present study affects the interpretation of the data of Rogers and Monsell (1995) and Waszak et al. (2003). These authors did not distinguish between shifting the target category and shifting the judgment (or, generally, a rule for translating the stimulus into a response). However, our results suggest that such a distinction is necessary. In the following, we will provide an explanation for some of their results based on our account. For simplicity, we will use the term *task* to refer to the judgment or any other rule to translate a stimulus into a response (e.g., retrieving the name of a picture).

In Rogers and Monsell's (1995) study, subjects alternated between a digit classification and a letter classification task. Because the stimuli always consisted of a target and a distractor, subjects had to start task execution by selecting the relevant target symbol, depending on the relevant judgment. For instance, in case of the digit classification task, the digit had to be selected rather than a letter or a neutral symbol. However, because task shifts went along with shifts of the target category, the distractor was in a more activated state after a task shift. This follows from the fact that following a task shift, the stimulus category that defined the target on the previous trial now defined the distractor. As a consequence, the effect of the distractor was amplified. This was true for task conflicts as well as response conflicts. Accordingly, the increased task conflict following a task shift was not a consequence of the task shift, but of the shift of the target category. This interpretation is also incompatible with Waszak et al.'s (2003) conclusion that the shift cost completely reflects a stimulus-induced task conflict. Rather, our results suggest that a stimulus-induced task conflict contributes only to the shift cost when task shifts imply a shift of the target category.

Analogous reasoning applies to the data of Waszak et al. (2003), from a study in which the subjects alternated between a word-naming and a picture-naming task. However, Waszak et al. observed increased stimulus-induced task conflicts in task shifts only for word naming. The other task, picture naming, showed similar and consistently high task conflicts for task repetitions as well as for task shifts. According to Waszak et al.'s analysis, this conflict resulted from the pronounced dominance of the word-naming task (comparable to word naming in Stroop experiments). Because of this, the word stimulus could always strongly activate its task during picture naming, irrespective of whether a task shift or a task repetition occurred. Such an explanation does not directly contradict our view; one merely has to assume that distractor salience modulates stimulus-induced task conflicts only when the association between a distractor and its task is moderate. With a very strong stimulus–task association, even a weakly salient distractor could produce strong conflicts.

The question remains, however, why the judgment conflicts in our experiments interacted only with the blockwise mixing manipulations, not with the trial-by-trial task shift manipulations. The answer to this question could be related to our paradigm. Waszak et al. (2003) as well as Rogers and Monsell (1995) used the alternate-runs paradigm, in which the tasks alternate in a prespecified order (e.g., AABBAABB . . .). In our experiments, however, we employed a task-cuing paradigm, in which the tasks were indicated by cues and the order of tasks was randomized.

Two explanations are conceivable of how the type of paradigm could affect the observation of stimulus-induced task conflicts. First, as already discussed, Tornay and Milán (2001) reported that only in the task-cuing paradigm does the shift cost decrease linearly in the course of several repetition trials; with alternate runs, a shift cost is observable exclusively on shift trials. This suggests that with respect to the activation of the irrelevant task, repetition and shift trials are more similar with the task-cuing paradigm than with alternate runs. As a consequence, the task-cuing paradigm could be less likely than alternate runs to reveal differences in the amount of task conflict.

A second explanation can be derived from the fact that task shift trials in the alternate-runs paradigm are always the first trials in a run. These trials could be influenced by additional mechanisms. For instance, there is the so-called *restart effect* that has been observed in task-shifting experiments. This effect refers to the fact that whenever a new block of trials starts, absolute response times as well as task conflict effects are increased (Allport & Wylie, 2000; Waszak et al., 2003). If we assume that subjects represent the blocks in the alternate-runs paradigm as a sequence of miniblocks consisting of runs of the same task, an increased shift cost could be present in this paradigm, consisting of the actual shift cost plus a restart effect, which is present only on shift trials. In this case, the additional restart effect could have led to an overestimation of the task conflict on shift trials. Since these conditions do not hold for the cuing paradigm, differences between shift and repetition trials with respect to the degree of task conflict might have been too small to be detected. Such an idea receives further support from Altmann (2004), who suggested that the shift cost in the alternate-runs paradigm is confounded by a first-trial cost that reflects cue-related processes only necessary in the first trial of a run.

Thus, the absence in our study of a statistically significant increase of stimulus-induced judgment conflicts on shift trials might be due to a lack of sensitivity. This is supported by the fact that trends toward such an interaction were consistently observed in Experiment 1, as well as in Experiment 2. Most importantly, such trends were observable for the level shift trials but not for the judgment shifts. Thus, these data support our main conclusion that it is distractor salience that modulates stimulus-induced judgment conflicts.

Control Strategies

In summary, we have demonstrated that stimulus-induced conflicts between judgments are not modulated by priming the irrelevant judgment, but rather by increasing the salience of distractors linked to the irrelevant judgment. This result also has implications for the question of how the cognitive system controls stimulus-induced conflicts. It suggests that conflicts between judgments are not necessarily controlled by inhibiting the irrelevant judgment. Rather, it seems that an effective way of controlling stimulus-induced conflicts is to inhibit irrelevant stimulus elements that cause conflicts—for instance, by means of visual selective attention.

This strategy can be illustrated by a model of task execution under task-shifting conditions that we introduced elsewhere (Steinhauser & Hübner, 2005; but see also Hübner et al., 2001). This model is based on the finding (also observed in the present data) that the costs of level mixing and judgment mixing are additive and, accordingly, reflect independent processing stages. We proposed that conflicts in such a paradigm are resolved in the course of several selection stages. In a first stage, the target is selected in order to reduce the impact of the distractor. In a second stage, the relevant judgment is selected (or the relevant stimulus categories of this judgment), in order to reduce judgment conflicts. In the final selection stage, the response is selected. The mixing costs represent increased conflicts as well as more conservative selection criteria within these stages. In this way, level mixing prolongs target selection, and judgment mixing prolongs judgment selection.

Within this model, we can assign each of the conflict types we observed in the present study to one of the selection stages. Whereas the nonspecific distractor effect is produced within the stage of target selection, judgment conflicts impair judgment selection. Finally, response conflicts increase the duration of the response selection stage. Most importantly, we assume that conflicts caused by the distractor are resolved early in the process, during target selection. According to this idea, the distractor can activate its corresponding judgment only until target selection has finished. In this way, judgment conflicts vary with the efficiency and duration of the target selection process. If the target level is constant, target selection is fast and efficient, and therefore leads only to a small judgment conflict. In contrast, with mixed target levels, target selection is less efficient because the distractor is highly salient. This, and an increased selection criterion, implies that target selection consumes more time. During this prolonged period, the distractor has additional time to activate its associated judgment. However, in each case, judgment conflicts caused by the distractor are resolved relatively early and, accordingly, are rather weak. This might be the reason why there is no interaction with task priming. Thus, our results indicate that selective visual attention serves to shield later processing from the influence of irrelevant stimulus elements, and thus plays an important role as an executive control function.

Of course, such a strategy is only possible given that task conflicts can be reduced by inhibiting an irrelevant stimulus. Assume, for instance, that only one stimulus element is presented (e.g., a digit), and that it can activate both possible tasks to the same extent. In this case, there is no target selection stage at which conflicts triggered by the irrelevant feature can be eliminated early. In such a case, it is even possible that the amount of stimulus-induced task conflict could vary with the activation of the irrelevant judgment. Such a result would demonstrate that executive control under task-shifting conditions is not a unitary mechanism. Rather, it depends on the structure of the applied tasks (see, e.g., Meiran & Marciano, 2002). Further research is necessary to investigate these issues. However, the present study strongly suggests that task structure and, accordingly, the levels of conflict involved in a task are important aspects that need to be considered when the results of task-shifting experiments are interpreted.

AUTHOR NOTE

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NOTES

1. In a hierarchical stimulus, the target and the distractor are not separate stimuli, but rather the content of the target and distractor levels. Nevertheless, we will sometimes use the terms *target* and *distractor* for simplicity.

2. A third type of congruency refers to the target itself. Each digit alone can be linked to the same or to different responses with respect to the two judgments. However, this type of congruency is not relevant to us, because it affects all stimulus conditions (incongruent, congruent, neutral, and single) in the same way.

3. The slight change in the judgment conflict effect in mixed-level blocks (1 msec) relative to constant-level blocks (−8 msec) even reached significance. This seems to be a consequence of the increased stability of the data in this experiment in comparison with those in the other experiments (see the error bars in Figures 2–4).

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