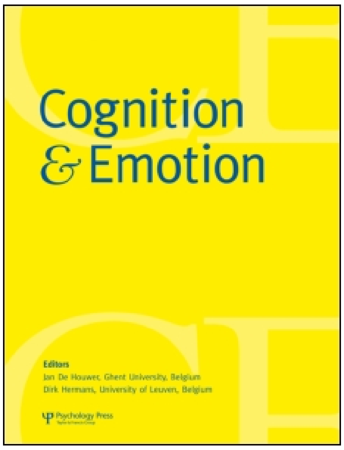

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Affective matching moderates S-R binding

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BRIEF REPORT

Affective matching moderates S–R binding

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We investigated the moderating influence of affective matching on S–R binding processes in a sequential priming study in which positive and negative nouns had to be categorised as referring to a person or to an object. Irrelevant positive and negative distractor words (adjectives) were integrated with responses into S–R episodes if they had the same valence as the target (affective match condition). In this case, repeating the prime distractor in the probe led to a retrieval of the prime response, which facilitated performance for response repetition sequences but had no effect on performance when responses changed between prime and probe. However, if target and distractor had different valences (affective mismatch condition), no interaction of distractor relation and response relation occurred, indicating that distractors were less likely to be associated with responses into event files during the prime trial episode. Findings reveal that affective mismatches are detected automatically and modulate a binding of irrelevant information with responses.

Keywords: Binding; Event files; Episodic retrieval; Affective matching.

One of the fundamental processes that enable our cognitive system to control our actions and behaviour efficiently is the binding of relevant stimulus information and response features into specific episodic memory structures, so called *event files* (Hommel, 1998, 2004). It is assumed that whenever stimulus and response features are (incidentally) activated sufficiently close in time, they are temporarily bound together and may become a unit (Hommel, 1998, 2004). Once the stimulus is encountered again, it may retrieve the previously executed response (Logan, 1988). If the same response is required again, performance is facilitated; however, if a different response is required, performance is impaired due to interference (Hommel, 1998).

Recent findings using variants of the *negative priming* (NP) paradigm suggest that irrelevant information (i.e., a distractor) can also become integrated into an event file together with the response. Subsequently, a distractor may thus also serve as a retrieval cue for a previous stimulus–response (S–R) episode (Rothermund, Wentura, & De Houwer, 2005; see also Frings,

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Rothermund, & Wentura, 2007; Mayr & Buchner, 2006; Mayr, Buchner, & Dentale, 2009). NP studies employ two sequentially presented displays, referred to as *prime* and *probe*, both of which contain a to-be-attended target stimulus and a to-be-ignored distractor stimulus. Assuming that the prime distractor is integrated in an event file of the prime episode implies that it becomes associated with the prime response. Repeating the prime distractor in the probe display then leads to an automatic retrieval of the prime response that facilitates responding if the prime response is also appropriate for the probe trial (positive priming for response repetition sequences). Distractor repetitions delay responding, however, if the prime response is inappropriate in the probe trial (negative priming due to response interference for response alternation sequences). This pattern of findings has been obtained in a number of studies. Importantly, effects of an automatic retrieval of the prime response were found if the prime distractor was repeated as a target stimulus in the probe (*ignored repetition condition*; Mayr & Buchner, 2006; Mayr et al., 2009) but also if the prime distractor was repeated as an irrelevant distractor stimulus in the probe again, revealing even more subtle evidence for the automatic retrieval of distractor–response associations (*distractor-to-distractor repetition condition*; Frings et al., 2007; Rothermund et al., 2005).

Apart from this accumulating evidence that even irrelevant stimuli may become integrated with response information into event files, there is hardly any knowledge on the boundaries of distractor integration. We would argue that binding processes by default tend to integrate all kind of stimulus information that occurs simultaneously within a certain spatial area into a perceptual unit. This binding process typically does not differentiate between relevant and irrelevant information, which is why even irrelevant distractor information is integrated with response information into event files. There can be situations, however, in which relevant and irrelevant stimuli do not form a perceptual unit, thus preventing an integration of distractors into S–R episodes.

Frings and Rothermund (2009) recently argued that Gestalt principles modulate the binding of distractor and response information. In their study, distractor–response bindings were weaker if the distractor and the target were presented as being part of two distinct perceptual objects. For instance, presenting target and distractor letters in a horizontal row creates the impression of one perceptual object (i.e., a letter string), whereas presenting the same letters in a vertical arrangement does not. Across several experiments, effects of S–R bindings between distractors and responses were consistently found for conditions in which target and distractor letters formed a single perceptual Gestalt, but were reduced for presentation conditions in which targets and distractors were perceived as separate perceptual objects. These findings suggest that an integration of distractors into event files is less likely if perceptual features indicate a separation of relevant and irrelevant information into different objects.

In the present study, we wanted to extend the investigation of what determines the integration of distractor stimuli into S–R episodes from perceptual properties to semantic features. Our basic hypothesis was that an affective match or mismatch between distractor and target stimuli is crucial for the incorporation of a distractor in the resulting S–R episode. We argue that an affective match between distractor and target fosters an integration of the two stimuli into a single, coherent cognitive representation. A distractor that is opposite in valence to the respective target stimulus, however, should be perceived as a separate object, which should counteract a binding of distractor, target, and response information in a common S–R episode.

Our proposal of a modulation of distractor–response bindings by affective matching rests on previous research in the domain of affective processing. A vast body of evidence has been accumulated demonstrating that the valence of objects and stimuli is processed automatically (Fazio, 2001). Of particular relevance for our hypothesis is the finding that the affective consistency of two stimuli that are presented together is automatically computed, regardless of the perceiver's current goals or task (Klauer & Musch, 2002; Klauer & Stern, 1992; Wentura, 2000). Affectively mismatching pairs of stimuli are automatically perceived as not fitting together, giving rise to feelings of falsity and implausibility. On the basis of these findings, we propose that affectively mismatching distractors and targets cannot easily be integrated into a single cognitive representation due to a code mismatch on the fundamental feature of valence. By implication, affectively mismatching distractors and targets should be represented as two distinct objects, thus preventing an integration of distractor and response information.

The affective matching of distractors and targets should have immediate implications for the pattern of distractor repetition effects in a sequential priming paradigm. In the case of affectively matching distractors and targets, the distractor is more easily integrated as part of the prime episode, and an automatic retrieval of the prime response during the probe becomes more likely, provided the distractor is repeated in the probe. Performance should then be facilitated if responses are identical in prime and probe, whereas performance should be impeded if responses are different in prime and probe (Frings et al., 2007; Rothermund et al., 2005). However, in the case of an affective mismatch between prime distractor and prime target, the prime distractor is less likely to be integrated into an S–R episode and a repetition of the prime distractor in the probe cannot cue the retrieval of the prime episode.

In order to investigate the effect of affective congruency on distractor–response bindings, a distractor-to-distractor repetition paradigm was employed. The advantage of this paradigm is that response repetitions and distractor repetitions can be varied orthogonally without switching tasks and without a confounding of these factors with response compatibilities in the prime or probe.[1] In each trial of the experiment, a noun and an adjective were presented. Participants had to classify the nouns as either persons or objects by pressing a right or left key, respectively. Independently of the classification task, the valence of targets and distractors was varied as well as the relation of distractors and responses across prime–probe-sequences (i.e., they could either repeat or change).

METHOD

Participants

In total, 100 students of the Friedrich Schiller University of Jena took part in the experiment.[2] Two participants had to be excluded from all analyses because of excessive error rates (> 20%). Thus, data of 98 (71 female, 27 male) participants were analysed. Participants' mean age was 22.4 years ($SD = 3.2$). They were tested individually and received 2 Euros and a bar of chocolate for their participation. Experimental sessions lasted approximately 30 minutes.

Design

The core design comprised three experimental within-subject factors: Prime valence congruency, distractor relation, and response relation (see Table 1 for samples of prime–probe sequences). Prime valence congruency was manipulated by presenting prime targets and distractors that either had the same valence (e.g., both positive) or had different valences (e.g., positive target/negative distractor). Second, distractor relation was

[1] Focusing on the effect of distractor-to-distractor repetitions and their interaction with response relation rules out alternative explanations that have been advanced for negative priming paradigms. For example, an interaction of distractor-to-distractor repetitions with response relation cannot be explained on the basis of an inhibition of the prime distractor (Tipper, 1985), nor would such a pattern be predicted by an episodic retrieval of "do not respond" tags (Neill, Valdes, Terry, & Gorfein, 1992) or by a feature mismatch between prime and probe (Park & Kanwisher, 1994).

[2] The data reported here were collapsed across two independent replications of the same experiment. Since all aspects of the results were identical in both experiments (in particular, the crucial three-way interaction was significant in both experiments), we decided to report the data as a single study.

Table 1. *Sample stimuli of prime–probe sequences for "person" responses to positive probe targets. Means and standard deviations of reaction times (ms) and error rates in the probe*

			% error		Sample sequences	
Condition		*RT*	*M (SD)*	*M (SD)*	*Prime*	*Probe*
Same prime valence	RR	D-ID	606 (96)	2.3 (3.6)	hero–honest	friend–honest
		D-SC	634 (111)	3.8 (5.0)	hero–honest	friend–gifted
		D-DC	634 (114)	3.5 (4.4)	hero–honest	friend–vicious
	RC	D-ID	632 (114)	3.6 (4.4)	flower–honest	friend–honest
		D-SC	630 (111)	2.9 (4.5)	flower–honest	friend–gifted
		D-DC	633 (122)	2.5 (3.9)	flower–honest	friend–vicious
Different prime valence	RR	D-ID	618 (111)	2.8 (4.3)	hero–vicious	friend–vicious
		D-SC	631 (113)	3.8 (4.3)	hero–vicious	friend–brutal
		D-DC	627 (111)	3.5 (4.1)	hero–vicious	friend–honest
	RC	D-ID	624 (107)	4.1 (4.4)	flower–vicious	friend–vicious
		D-SC	635 (110)	2.5 (3.3)	flower–vicious	friend–brutal
		D-DC	631 (110)	2.8 (4.2)	flower–vicious	friend–honest

Notes: RT = reaction times; RR = response repetition; RC = response change; D-ID = identical distractor repetition; D-SC = probe distractor from same valence category as prime distractor; D-DC = probe distractor from different valence category as prime distractor.

manipulated by presenting the identical distractor in the prime and in the probe trial or by presenting two different distractors that either shared the same valence (e.g., both prime and probe distractors were positive) or had different valences (e.g., positive prime distractor/negative probe distractor). The comparison of identical distractor repetitions and sequences in which different distractors of the same valence were presented is crucial for the analysis of distractor repetition effects because it is not confounded with valence repetition effects. The different valence condition was added to guarantee that the probe distractor valence cannot be predicted on the basis of the prime distractor valence; however, this condition did not enter into the analyses.[3] Third, response relation was manipulated: Responses could either repeat between prime and probe (e.g., both prime and probe displays require a *person* response) or change (e.g., prime response *person*, probe response *object*). Several additional factors were varied orthogonally to the previously mentioned factors for counterbalancing purposes: One factor controlled for target valence across prime and probe, which could either be the same or different. This factor was added to ascertain that the probe target valence could not be predicted on the basis of the prime target valence. Two other factors, namely probe target valence and probe target response were also counterbalanced within participants. In addition, the position of the target (above or below the distractor) in the prime and probe display was randomly determined for each trial. The latter factors were not incorporated into the analyses because they were not of theoretical interest and did not interact with the factors of interest.

Materials

Six nouns (three person nouns, three object nouns) and six adjectives were selected for each valence category. All words were either mono- or disyllabic, ranging between four and ten letters. A pilot study ($n = 10$) using a scale ranging from -10 (*extremely negative*) to $+10$ (*extremely positive*) confirmed that the four groups of words had clearly positive and negative valences of similar extremity

[3] Using the different valence condition as a baseline leads to a confounding of specific stimulus–response binding effects with a valence change from prime to probe. However, using sequences of different valence distractors as baseline yields virtually identical results (see Table 1). In particular, the three-way interaction was significant in this analysis as well, $F(1, 97) = 7.20$, $p < .01$, $\eta_p^2 = .07$.

(negative nouns: $M = -7.26$, $SD = 0.94$; negative adjectives: $M = -7.10$, $SD = 1.67$; positive nouns: $M = +7.08$, $SD = 0.98$; positive adjectives: $M = +7.57$, $SD = 0.78$). Throughout the experiment, target and distractor words were presented in uppercase letters in a white font on a black computer screen.

Procedure

Participants were tested individually. Instructions were given on the screen. Participants were informed that in each trial, two words (a noun and an adjective) would be presented on the screen one below the other. Participants had to classify the nouns as referring either to a person or to an object by pressing two corresponding keys, which were labelled accordingly, on a response pad. Participants were instructed to keep their left and right index fingers above the response keys throughout the experiment. A third key, labelled with "space", served to start each sequence of two trials via thumb press. Participants were reminded to respond as quickly and accurately as possible. Each participant performed a block of 15 practice trials first, followed by 288 experimental prime–probe sequences. Practice trials paralleled the experimental trials except that different adjectives and nouns were used. Additionally, participants also received feedback regarding the correctness of their performance after each prime–probe sequence during the practice trials. The experiment started if at least 80% of the responses in the practice trials were correct, otherwise, the practice block had to be repeated.

Each experimental prime–probe sequence was as follows (see Figure 1): A fixation cross (+) appeared at the centre of the screen until participants pressed the "space" key to start the prime–probe sequence. After 750 ms, both prime target and prime distractor were displayed simultaneously and closely above and beneath the screen centre. Stimuli remained on the screen until participants pressed either the "person" or "object" response key. The screen was then cleared for 250 ms. Subsequently, probe target and probe

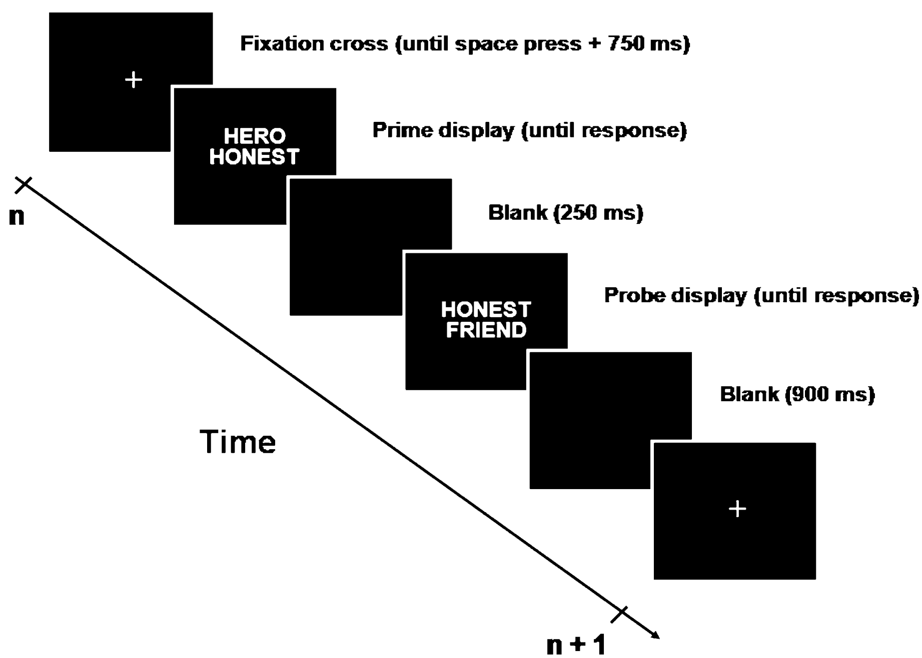

Figure 1. *Schematic display of the trial structure in this study. For both prime and probe display, participants were instructed to classify nouns as either "person" or "object", giving their response via key press (right or left, respectively).*

distractor were presented at the same positions on the screen and remained there until participants pressed one of the two response keys. Then the screen was cleared again. After an inter-trial interval of 900 ms, the fixation cross for the next trial sequence appeared. Approximately halfway through the experiment, participants were given a short break and could continue the experiment by pressing the "space" key. At the end of the experiment, participants were asked whether they had used any strategies during the task. Finally, participants were thanked, debriefed, and rewarded accordingly.

RESULTS

For all analyses, a significance level of $\alpha = .05$, two-tailed, was maintained. Because only prime–probe sequences with correct responses in the prime and probe trials were considered, 5.7% of all trials were excluded from the RT analyses. Furthermore, limits for outlier values were computed individually for each participant: Reaction times in the probe that were below 250 ms or more than 1.5 inter-quartile ranges above the third quartile of the individual distribution of probe RTs (4.1%; Tukey, 1977) were discarded from analyses.

Average probe RTs were computed for every condition of the factorial design and separately for each participant (see Table 1). These means were then entered into a $2 \times 2 \times 2$ analysis of variance (ANOVA) with the within-subject factors Prime Valence Congruency (congruent vs. incongruent), Distractor Relation (identical repetition vs. same valence), and Response Relation (repetition vs. alternation).[4] The analysis revealed a main effect of Distractor Relation, $F(1, 97) = 24.85$, $p < .001$, $\eta_p^2 = .20$, indicating generally faster responses if the identical distractor was repeated in the probe trial. Also, the main effect of Response Relation was significant, $F(1, 97) = 4.23$, $p < .05$, $\eta_p^2 = .04$, signalling faster responses for prime–probe sequences with response repetition. The main effects were qualified by an interaction between Distractor Relation and Response Relation, $F(1, 97) = 12.71$, $p < .001$, $\eta_p^2 = .11$. Repetition of the prime distractor in the probe led to faster performance for response repetition sequences but not for sequences with response alternations. Most central to the prediction, a three-way interaction between Prime Valence Congruency, Distractor Relation, and Response Relation emerged, $F(1, 97) = 11.25$, $p < .001$, $\eta_p^2 = .10$, indicating that prime valence congruency had a moderating influence on the interaction between distractor relation and response relation. All other effects failed to reach conventional levels of significance (all Fs < 1.2). To follow up on the significant three-way interaction, two separate 2 (Distractor Relation: identical repetition vs. same valence) $\times$ 2 (Response Relation: repetition vs. alternation) ANOVAs with repeated measures were conducted for each of the two levels of the prime valence congruency factor. For trials with affectively matching prime targets and prime distractors, the interaction of Distractor Relation and Response Relation was highly significant, $F(1, 97) = 21.04$, $p < .001$, $\eta_p^2 = .17$. Distractor repetitions facilitated performance if the prime response was also repeated in the probe, $t(97) = 5.72$, $p < .001$, but had no significant influence on response alternation sequences, $t(97) = -0.56$, *ns*.[5] For sequences with affectively mismatching distractors and targets in the prime, however, the interaction of Distractor Relation and Response

[4] The same $2 \times 2 \times 2$ repeated-measurement ANOVA on mean prime RTs yielded no significant effects (all Fs < 1.6). However, for mean error rates of the prime trials, a main effect of prime valence congruency emerged, $F(1, 97) = 8.89$, $p < .01$, $\eta_p^2 = .08$, indicating that participants made somewhat more errors in affectively matching prime trials (2.9%) than in affectively mismatching prime trials (2.4%; all other Fs < 2.2).

[5] The asymmetric pattern of distractor repetition effects with significant facilitation for response repetitions and only a slight and non-significant delay for the response alternation sequences is due to the main effect of distractor repetitions. Repeating the prime distractor as a distractor in the probe had a general facilitating effect that can be explained by an enduring inhibition of the distractor (Tipper & Cranston, 1985). Such an inhibition effect is independent from the binding and retrieval of distractor and response information and was not modulated by affective congruency in the prime.

Relation was not significant, $F < 1$, indicating that distractor repetition effects did not differ between response repetition and response alternation sequences.

The same $2 \times 2 \times 2$ repeated-measurement ANOVA on mean error rates yielded only a significant interaction of Distractor Relation and Response Relation, $F(1, 97) = 26.00$, $p < .001$, $\eta_p^2 = .21$ (all other Fs < 1.9). Repeating the prime distractor in the probe led to fewer errors if participants had to repeat the response from the prime trial, $t(97) = 3.81$, $p < .001$. In contrast, distractor repetitions increased error rates in the probe for response alternation sequences, $t(97) = -3.46$, $p < .001$.

DISCUSSION

Consistent with our prediction, the binding and retrieval of distractors and responses was modulated by affective congruency: If prime target and prime distractor had the same valence, repeating the prime distractor as a distractor in the probe facilitated responding for response repetition sequences but had no effect on sequences with response changes. This interaction of distractor repetition effects with response relation attests to an association of the distractor with the response in the prime and to an automatic retrieval of this S–R episode if the distractor stimulus is repeated in the following probe trial (Frings et al., 2007; Rothermund et al., 2005). Besides providing a baseline for the affective mismatch condition, the finding of an integration of affectively congruent distractor words into S–R episodes is noteworthy on its own, because it provides the first demonstration of S–R binding and retrieval effects in a stimulus situation in which two words were presented as target and distractor.[6]

In contrast, no interaction of distractor relation and response relation emerged for sequences with affectively mismatching target–distractor pairings in the prime. This null finding cannot be attributed to low power because due to the large sample size of our study, even small effects could be detected with sufficient power (a power of $1 - \beta \geq .80$ was reached for effect strengths of $d \geq 0.25$; post hoc power calculations were conducted with G*Power 3; Faul, Erdfelder, Lang, & Buchner, 2007). The absence of a distractor–response binding in this condition indicates that affective incongruency prevents an integration of distractor and target information into a single event file. Apparently, detecting an affective mismatch between two stimuli counteracts binding processes and leads to the creation of separate object files for the distractor and target stimuli.

The present study did not contain a neutral baseline condition and thus does not allow a definitive decision on whether affective matching promotes binding, or whether affective mismatches reduce binding of distractor and response information. Given that previous studies provided clear evidence for distractor–response integration for neutral distractor (and target) stimuli (Frings et al., 2007; Mayr & Buchner, 2006; Mayr et al., 2009; Rothermund et al., 2005), it seems likely that a binding of distractors into S–R episodes is a default process that is weakened by the detection of affective mismatches between distractors and targets.

It has to be noted that although the interaction of response relation and distractor relation was eliminated in the affective mismatch condition in the RT analysis, we found no comparable modulation of distractor–response bindings by affective congruency in the error data. Noticing this discrepancy between RT and error data in a first study led us to conduct an independent replication of the same experiment (see Footnote 2). With respect to RTs, we consistently observed a significant three-way interaction across both replications. Crucially, distractor–response binding

[6] Given the results reported by Frings and Rothermund (2009), it might appear surprising that two words become integrated as a perceptual unit at all. It has to be noted, however, that Frings and Rothermund (2009) reported evidence for a reduction rather than an elimination of S–R bindings. Another crucial difference between the two studies is that target and distractor stimuli were presented in different colours in the study by Frings and Rothermund (2009), which might allow for an easy perceptual separation.

effects were far from being significant within the affective mismatching condition in both replications (both Fs < 1). For the error data, the pattern is somewhat mixed. The clearly significant interaction of distractor repetition effects with response relation that we found in the affective mismatch condition in our first study was no longer significant in the replication experiment, although we still found a tendency of such an effect ($p < .10$). This might indicate that the evidence for distractor–response bindings in the affective mismatch condition that emerged in the error data might not constitute a robust phenomenon.

Since the overall data pattern clearly differs between RTs and errors, however, we should also consider the possibility that response speed and response accuracy might be influenced by different underlying mechanisms. Specifically, the interaction of distractor repetition and response relation that emerged for the error data can be explained with a general response strategy that has been called the "bypass rule" (Fletcher & Rabbitt, 1978). In binary decision tasks, participants tend to respond with the same response as in the previous trial if some stimulus element of the preceding trial is repeated in the current trial, whereas they tend to switch responses if the stimuli of the current trial are clearly different from the preceding trial. Applying the bypass rule results in more errors in response change sequences if some salient stimulus element of the previous trial is repeated in the current trial (i.e., in the case of distractor repetitions) because participants then tend to give the same response as before (which produces an error in a response change sequence). In the case of a response repetition sequence, however, repeating the distractor should result in fewer errors compared to a condition without stimulus repetitions, because in the latter condition there is a tendency to give the opposite response (producing an error in a response repetition sequence).

The pattern of results that we observed for the error data can thus be fully explained with the "bypass rule". Importantly, applying the bypass rule does not involve a retrieval of specific S–R associations and therefore does not require an integration of distractor stimuli and responses into event files. All that is needed is a quick check on whether the current display is similar to or different from the previous one, and to give either the same or the opposite response as before accordingly. Affective matches or mismatches between target and distractor should not modulate this response tendency.

The pattern of results that we found for the RT data, however, cannot be explained on the basis of a simple bypass rule. Because the interaction of distractor repetition effects and response relation obtained only for affectively matching prime trials in the RT data, the effect must be mediated by a process that is affected by the affective congruency of targets and distractors. According to our hypothesis, an integration of distractors into event files should depend on the perceived match or mismatch between distractors and targets, and should be confined to situations in which no affective mismatch is detected.

Our findings also bear some more general implications for the concept of feature binding, because they illustrate that feature integration is not a fully automatic process (Hommel, 2004), but is prone to modulating influences. Our findings suggest that ambivalent objects or stimulus features may constitute an interesting case.[7] A perceptual integration of objects containing positive as well as negative features might be more difficult due to a salient feature mismatch. Similarly, S–R bindings might be generally less likely to occur for ambivalent objects, because they oppose against integration.

Summing up, the present findings provide insight into the boundaries of distractor integration. Recent experiments by Frings and Rothermund (2009) revealed that perceptual cues emphasising that target and distractor stimuli

[7] We want to thank an anonymous reviewer for directing our attention to ambivalent objects.

belong to different objects can undermine an integration of distractors into S–R episodes. Extending these findings to the semantic domain, the results of the present study support the notion that affective mismatches between distractors and targets can also prevent distractors from becoming integrated into an event file. Based on the findings reported by Klauer and Musch (2002), however, it seems likely that valence occupies a unique role in the semantic domain in that it is the only semantic dimension that is processed and compared automatically. Further research is necessary to determine whether similar influences of match–mismatch relations on binding also emerge for other semantic dimensions.

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