

Distractor Repetitions Retrieve Previous Responses and Previous Targets: Experimental Dissociations of Distractor–Response and Distractor–Target Bindings

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Even an irrelevant distractor stimulus is integrated into event files. Subsequently repeating the distractor triggers retrieval of the event file; however, an unresolved issue concerns the question of *what* is retrieved by the distractor. While recent studies predominantly assume that the distractor retrieves the previous response, it is also possible that distractor repetition triggers retrieval of the previous target stimulus. In 3 experiments, we dissociated distractor–response and distractor–target binding processes using a sequential distractor-to-distractor repetition paradigm. In Experiment 1, response relation and target relation were manipulated orthogonally; results yielded independent evidence for both mechanisms. Experiment 2 provided distinct evidence for distractor–target binding and retrieval by avoiding response repetitions of any kind. Experiment 3 provided distinct evidence for distractor–response binding and retrieval by eliminating target stimuli. We conclude that both distractor–target and distractor–response binding reflect independent processes in the service of behavior automatization.

Keywords: stimulus–response binding, event files, stimulus–stimulus associations, episodic retrieval, repetition priming

Presenting participants with colored words in a sequence of two displays (called *prime* and *probe*) and asking them to perform a color categorization task for each display has led to an interesting observation (Rothermund, Wentura, & De Houwer, 2005): Repeating the irrelevant meaning of the prime word in the following probe leads to faster categorization responses if the word color is also repeated from prime to probe (compared with a baseline condition where two unrelated words are successively presented in the same color). However, repetition of the prime word in the probe delays categorization responses if the probe word has a different color than the prime word (again compared with a baseline sequence of two unrelated words with different colors). Apparently, although the word meaning is irrelevant for the color categorization task, its repetition differ-

entially affects performance, depending on whether responses are repeated or not—but why is this so?

Instance-based theories (e.g., Logan, 1988; see also Hommel, 1998, 2004, 2007) offer a straightforward explanation for the described effect: They propose that perceiving a stimulus and executing a response in close temporal proximity suffices for both elements to be encoded together as an integrated unit or *event file* (Hommel, 1998) in episodic memory. Re-presenting one of its elements later on automatically retrieves the entire event file from memory, which often facilitates performance because memory retrieval is much faster than ad hoc response generation. It is important to note that recent research findings indicate that not only (task-) relevant features of the target stimulus and response codes are bound together (e.g., Denlinger & Koutstaal, 2009; Hommel, 1998, 2007; Horner & Henson, 2009, 2011; Logan, 1988; Waszak, Hommel, & Allport, 2003, 2005) but also irrelevant stimulus features that merely accompany the target (i.e., distractors) are integrated into event files (Rothermund et al., 2005; see also Frings, 2011; Frings & Moeller, 2010, 2012; Frings & Rothermund, 2011; Frings, Rothermund, & Wentura, 2007; Gibbons & Stahl, 2008; Giesen, Frings, & Rothermund, 2012; Giesen & Rothermund, 2011, 2013; Mayr & Buchner, 2006; Mayr, Buchner, & Dentale, 2009; Moeller & Frings, 2012; Moeller, Rothermund, & Frings, 2012). Consequently, retrieval of central elements of an event file can be purely distractor-based, triggered by repetition of an irrelevant stimulus (or stimulus feature).

In the simplest case under consideration, the event file consists of three elements: the target feature, the distractor, and the executed response. What remains ambiguous, however, is the issue of which element of the event file is *retrieved* by the distractor: Do

This article was published Online First December 2, 2013.

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The research reported in this article was supported by Grant DFG RO 1272/6-2 from the Deutsche Forschungsgemeinschaft to Klaus Rothermund.

We thank Anna Kornadt and Birte Moeller for their valuable feedback on earlier versions of the manuscript, Nils Meier for his support in programming the experiments, and our student research assistants for collecting the data.

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distractors retrieve the previous response, or the previous target?¹ In many cases, responses are uniquely assigned to specific target stimuli so that repeating or changing the response is perfectly confounded with repeating or changing the target. However, distinguishing between the two types of binding and retrieval is important, because they reflect distinct types of binding processes (i.e., stimulus–response binding vs. stimulus–stimulus binding).

In the majority of the previously mentioned studies on distractor integration effects, investigators interpreted their findings in terms of *distractor–response (D–R) binding and retrieval* (e.g., Frings & Rothermund, 2011; Frings et al., 2007; Giesen, Frings, & Rothermund, 2012; Giesen & Rothermund, 2011; Hommel, 1998; Mayr & Buchner, 2006; Mayr et al., 2009; Rothermund et al., 2005): The central idea is that irrelevant features of a stimulus are tied to the codes of a simultaneously executed response (i.e., a stimulus–response association); once the distractor is repeated, it automatically retrieves the associated response.² Response retrieval either facilitates or hampers subsequent performance, depending on whether the retrieved response is appropriate or not.

What has been mostly neglected in the existing literature on distractor repetition effects, however, is that the same pattern of results may also be indicative of what we call *distractor–target (D–T) binding and retrieval*. Distractor–target binding means that the relevant and irrelevant stimuli (or stimulus features) are bound together in the prime (i.e., a stimulus–stimulus association or *object file*, e.g., Kahneman, Treisman, & Gibbs, 1992). Subsequently repeating the distractor automatically retrieves the prime target. The retrieved prime target then either perceptually matches or mismatches the probe target, which leads to facilitation or interference, respectively (Kahneman et al., 1992). A similar account of positive/negative priming effects in terms of feature matches/mismatches within a stimulus has been proposed by Park and Kanwisher (1994; see also MacDonald & Joordens, 2000; MacDonald, Joordens, & Seergobin, 1999; Macleod, Chiappe, & Fox, 2002). Some studies controlled for the confounding of response relations and target relations by assigning two (or more) targets to the same response key, which allows for response repetitions even within the target category independently of target repetitions (e.g., Frings et al., 2007; Giesen et al., 2012; Moeller & Frings, 2012). The results of these studies support the claim that distractor repetition effects reflect stimulus–response binding and retrieval. However, these studies did not provide a direct test of distractor–target binding and retrieval effects, and thus do not speak against the existence of these processes that are based on stimulus–response retrieval. In particular, distractor repetition effects are somewhat weaker when effects of target repetitions are controlled for, indicating that distractor–target bindings might also have contributed to the original effect. Furthermore, although response repetitions are no longer confounded with repetitions of specific targets in case of a many-to-one mapping, they are still confounded with repetitions of a specific target category. The previous studies thus do not provide unambiguous evidence for the existence of associations between distractors and responses but might rather reflect relations between the distractor and more abstract superordinate stimulus representations. As a consequence, the obtained distractor-based retrieval effects demonstrated in previous studies are not process-pure but may actually reflect a compound of distractor–response and distractor–target binding and retrieval.

The aim of our study was to dissociate distractor–response and distractor–target binding and retrieval, and to provide pure measures of either of the two processes. In our view, retrieval of distractor–response and/or distractor–target bindings is not mutually exclusive. They may operate more or less independently, and they might even result from the same underlying binding principles: According to Hommel (1998, 2007), bindings are predominantly feature-based (i.e., bindings emerge between particular features of stimuli and/or responses), binary (i.e., always two features are linked together), and local (i.e., the same features may be part of several independent bindings). It is still unclear, however, whether these binding principles also apply to the same extent to irrelevant features. To our knowledge, no previous study has yet tried to systematically disentangle retrieval of distractor–response from distractor–target bindings. We hence consider it essential to dissociate effects of response retrieval from stimulus feature retrieval, not only to understand the mechanisms that underlie distractor repetition effects but also to gain deeper insight into the functional principles of binding processes that operate in the service of efficient behavior regulation.

The purpose of the following experiments was twofold: First, we aimed to clarify whether, and to what extent, typical distractor repetition effects reflect prime response retrieval, prime target feature retrieval, or both. In Experiment 1, we wanted to obtain estimates for the relative contribution of these two processes to overall distractor-based repetition effects within a single study. For this purpose, the mapping of targets to responses was not fixed but varied for each prime and probe trial in order to orthogonally manipulate the relation of responses and targets. This allowed us to test for distractor–response and distractor–target binding and retrieval simultaneously within the same experiment. A second aim of our study was to provide unique evidence for both distractor–response and distractor–target binding in experimental contexts that allowed for only one type of retrieval process and completely eliminated the other. In Experiments 2, we aimed to measure “pure” distractor–target binding and retrieval by using a manipulation that precluded retrieval of distractor–response bindings as an

¹ In principle, four different types of bindings can emerge in an event file (i.e., distractor–response, distractor–target, distractor–target–response, and target–response bindings; cf. Frings & Rothermund, 2011; Mayr & Buchner, 2006; Mayr, Buchner, & Dentale, 2009; Mayr, Buchner, Möller, & Hauke, 2011). Only three of those bindings can be retrieved by repeating the *distractor* later on (i.e., distractor–response, distractor–target, and distractor–target–response bindings). In the following, we focus predominantly on ways to dissociate distractor–response and distractor–target bindings. However, we come back to the issue of additional binding types like distractor–target–response bindings (which depict a special case of distractor–target bindings) and target–response bindings (which are of secondary importance in the present study since they are orthogonal to distractor-based bindings) in the General Discussion.

² Although Mayr and Buchner (2006; see also Mayr et al., 2009) assume that the prime distractor retrieves the prime response if it repeats on a subsequent trial, they do not explicitly discuss the underlying binding structure. In this respect, according to Mayr et al. (2009), “the prime–response retrieval variant of the episodic retrieval model (Mayr & Buchner, 2006) postulates that the response associated with the prime target is retrieved in ignored repetition trials” (p. 408), which allows for the possibility of distractor–target–response bindings as an underlying associative structure instead of more direct distractor–response bindings that do not involve any associations with the target. We discuss the possibility of alternative binding types in more detail in the General Discussion.

alternative explanation: Effectively, prime response retrieval was prevented in Experiment 2 because participants did not execute a response during the prime. To the contrary, Experiment 3 circumvented any effects of stimulus-stimulus associations by eliminating the targets altogether: Response sequences for the prime and probe trials were instructed in advance, which allowed us to present stimulus displays containing only distractors without any target features at all. In this case, effects of distractor binding and retrieval can no longer reflect distractor-target associations and constitute a pure indicator of distractor-response bindings.

All of the present experiments employed a distractor-to-distractor repetition paradigm (Rothermund et al., 2005), which is ideally suited to investigate distractor-based binding and retrieval effects. In a sequence of a prime and a probe display, neutral adjectives that were irrelevant to the task at hand appeared in different colors. For prime and probe trials, participants performed a binary choice task depending on each word's color, which constituted the task-relevant target feature, whereas the word meaning was task-irrelevant and served as distractor (Rothermund et al., 2005). The word meaning was either identical in prime and probe (distractor repetition condition) or different (baseline condition). This manipulation is critical: If the distractor becomes subject to binding processes during the prime trial, distractor repetition in the probe provides a measure of distractor-based retrieval of these prime trial bindings. That is, distractor repetition effects (computed as the difference of baseline minus distractor repetition probe trials) function as an index of performance (dis-)advantages due to distractor-based retrieval processes, relative to the baseline condition.

To specify what kind of information is retrieved by the distractor, we manipulated target feature relation (Experiments 1 and 2) and response relation (Experiments 1 and 3) orthogonally to the distractor relation: That is, prime and probe color were either the same (target feature match) or different (target feature mismatch); also, participants either pressed the same response key in prime and probe (response repetition) or pressed different response keys (response change). The pattern of distractor repetitions effects in the probe is then indicative of whether the distractor retrieves a distractor-response or a distractor-target binding: That is, if the distractor is bound to and later retrieves the prime response, analysis of distractor repetitions effects should yield a performance advantage for probe trials in which the prime response is to be repeated, whereas there should be a performance disadvantage in probe trials in which the to-be-performed response differs from the prime response. Retrieval of distractor-response bindings disregards target features, meaning that the predicted performance pattern should prevail irrespective of whether the target feature repeats or changes from prime to probe. In contrast, if the distractor is bound to the prime target feature, distractor repetition effects should vary as a function of target feature (mis-)matches in the probe: That is, distractor repetition should lead to a performance advantage for probe trials that match the prime target color, whereas there should be a performance disadvantage for probe trials that mismatch the prime target color. Crucially, distractor-based retrieval of the previous target disregards which response was executed. Hence, effects of target feature (mis-)match on distractor repetition from prime to probe should prevail irrespective of whether the response repeats or changes across prime and probe.

Experiment 1

The aim of Experiment 1 was to dissociate the contribution of processes of distractor-response and distractor-target binding and retrieval to distractor repetition effects within a single study. In both prime and probe trials, a word was presented that was printed in either red or green ink. Word color served as the target feature and participants had to press a left/right response key to categorize each stimulus according to its color. Content of the words was irrelevant for the color categorization task and served as distractor. Distractor relation was manipulated, implying that the word was either repeated or changed from prime to probe. In order to independently manipulate the relation (i.e., repetition vs. change) of target features and responses, the mapping of target features to response keys was not fixed but varied randomly and unpredictably for each prime and probe trial.

Method

Participants. Forty-nine students of the Friedrich Schiller University Jena with German as their native language were recruited for the experiment. Four participants had to be excluded from all analyses because of excessive error rates (> 19%). Thus, data of 45 (27 female) participants were analyzed. Participants' mean age was 22.2 years ($SD = 2.5$). They were tested individually and received 3 euros for their participation and an additional chocolate bar if their performance fulfilled both speed and accuracy criteria. Experimental sessions lasted approximately 40 min.

Apparatus and stimuli. The experiment was programmed with E-Prime 2.0 (Psychology Software Tools, Sharpsburg, PA). Twenty-five neutral, frequently used German adjectives that are either mono- or disyllabic and consisted of from four to seven letters (e.g., *small*, *quiet*, *edgy*) served as stimuli in the experiment. Stimuli were presented centrally in 16-point Times New Roman font on a black screen of a 17-in. CRT monitor. Stimulus color was either red or green. Participants gave their response by pressing either the "D" or the "L" key (marked with small adhesive labels) of a QWERTZ-keyboard.

Design. The experiment comprised a $2 \times 2 \times 2$ within-subject design with the factors distractor relation, target feature relation, and response relation, which were orthogonally manipulated (see Table 1 for sample stimuli). Distractor relation was manipulated by repeating the prime word in the probe in 50% of all prime-probe sequences (identical repetition; e.g., *small-small*) and by presenting two different words in prime and probe in 50% of all prime-probe sequences (baseline; e.g. *quiet-small*). Target feature relation was varied by repeating the stimulus font color in prime and probe in 50% of all prime-probe sequences (target feature match; e.g. *red-red*) and by changing the stimulus font color from prime to probe in 50% of all prime-probe sequences (target feature mismatch, e.g. *green-red*). Response relation was manipulated by requiring the same key-press response in prime and probe in 50% of all prime-probe sequences (response repetition, e.g. *left-left*) and by requiring two different key presses in prime and probe in 50% of all prime-probe sequences (response change; e.g. *right-left*).

Procedure. Instructions were given on the screen. For both prime and probe displays, participants' task was to categorize

Table 1
Sample Stimuli for Prime–Probe Sequences in Experiment 1

Distractor/target feature/ response relation	Prime mapping rule	Prime stimulus	Probe mapping rule	Probe stimulus
Identical repetition				
Match				
Response repetition	R G	small	R G	small
Response change	R G	small	G R	small
Mismatch				
Response repetition	R G	small	G R	<i>small</i>
Response change	R G	small	R G	<i>small</i>
Baseline				
Match				
Response repetition	R G	quiet	R G	small
Response change	R G	quiet	G R	small
Mismatch				
Response repetition	R G	quiet	G R	<i>small</i>
Response change	R G	quiet	R G	<i>small</i>

Note. Prime/probe stimuli in boldface were presented in red; stimuli in italics were presented in green in Experiment 1. R G indicates that red was assigned to the left response key and green to the right response key (and vice versa in the case of G R). Prime–probe sequences were counterbalanced across prime color (red/green) and prime mapping rule (R G/G R).

the color of the presented stimulus word via key-press. The meaning of the word was irrelevant for the task and served as a distractor in both prime and probe displays (Rothermund et al., 2005). Participants were instructed to keep their left and right index fingers on the “D” and “L” keys throughout the experiment. The mapping of target color to response keys varied randomly for each prime and probe stimulus; hence, participants were informed of the mapping rule only immediately before each new stimulus appeared. We used the letters “R” and “G” as abbreviations for the target colors “rot” (red) and “grün” (green) and informed participants that the relative position of each letter (separated by a single space between them) indicated the response key to which each color was assigned. That is, the cue “R G” signaled that participants had to press the left key if the stimulus was red and to press the right key if the stimulus was green, whereas the cue “G R” signaled that participants had to press the left key if the stimulus was green and the right key if the stimulus was red. The assignment of colors to response keys was counterbalanced in prime and probe, meaning that in 50% of all prime and probe trials, red (green) was assigned to the left (right) button and vice versa. For 50% of all prime–probe sequences, the prime mapping was also the probe mapping, whereas for the remaining trials, the prime mapping was reversed in the probe (i.e., repetition or change of the prime mapping rule in the probe depended on the combination of the factors’ response relation and target feature relation; see Table 1).

After reading the instructions, participants performed a practice block of 32 prime–probe sequences that included feedback for erroneous or too-slow responses in prime and/or probe displays. That is, if participants performed an erroneous response, the message “Error –wrong key!” appeared; if responses were slower than 1,000 ms, the message “Respond faster!” appeared; all feedback messages were presented centrally in white font on red background for 1,000 ms. The practice block was repeated if participants made more than 20% errors or responded slower than 1,000 ms in more than 50% of

all trials. Upon successful completion of the practice block, participants were told that they would receive a chocolate bar as an extra reward if they performed the task quickly (faster than 1,000 ms in 75% of all trials) and without making too many errors (less than 15% errors).

Participants then performed 320 experimental prime–probe sequences that were constructed with respect to the factorial design. For each sequence, a prime word was randomly chosen from the stimulus set. In case of identical repetition trials, the prime word was also presented as probe word; in case of baseline trials, a different word was sampled as probe word. Identical stimuli were never sampled for two successive prime–probe sequences. Prime stimulus color was counterbalanced, meaning that 50% of all prime stimuli were red and 50% of all prime stimuli were green (probe stimulus color depended on the experimental factor target feature relation, implying that 50% of all probe stimuli were red, and 50% of all probe stimuli were green).

Each prime–probe sequence was as follows (see Figure 1): First, as a ready signal, three exclamation marks (!!!) were presented centrally on the screen for 1,500 ms, followed by the cue for the prime mapping rule (R G vs. G R) which was presented for 500 ms. Subsequently, the prime display appeared in which a colored word stimulus was presented that remained on screen until participants responded or until a maximal duration of 1,500 ms had elapsed. Then, the cue for the probe mapping rule (R G vs. G R) was presented for 500 ms, which was followed by the probe display in which another colored word stimulus was presented that remained on screen until participants responded or until a maximal duration of 1,500 ms had elapsed. After an intertrial interval of 1,250 ms with a blank black screen, the next prime–probe sequence started.

Halfway through the experiment, participants were given a short break. At the end of the experiment, participants were asked whether they had used any strategies during the task. Participants then received feedback with regard to the speed and

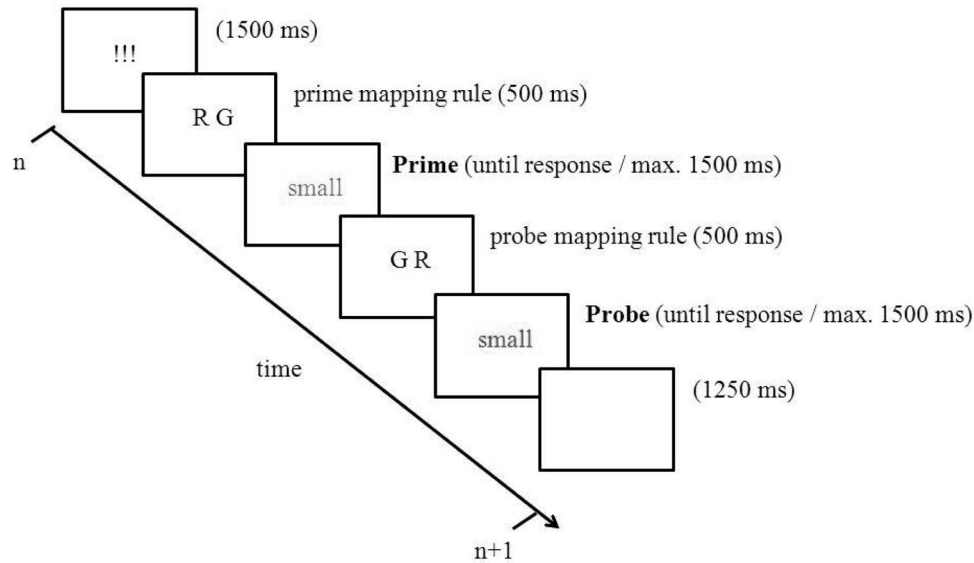


Figure 1. Sequence of events in Experiment 1. Participants performed a color categorization task for each prime and probe stimulus. Stimuli are not drawn to scale. R = red; G = green.

accuracy criteria and were thanked, debriefed, and rewarded accordingly.

Results

Prime-probe sequences with erroneous responses in prime and/or probe displays (9.8%) and probe reaction times (RTs) outlier values³ (0.8%) were excluded from analyses. For analyses, a significance level of $\alpha = .05$, two-tailed, was maintained; however, since distractor-response and distractor-target binding and retrieval make directional predictions, we applied a one-tailed test strategy for all follow-up tests on distractor repetition effects.

We computed distractor repetition effects from average probe RT and error rates (see Table 2) by subtracting trials with identical distractor repetition from baseline trials (baseline minus identical repetition) for every condition of the Target Feature Relation \times Response Relation factor combination and separately for each participant. Distractor repetition effects for probe RTs were then entered into a 2 (target feature relation: match vs. mismatch) \times 2 (response relation: repetition vs. change) analysis of variance (ANOVA).⁴

The main effect of target feature relation was significant, $F(1, 44) = 13.90$, $p = .001$, $\eta_p^2 = .24$, as was the main effect of response relation, $F(1, 44) = 4.67$, $p = .03$, $\eta_p^2 = .10$ (see Figure 2, Panel a). In particular, repeating the prime distractor in the probe facilitated performance if the probe target feature matched the prime target feature, $\Delta = 12$ ms, $t(44) = 3.49$, $p < .001$, one-tailed, $d_z = 0.52$, but delayed performance if the probe target feature mismatched the prime target feature, $\Delta = -7$ ms, $t(44) = 1.90$, $p = .03$, one-tailed, $d_z = 0.28$. In addition, repeating the prime distractor in the probe also sped up performance for sequences with response repetition, $\Delta = 8$ ms, $t(44) = 2.09$, $p = .02$, one-tailed, $d_z = 0.31$, but led to nonsignificant slowing down for sequences with response change, $\Delta = -3$ ms, $t(44) = -0.958$, $p = .17$, one-tailed, $d_z = 0.14$. The interaction of target feature

relation and response relation was not significant, $F(1, 44) = 2.25$, $p = .14$, indicating that both effects were additive.

The same 2×2 ANOVA on distractor repetition effects for probe error rates yielded only a main effect of target feature relation, $F(1, 44) = 23.21$, $p < .001$, $\eta_p^2 = .35$ (all F s < 3.61 , ns ; see Figure 2, Panel b). That is, repeating the prime distractor in the probe reduced error rates if the probe target feature matched the prime target feature, $\Delta = 1.2\%$, $t(44) = 2.95$, $p = .002$, one-tailed, $d_z = 0.44$, but increased error rates in case the probe target feature mismatched the prime target feature, $\Delta = -2.1\%$, $t(44) = 3.65$, $p < .001$, one-tailed, $d_z = 0.54$.

Discussion

Do distractors retrieve prime responses to targets, do they retrieve the prime targets themselves, or both? The results of Experiment 1 support a straightforward answer: Distractors retrieve both, prime responses *and* prime targets, and these binding and retrieval effects operate independently of each other. We rest this conclusion on the analysis of distractor repetition effects, which indicated that processes of distractor-response and distractor-target binding and retrieval are significant and additive: Repetition of the prime distractor in the probe led to faster performance if the prime response had to be repeated in the probe, but delayed

³ Probe reaction times (RTs) below 200 ms or more than three inter-quartile ranges above the third quartile of the individual distribution of probe RTs were regarded as outliers (Tukey, 1977). Outliers were calculated separately for prime-probe sequences in which prime mapping rules repeated versus changed in the probe in Experiment 1.

⁴ Analysis of variance (ANOVA) results for the full design on mean probe RT and mean error rates in Experiments 1–3 are depicted in the Appendix. Since the main focus of the present research was on distractor repetition effects, factors that did not interact with the distractor relation factor are not of theoretical interest and are therefore not further discussed (but see Footnote 6).

Table 2

Means (Standard Deviations) of Probe Reaction Times and Error Rates in Experiments 1–3

Experiment/target feature/response relation	Distractor relation RT (ms)		DR effect	Distractor relation % errors		DR effect
	IR	Baseline		IR	Baseline	
Experiment 1						
Match						
Response repetition	474 (69)	495 (81)	21 [5.0]	0.9 (1.6)	2.2 (3.0)	1.3 [0.4]
Response change	566 (111)	568 (114)	2 [5.7]	5.9 (5.4)	7.1 (6.0)	1.2 [0.8]
Mismatch						
Response repetition	680 (147)	674 (142)	−6 [6.6]	17.6 (11.4)	14.1 (10.9)	−3.5 [1.1]
Response change	531 (93)	522 (94)	−9 [3.4]	3.1 (2.8)	2.5 (3.0)	−0.6 [0.4]
Experiment 2						
Match	854 (345)	875 (382)	21 [10.5]	1.3 (1.9)	1.4 (2.6)	0.1 [0.3]
Mismatch	990 (449)	974 (421)	−16 [9.9]	4.2 (5.2)	4.0 (4.7)	−0.2 [0.4]
Experiment 3						
Response repetition	241 (63)	246 (53)	5 [2.6]	0.8 (1.3)	1.1 (1.6)	0.3 [0.2]
Response change	245 (58)	238 (53)	−7 [3.0]	1.1 (1.8)	0.8 (1.5)	−0.3 [0.2]

Note. DR effect = distractor repetition effect, computed as the difference between baseline minus identical repetition (IR); standard errors of the means in square brackets.

performance if responses changed from prime to probe. In addition, distractor repetition in the probe also speeded up performance if prime and probe target features matched, but delayed performance if prime and probe target features mismatched. On the one hand, these findings are consistent with the idea that once a distractor is integrated into a prime processing episode, it automatically retrieves the prime response if it is re-encountered in a subsequent trial (Frings et al., 2007; Rothermund et al., 2005). However, the obtained results substantially extend this view by showing that independently of prime responses, distractors also retrieve prime target features – a finding that was obscured in previous studies.

Apparently, both processes operate independently of each other, as was indicated by the lack of an interaction between target feature relation and response relation. To corroborate this reasoning, we conducted a post hoc power analysis with G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007). Indeed, the power of the present study was substantial due to its large sample size (i.e., the probability to detect a medium-sized effect was $1 - \beta = .95$). This null effect attests to the additive nature of both kinds of retrieval effects. It shows that even in case of distractors, bindings are binary, feature-based, and local (Hommel, 1998, 2004, 2007) and supports the assumption that distractor–response and distractor–target binding are independent processes operating in the service of behavior automatization.

The interpretation of distractor–target binding and retrieval processes, however, is challenged by an interpretational ambiguity that is inherent to the manipulation of target feature relations in Experiment 1. In order to orthogonally manipulate the factors target feature relation and response relation, we varied the mapping or task rules for prime and probe displays, implying that mapping rules were sometimes identical for prime and probe (“task repetition”, e.g., “R G”–“R G”; see Table 1), and sometimes different (“task switch”, e.g., “R G”–“G R”). By implication, the factor target feature relation is equivalent to the factorial combination of response relation and mapping relation (technically, an effect of target relation is mathematically iden-

tical to an interaction of mapping relation and response relation). The finding that distractor repetition effects were positive for target feature matches and negative for target feature mismatches thus does not necessarily reflect distractor–target bindings, but could be re-interpreted in terms of an influence of the combination of task switches and response switches on distractor repetition effects: Distractor repetition effects were positive when mapping and response were both either repeated or changed, but were negative when only the mapping rules or only the responses changed from prime to probe while the other factor remained constant. This point is particularly noteworthy, because it is known from the task-switching literature that response repetitions and task repetitions do interact (i.e., response repetitions compared with response changes produce performance benefits on task repetition sequences but lead to performance costs on sequences with task switches; e.g., Druey & Hübner, 2008; Hübner & Druey, 2006; Mayr & Kliegl, 2003; Rogers & Monsell, 1995). Of course, an interaction of task switches and response switches with regard to response speed (simple RT) is not the same as an interaction of these factors with respect to distractor repetition effects. Nevertheless, we should be careful in interpreting the effect of target feature relation on distractor repetition effects in Experiment 1. We cannot be sure whether (a) repetition of the prime distractor in the probe retrieved the prime target feature (as initially assumed) or (b) whether distractor repetition effects were modulated by the interaction of task and response switches (i.e., matching repetitions/changes regarding mapping and response relation might produce positive distractor repetition effects, whereas negative distractor repetition effects might result in case of mismatching changes with regard to these factors). To overcome this problem of interpretational ambiguity, we designed the following experiment to investigate processes of distractor–target binding and retrieval separately (i.e., by eliminating effects of distractor–response bindings) and in a situation that avoids task or mapping switches between prime and probe displays.

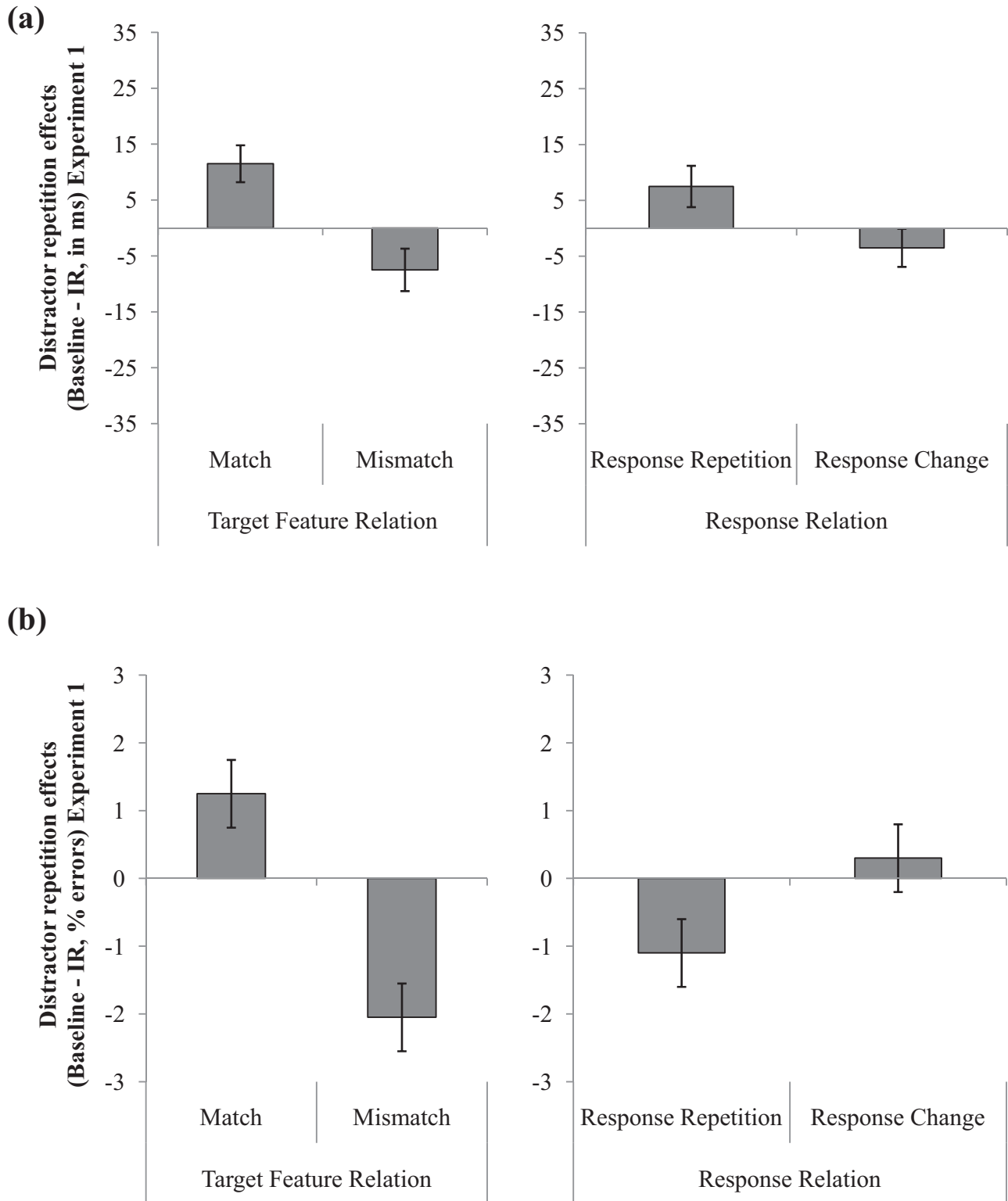


Figure 2. Main effects of target feature relation and response relation on distractor repetition effects: baseline – identical repetition [IR]) based on (Panel a) probe reaction times and (Panel b) probe error rates (Experiment 1). Error bars depict the standard errors of the mean. Positive (negative) values indicate facilitated (impeded) performance due to distractor repetition compared with baseline.

Experiment 2

The aim of Experiment 2 was to provide a “pure” test of distractor–target binding and retrieval processes that at the same time allowed us to exclude retrieval of distractor–response bindings or interactions of distractor repetition effects with task switches and response switches as an alternative explanation. We again used stimulus color (red/green) as the target feature and stimulus content as the distractor in prime and probe trials. Experiment 2 was designed as a study in which *no response at all* had to be executed during the prime trial. Participants were asked to memorize the color of the prime word; then they performed a manual color categorization as probe task. After the probe response was carried out, participants had to indicate the prime color in a memory test. To prevent participants from preparing responses during the prime trial (e.g., preparing the memory test response or applying the probe mapping to the prime stimulus), we randomly varied the mapping of the target feature to response keys (as in Experiment 1) for both the probe display and prime memory test. Not knowing the mapping rules for these tasks in advance makes it impossible to (covertly) translate the prime stimulus into a response during the prime trial.

Therefore, because participants did not execute a prime response and were prevented from preparing one, any contribution of prime response retrieval to distractor repetition effects can be ruled out. In addition, since no prime task was executed, we can also exclude that effects of target feature relations are confounded with task switches. Furthermore, no prime mapping rule could be retrieved during the probe, because participants were not aware of the mapping rule for prime target features until the memory test took place (i.e., *after* the probe response was executed).

It is important to note that we should still obtain a pattern of distractor–target binding and retrieval effects with this manipulation: That is, if the distractor is bound to the target feature (color) during the prime and retrieves it subsequently, distractor repetition in the probe should yield better performance if prime and probe target features match and worse performance if they mismatch.

Method

Participants. Fifty-one students of the University Jena with German as their native language were recruited for the experiment. One participant was excluded because of an excessive error rate (>27%). Hence, data of 50 (29 female) participants were analyzed. Participants’ mean age was 24.4 years ($SD = 5.1$). Participants were tested individually in soundproof cubicles; experiment duration and payment paralleled those in Experiment 1.

Design. The experiment comprised a 2×2 within-subject design with the factors distractor relation (identical repetition vs. baseline) and target feature relation (match vs. mismatch), which were manipulated orthogonally.

Materials and procedure. Materials and procedure were similar to Experiment 1 except for the following changes: We changed the prime task to a memory task and instructed participants to memorize the color of the prime word. Participants were informed that a memory test for the prime color would follow after the probe display. In the memory test, participants were asked to indicate the memorized prime color by pressing one of the two response keys; the mapping rule for the memory test (i.e., either “R G” or “G R”) varied randomly between trials and was presented only after the

probe. As in Experiment 1, the probe task was a manual color categorization; mapping rules of color to response keys varied randomly also for the probe task.

Each trial sequence started with the ready signal (!!!) for 1,500 ms, followed by the prime display in which a colored stimulus word was presented for 1,500 ms. Then the probe mapping rule was presented for 500 ms, followed by the probe display in which another colored stimulus word was presented that remained on the screen until participants gave a manual color categorization response. Then the memory test followed in which the question “What was the first word’s color?” was presented together with the mapping rule and remained on the screen until participants responded. After an intertrial interval of 1,250 ms with a blank black screen, the next prime-probe sequence started.

Participants performed a practice block followed by 320 experimental prime–probe sequences that were constructed with the same experimental design and constraints as Experiment 1.

Results

According to the same criteria as in Experiment 1, 6.1% of all probe trials were excluded due to erroneous responses in the probe or in the prime memory test; additionally, 1.8% of all probe trials were excluded because of outlier values. We computed distractor repetition effects from average probe RTs and error rates (see Table 2) separately for probe trials that matched and mismatched the preceding prime target feature.

A paired *t*-test for probe RTs revealed that the distractor repetition effect for probe trials with a target feature match differed significantly from those with target feature mismatch, $t(49) = 2.65$, $p = .01$, $d_z = 0.37$ (see Figure 3, Panel a). In particular, repeating the prime distractor in the probe significantly facilitated performance if the probe target matched the prime target, $\Delta = 21$ ms, $t(49) = 2.00$, $p = .02$, one-tailed, $d_z = 0.28$, but delayed performance if the probe target feature mismatched the prime target feature; however, the latter effect missed the preset criterion for significance, $\Delta = -16$ ms, $t(49) = 1.56$, $p = .06$, one-tailed, $d_z = 0.22$.

For probe error rates, there was no significant difference between distractor repetition effects for probe trials with target feature match compared to mismatch, $t(49) = 0.795$, $p = .43$, $d_z = 0.11$ (see Figure 3, Panel b).

Discussion

Experiment 2 provides a pattern of results that indicates distractor-based retrieval of the prime target feature: If the distractor was repeated in the probe, participants responded faster if the prime and probe target features matched, but were slowed down if prime and probe target features mismatched. The obtained results thus provide distinct evidence for the operation of distractor–target binding and retrieval processes. It should be noted that the present evidence was obtained in a situation that completely precludes retrieval of distractor–response bindings: Effectively, no prime response was performed that could have been linked to the prime distractor. Since the mapping rules for the prime memory test varied unpredictably between trials, we can further exclude that participants covertly prepared some kind of response during the prime. The fact that prime mapping rules were presented only after the

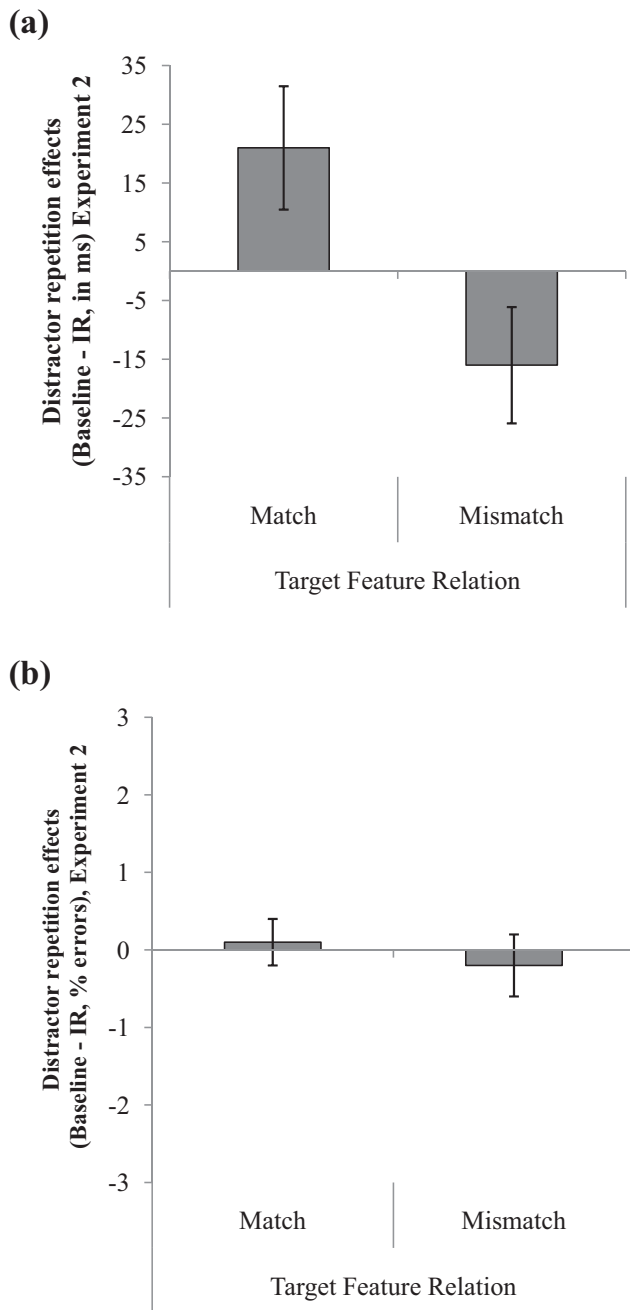


Figure 3. Distractor repetition effects (baseline – identical repetition [IR]) for (Panel a) probe reaction times and (Panel b) probe error rates (Experiment 2) as a function of target feature relation. Error bars depict the standard error of the mean.

the probe response was executed precludes the possibility that retrieval of the prime mapping rule might have influenced responding in the probe. Since the execution of the prime task was delayed until after the probe trials, Experiment 2 did not contain a task switch between prime and probe that might have interacted with distractor-repetition effects. Thus, Experiments 2 provides unambiguous evidence that distractors automatically retrieve

distractor-target bindings that emerged incidentally during the prime trial.

Experiment 3

So far, we demonstrated that the emergence and retrieval of distractor–target bindings are unaffected if the manipulation counteracts the formation of distractor–response bindings. What is still lacking to complete the picture is a demonstration of the reverse case, namely, that distractor–response bindings still emerge under conditions that selectively prevent distractor–target bindings. Hence, we designed the last experiment as a test for “pure” distractor–response binding and retrieval processes. Effectively, Experiment 3 was a study without target features, so that retrieval of distractor–target bindings can be ruled out as an explanation of distractor repetition effects.

Before the start of each prime–probe sequence, we instructed participants to memorize a particular sequence of key-press responses. By that, we removed any response-defining feature from the word stimuli in prime and probe, so that stimuli would only trigger a predetermined response. Participants were instructed to carry out the first (second) response as soon as the prime (probe) stimulus word changed its color from white to yellow. Hence, in Experiment 3, each word’s color change functioned as a go signal to carry out the previously instructed response, whereas the word stimuli themselves did not provide any relevant information on the particular kind of response that had to be executed.⁵

The manipulation used in Experiment 3 bears some resemblance to the procedure adopted by [Hommel \(1998\)](#) to provide evidence for the existence of event files. In his study, participants are first provided with a cue to prepare prime responses (e.g., a left/right pointing arrow) so that the prime stimulus (e.g., an X/O) is irrelevant for the task and solely functions as a go signal to execute the prepared response (as in the present experiment). In the probe, participants have to apply a stimulus–response rule to the probe stimulus (e.g., “X”: press left; “O”: press right). This procedure allows manipulating stimulus and response relations independently across prime and probe. However, there is a subtle problem with this procedure, which suggests an alternative explanation of his findings in terms of stimulus-feature-specific inhibition ([De Houwer, Rothermund, & Wentura, 2001](#)): Although the probe task is not relevant when the prime stimulus is presented as a go signal, it can be applied to the prime stimulus nonetheless. If the prime stimulus is assigned to a conflicting response in the probe task, this leads to an inhibition of the prime stimulus’ feature that is relevant for the probe task to prevent interference ([De Houwer et al., 2001](#); see also [Rothermund et al., 2005](#), p. 487). Persistence of the inhibition of the feature that is relevant for the probe task then delays probe responses if the stimulus repeats and has to be

⁵ The temporal order of occurrence of the prime and probe stimuli might be seen as a relevant (“target”) feature that specifies the to-be-executed response (first word indicates retrieval and execution of the first response, second word indicates retrieval and execution of the second response). However, this temporal order information (a) does not specify which of the two responses is to be executed and (b) does not vary across trials, but is constant for all prime–probe sequences in the present design. By implication, retrieval of this constant piece of information cannot explain why distractor repetition effects differed systematically between the response repetition and response change conditions.

categorized according to its relevant feature. Response conflict during the prime and resulting inhibition effects occur only in response-change sequences (in a response-repetition sequence, there is no response conflict during the prime because the repeated prime stimulus is associated with the same response in the probe task). Thus, stimulus-feature-specific inhibition offers an alternative explanation for the interaction between stimulus relation and response relation that has been interpreted as an indicator of a retrieval of stimulus–response bindings by Hommel (1998). To avoid this confound, we used a procedure in which the repeated word stimuli were irrelevant in both prime and probe task, and in which both prime and probe responses were pre-instructed. Eliminating task-relevant features completely from the procedure excludes any effects of stimulus-feature-specific inhibition.

Method

Participants. Forty-six students of the University Jena with German as their native language were recruited for the experiment. One participant was excluded because of an excessive error rate ($>23\%$). Hence, data of 45 (28 female) participants were analyzed. Participants' mean age was 22.4 years ($SD = 2.8$). Participants were tested individually and received 2euro for their participation and a chocolate bar if their performance fulfilled the speed and accuracy criteria. The experiment lasted around 20–25 min.

Design. The experiment comprised a 2×2 within-subject design with the factors distractor relation (identical repetition vs. baseline) and response relation (response repetition vs. change) that were manipulated orthogonally.

Materials and procedure. Materials and procedure were similar to those in Experiment 1 except for the following changes: Participants no longer had to categorize the word color in prime and probe display. Instead, at the beginning of each trial, a response sequence was instructed (depending on the experimental factor response relation) which participants had to memorize. We used the letters “l” and “r” as abbreviations for the responses “links” (left) and “rechts” (right). For instance, the instruction “r – l” signaled that participants had to press the right key for the prime and the left key for the probe stimulus. To avoid confusion with abbreviations and response keys, participants now gave their responses by pressing either the “F” (left) or the “K” (right) response keys (marked with small adhesive labels). Participants were told to execute the first (second) pre-instructed response as soon as the prime (probe) stimulus changed its color. Hence, prime and probe stimuli were initially presented in white color that changed to yellow after the go delay duration had elapsed. To prevent an exact anticipation of the response execution, go delay duration varied randomly between 250–400 ms (in steps of 50 ms). The color change served as a go signal to execute the pre-instructed responses for each prime/probe display.

Each trial sequence started with the ready signal (!!!) for 300 ms, followed by the to-be-memorized response sequence that was presented centrally for 1,500 ms. Subsequently, a blank black screen was presented for $M = 250$ ms. Then the prime display followed, and a word stimulus was first presented in white for a variable prime go delay (between 250–400 ms) but then turned yellow until participants responded or until an overall duration of 1,500 ms had elapsed. Then a blank black screen appeared for $M = 250$ ms, which was followed by the probe display: Another word stimulus was first presented in white for a variable probe go delay

(between 250–400 ms) but turned yellow until participants responded or until an overall duration of 1,500 ms had elapsed. After an intertrial interval of 1,250 ms with a blank black screen, the next prime-probe sequence started.

Participants performed a practice block and 320 experimental prime–probe sequences that were constructed with respect to the experimental design and with the same constraints as in Experiment 1.

Results

According to the same criteria as in Experiment 1, 2.1% of all probe trials were excluded because of erroneous responses in the prime and/or probe display; outlier values (0.7%) and probe trials with responses that were executed during the probe go delay (2.4%) were also excluded. We computed distractor repetition effects from average probe RT and error rates (see Table 2) separately for prime–probe sequences with response repetition or change.

A paired t test for probe RTs revealed that the distractor repetition effect for probe trials in which the prime response had to be repeated differed significantly from probe trials with response change, $t(44) = 3.80$, $p < .001$, $d_z = 0.57$ (see Figure 4, Panel a). In particular, repeating the prime distractor in the probe significantly facilitated performance in response repetition sequences, $\Delta = 5$ ms, $t(44) = 2.11$, $p = .02$, one-tailed, $d_z = 0.31$, but significantly delayed response latencies in response change sequences, $\Delta = -7$ ms, $t(44) = 2.29$, $p = .01$, one-tailed, $d_z = 0.34$.

A paired t test on probe error rates revealed a similar pattern: The distractor repetition effect for probe trials in which the prime response had to be repeated differed significantly from probe trials with response change, $t(44) = 1.99$, $p = .05$, $d_z = 0.30$ (see Figure 4, Panel b). Descriptively, repeating the prime distractor in the probe led to nonsignificantly fewer errors in sequences with response repetition, $\Delta = 0.3\%$, $t(44) = 1.31$, $p = .10$, one-tailed, $d_z = 0.19$, but led to a nonsignificant increase in error rates in sequences with response change, $\Delta = -0.3\%$, $t(44) = 1.22$, $p = .12$, one-tailed, $d_z = 0.18$.

Discussion

Experiment 3 provided results that are consistent with the assumption of a distractor-based retrieval of the prime response: Distractor repetitions facilitated performance if the same response had to be executed in prime and probe, but impeded performance if the probe required a different response than the prime trial. In line with previous studies (e.g., Frings et al., 2007; Rothermund et al., 2005), the present findings once again demonstrate the storage and automatic retrieval of distractor–response bindings.

Going beyond previous studies that claimed to have demonstrated distractor–response binding and retrieval effects, we can positively discount retrieval of distractor–target bindings as an alternative explanation for the present findings. Word stimuli in prime and probe no longer carried any response-defining target feature that could have been bound with the irrelevant stimulus content. Eliminating target features from the prime and probe displays also rules out that processes of distractor–target binding and retrieval might contribute to the observed pattern of effects. Instead, the present findings are consistent with the distractor–

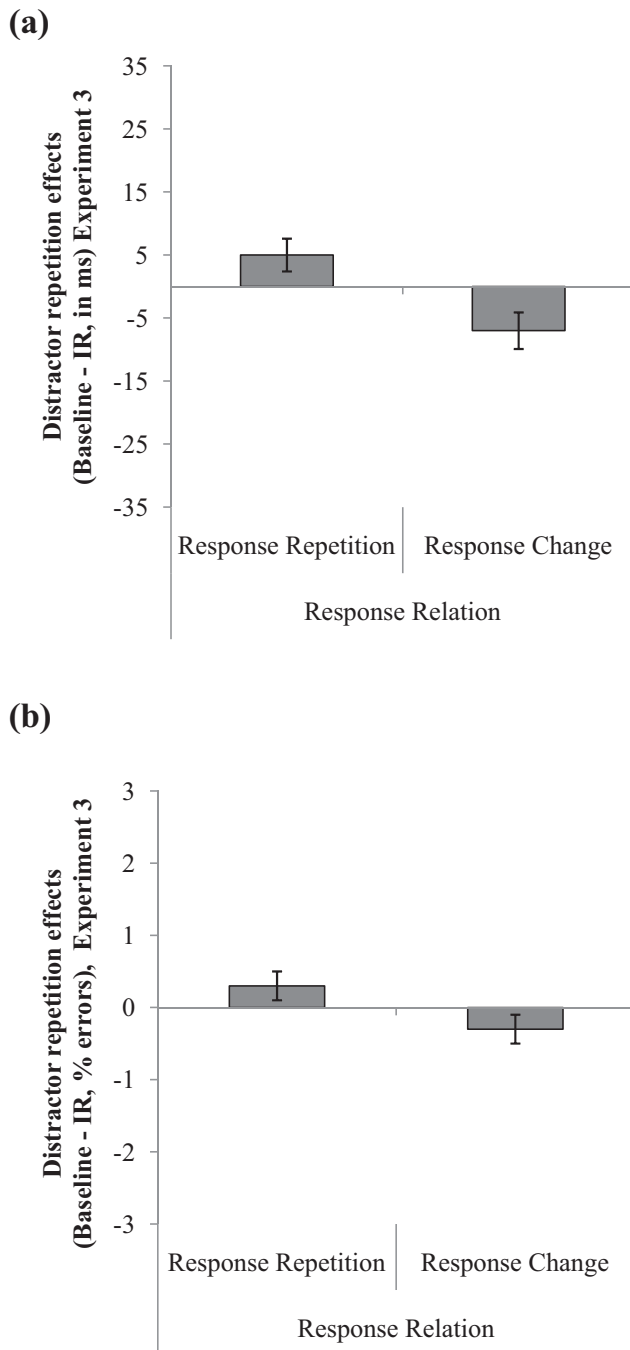


Figure 4. Distractor repetition effects (baseline – identical repetition [IR]) for (Panel a) probe reaction times and (Panel b) probe error rates (Experiment 3) as a function of response relation. Error bars depict the standard errors of the mean.

response binding account and document that the emergence and retrieval of distractor–response bindings functions independently of distractor–target binding and retrieval.

We want to point out that obtaining evidence for distractor–response binding and retrieval in the present experiment was all but trivial: Participants had explicit foreknowledge of each

response sequence (i.e., whether it involved a switch of responses or not) and ample time to prepare themselves for the to-be-performed response sequence: Although participants knew in advance that they had to produce the same response twice in quick succession, repetition of the distractor still added a significant response time advantage when participants executed the second response. In contrast, even though participants knew of an oncoming switch between two (fairly easy) left or right responses, repetition of the distractor came with an additional response time cost.

General Discussion

In recent years, several studies have documented that not only relevant stimulus features and responses are integrated into an event file but also irrelevant stimulus features. These findings demonstrate that an automatic retrieval of a *previous response* cannot only be triggered by repeating the previous target (e.g., Denkinger & Koutstaal, 2009; Hommel, 1998, 2004, 2007; Horner & Henson, 2009, 2011; Waszak et al., 2003, 2005) but also by repeating the previous distractor (Frings, 2011; Frings & Moeller, 2010, 2012; Frings & Rothermund, 2011; Frings et al., 2007; Gibbons & Stahl, 2008; Giesen et al., 2012; Giesen & Rothermund, 2011, 2013; Mayr & Buchner, 2006; Mayr et al., 2009; Moeller & Frings, 2012; Moeller et al., 2012; Rothermund et al., 2005). The present study sought to extend existing knowledge of distractor-based retrieval effects by investigating whether distractors also retrieve *previous target stimuli* (or stimulus features), above and beyond responses. We conducted three experiments that employed a sequential distractor-to-distractor repetition paradigm (Rothermund et al., 2005) to subject the issue of what is retrieved by distractors to close scrutiny.

The results of the present experiments substantiate our reasoning that distractor repetitions automatically retrieve previous responses, but also previous targets. Furthermore, the present findings demonstrate that processes of distractor–response and distractor–target binding and retrieval operate independently of each other and hence may work in parallel. In this respect, our study is the first to show that distractor–response and distractor–target retrieval can be experimentally dissociated within the same experiment and also with specific manipulations that selectively disrupt one process from operating while leaving the other intact. Specifically, to test whether distractors (apart from responses) can also become associated with prime target features, we orthogonally manipulated the relation of distractors, responses, and target features across prime and probe trials in Experiment 1. The obtained results demonstrate that distractor repetition in the probe not only triggered retrieval of the prime response, but also retrieved the prime target feature. The absence of any higher order interaction in this study is particularly noteworthy: Since it cannot be attributed to insufficient power, it suggests that distractor–target retrieval operates independently of distractor–response retrieval. Experiments 2 and 3 provided additional evidence for the two kinds of binding and retrieval processes. These experiments revealed that completely eliminating one process did not prevent the occurrence of the other type of distractor-based binding and retrieval effect, which speaks in favor of the existence of two

independent processes. Specifically, Experiment 2 provides evidence that conditions that prevent the emergence or retrieval of distractor–response bindings leave processes of distractor–target binding and retrieval unaffected. The obtained results show that distractor repetition in the probe still retrieved the prime target feature, which is reflected in performance advantages (disadvantages) if the prime target feature matched (mismatched) the probe target feature, respectively. Conversely, controlling for influences of distractor–target bindings by pre-instructing fixed response sequences and eliminating the target information from the prime and probe displays in Experiment 3 did not prevent the emergence of distractor–response bindings. Taken together, our findings thus provide strong evidence for the existence of independent mechanisms of irrelevant stimulus–response and irrelevant stimulus–stimulus bindings.

Distinguishing Between Stimuli And Responses

Although the distinction between target stimuli and responses seems evident and trivial at first sight, a closer look reveals that the boundaries between stimulus–stimulus and stimulus–response bindings are sometimes difficult to draw. For example, with respect to Experiment 2, it can be asked whether a perceptual representation of the prime target is retrieved that facilitates or interferes with processing of the probe target, or whether the distractor retrieves a covert identification “response” through which the target was categorized as either “green” or “red.” In the latter case, retrieving the result of such a covert activity might facilitate or interfere with producing an adequate categorization in response to the probe target.

Conversely, it can also be asked what exactly it is that is retrieved in case of distractor–response bindings. For example, responses might internally be coded with semantic labels (e.g., “red” or “green”, “right” or “left”), and repeating the distractor retrieves these label stimuli rather than reactivating a specific motor code (Rothermund et al., 2005; see also Eder & Rothermund, 2008, for a similar argument as to what constitutes approach and avoidance responses).

The question of whether and how stimuli and responses can be separated is reminiscent of the influential theory of event coding (TEC; Hommel, Müsseler, Aschersleben, & Prinz, 2001). According to the TEC, stimuli and actions are coded in a common format, which makes it difficult to distinguish between cognitive representations of stimuli and responses. Nevertheless, although mental representations between stimuli and actions may show considerable overlap or similarities, this does not render the distinction meaningless.

The crucial difference between stimuli and responses consists in what it is that is represented mentally. In case of stimulus bindings, the association refers to perceptual features, semantic labels, and so on that specify the identity and the attributes of an external object. Response bindings, on the other hand, refer to features and codes that characterize an activity of the organism. Accordingly, we would argue that the output of a covert categorization of a target stimulus still is a mental code that characterizes a stimulus rather than an activity, which renders Experiment 2 as an example of stimulus–stimulus binding and retrieval. Similarly, even a semantic coding of a response still reflects a mental representation of an activity, which renders the results reported in Experiment 3 as

evidence of stimulus–response binding and retrieval. Thus, although the conceptual distinction between stimuli and responses might sometimes appear to be difficult and artificial, this must not detract from the fact that the identification of what is a stimulus and what is a response is clear beyond reasonable doubt in most cases.

Additional Types of Bindings

Though the main focus of the present set of experiments was to dissociate processes of distractor–response and distractor–target binding and retrieval, we want to emphasize that other types of bindings can emerge within an event file that can also influence subsequent behavior. Indeed, two additional types of binding are conceivable in this situation, namely, target–response and distractor–target–response bindings.⁶ Target–response (T-R) bindings denote a binding between the target stimulus and the (assigned or executed) response; repetition of the target in a subsequent trial then automatically retrieves the former response. With respect to the present experiments, only Experiment 1 allowed us to test for target–response bindings, since in Experiment 2, no prime response was executed, whereas in Experiment 3, response-defining target features were absent. Indeed, a supplementary analysis of the data of Experiment 1 revealed clear evidence of target–response binding and retrieval effects that were functionally independent of distractor–response and distractor–target bindings (i.e., there was no interaction between the respective retrieval effects).⁷ However, the distractor is not involved in this kind of binding, and distractor–response bindings were manipulated orthogonally to target feature-related bindings in our experiments. Target–response bindings thus cannot explain the obtained distractor repetition effects of our study.

Distractor–target–response (D–T–R) bindings, in turn, are a different matter. They represent a special case of distractor–target bindings that provide an indirect link between distractor and response: The central idea is that distractor-based retrieval of the previous target leads to a reactivation of the target representation, which in turn initiates a second retrieval process of the response via an activation of a target–response binding. In such a case, the distractor can retrieve a response without being itself directly associated with the executed response. This kind of indirect distractor-based response retrieval would be

⁶ We want to thank an anonymous reviewer for drawing our attention to this important point.

⁷ An ANOVA on mean probe RTs of Experiment 1 using the full 2 (distractor relation) \times 2 (target feature relation) \times 2 (response relation) design yielded a significant interaction of target feature relation and response relation (see Appendix). Follow-up tests showed that target feature matches in the probe (in contrast to mismatches) significantly facilitated performance for sequences with response repetition, $\Delta = 192$ ms, $t(44) = 12.16$, $p < .001$, $d_z = 1.81$, but significantly delayed performance for response change sequences, $\Delta = -40$ ms, $t(44) = 4.34$, $p < .001$, $d_z = 0.65$, indicating retrieval of target–response bindings. Furthermore, the absence of the three-way interaction among distractor relation, target feature relation, and response relation in Experiment 1 (which corresponds to the Target Feature Relation \times Response Relation interaction for distractor repetition effects) supports the conclusion that target–response bindings are functionally independent from distractor–response and distractor–target bindings.

accomplished (“mediated”) by first retrieving the previous target (cf. Frings & Rothermund, 2011; Mayr & Buchner, 2006; Mayr et al., 2009; Mayr, Buchner, Möller, & Hauke, 2011), which then retrieves the response via a previously established target–response link. A differentiation between (direct) distractor–response and (indirect) distractor–target–response bindings is an important question, and not all of our experiments allowed us to disentangle these two forms of distractor–response bindings (evidence for distractor–response bindings in Experiment 1 can be explained with direct [D–R] and indirect [D–T–R: D–T + T–R] bindings, but Experiment 3 yielded unequivocal evidence for direct bindings, because targets were eliminated from the design).⁸

Implications

The insight that processes of distractor–target and distractor–response binding and retrieval are functionally independent is as new as it is important, and it bears some relevant theoretical and practical implications. Theoretically, the structural similarity between distractor–response binding and retrieval and Pavlovian conditioning (PC) is striking: The distractor corresponds to the “irrelevant” stimulus (conditioned stimulus; CS) that is paired with the “relevant” stimulus (unconditioned stimulus; US) which elicits a certain response (unconditioned response; UR). Pairing of the distractor (CS) with the target (US) and the response (UR) leads to an association of the distractor with the target (US) and/or the response (UR), so that later presentations of the distractor (CS) also elicit the respective response tendency (conditioned response; CR). We do not want to deny the differences between these paradigms—associations between stimuli and respondent behavior (e.g., autonomously controlled responses or reflexes) versus associations between stimuli and operant responses (behavior that is under volitional control); or contingent pairings versus one-trial learning. Nevertheless, acknowledging these similarities provides an important link between cognitive instance theories of behavioral automatization (Logan, 1988) and classical learning theories, and it might also help to generate new hypotheses regarding the underlying mechanisms that mediate learning effects in PC paradigms. Specifically, the current research might throw an interesting light on a question that has occupied conditioning research as well, namely, whether PC effects reflect stimulus–stimulus (CS–US) or stimulus–response (CS–UR) associations (for an overview, see Wasserman & Miller, 1997; see also Gast & Rothermund, 2011; Rescorla, 1979; Rizley & Rescorla, 1972; and Footnote 8).

With regard to practical implications, our findings highlight the importance to carefully distinguish between stimulus–stimulus-based and stimulus–response-based interpretations of distractor repetition effects whenever both processes predict similar effects. In order to use distractor repetition effects as unambiguous indicators for either, distractor–response or distractor–target retrieval, one would be well advised to follow the present examples and employ manipulations that sideline one process while leaving the other intact (see Experiments 2 and 3). Alternatively, response relation and target relation can be manipulated independently, so that both processes would predict opposing patterns of results and can be disentangled statistically (see Experiment 1).

Conclusion

The obtained results provide us with deeper insight into the structural bonds within an event file that come about once a distractor is integrated. Our findings suggest that distractor integration is accomplished through the formation of multiple binary bindings that link irrelevant features or stimuli with response codes and/or other stimulus features simultaneously. These various distractor–response and distractor–target bindings emerge independently of each other and consequently can be accessed and retrieved independently as well. Hence, we conclude that distractor-based bindings follow the same basic principles that hold true for bindings between relevant stimulus features and response codes (Hommel, 1998, 2007). Both processes contribute to automatic behavior regulation in a bottom-up fashion.

⁸ In order to test whether indirect bindings between a distractor and a response play a role in explaining distractor repetition effects, researchers might employ a design that is reminiscent of sensory preconditioning (e.g., Brogden, 1939). In such a study, distractor–target and target–response bindings are first established independently of each other in a sequence of two displays (I. D–T1; II. T1–R1). In a third test display, the distractor from the first display is repeated together with a new target that requires a response that is either compatible (D–T2–R1) or incompatible (D–T2–R2) with the response in the second display. If the distractor retrieves the previous response (R1) indirectly via the previous target (T1), distractor repetition effects should be obtained in the third display.

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Appendix

Results of Repeated-Measures Analyses of Variance for the Full Factorial Design of Experiments 1–3

Experiment and variables	Mean probe reaction time (ms)				Mean error rate (%)			
	<i>df</i>	<i>MSE</i>	<i>F</i>	η_p^2	<i>df</i>	<i>MSE</i>	<i>F</i>	η_p^2
Experiment 1								
Distractor relation (D)	1, 44	569	0.8	.02	1, 44	.001	1.5	.03
Target feature relation (T)	1, 44	7,383	70.2**	.62	1, 44	.005	54.5**	.55
Response relation (R)	1, 44	4,265	24.3**	.36	1, 44	.004	35.3	.45
D \times T	1, 44	573	13.9**	.24	1, 44	.001	23.2**	.35
D \times R	1, 44	596	4.7*	.10	1, 44	.001	2.9	.06
T \times R	1, 44	7,783	156.5**	.78	1, 44	.008	89.4**	.67
D \times T \times R	1, 44	794	2.3	.05	1, 44	.001	3.6	.07
Experiment 2								
D	1, 49	2,855	0.1	.00	1, 49	.000	0.0	.00
T	1, 49	22,159	31.1**	.39	1, 49	.001	40.7**	.45
D \times T	1, 49	2,376	7.0*	.13	1, 49	.000	0.6	.01
Experiment 3								
D	1, 44	231	0.1	.00	1, 44	.000	0.0	.00
R	1, 44	508	0.3	.01	1, 44	.000	0.1	.00
D \times R	1, 44	117	14.4**	.25	1, 44	.000	4.0	.08

Note. Analyses were conducted separately (a) for each experiment and (b) for mean probe reaction time (ms) and mean error rates (%). *df* = degrees of freedom; MSE = mean square error.

* $p < .05$. ** $p < .01$.

Received January 18, 2013

Revision received October 14, 2013

Accepted October 16, 2013 ■