

Short article

No evidence for a cue mismatch in negative priming

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An experiment is reported in which the cue mismatch hypothesis of negative priming, an important novel variant of the mismatching hypothesis, was tested. A cue mismatch and a no mismatch condition were contrasted in a visual discrimination task. In the prime display of cue mismatch ignored-repetition trials, the colour of the prime distractor was different from the colour of the cue indicating the selection feature (coloured square). In probe displays, cue and repeated stimulus had the same colour. In the no mismatch condition, the visual cue was neutral in terms of colour (always black), so that there was always no cue mismatch between prime and probe displays. Contrary to the prediction of the cue mismatch hypothesis, the negative priming effect was not larger in the cue mismatch than in the no mismatch condition. The cue mismatch hypothesis must therefore be rejected. In contrast, the episodic retrieval account is consistent with the results.

Keywords: Negative priming; Cue mismatch; Feature mismatch; Auditory selective attention.

The negative priming effect denotes slowed-down responses to a stimulus that had to be ignored in a previous prime display compared with responses to a stimulus that did not occur in the previous prime display. According to the distractor inhibition account (Tipper, 1985) this effect is caused by an inhibition of distracting information during the prime. Inhibition is assumed to persist so that the reacting to the inhibited item is subsequently hampered. The episodic retrieval account (Neill & Valdes, 1992; Neill, Valdes, Terry, & Gorfein, 1992) assumes that in ignored repetition trials

the probe target serves as a retrieval cue to the recent prime episode. Among other things, this prime episode contains “do-not-respond” information associated with the prime distractor, conflicting with the probe trial requirement to respond to the same stimulus, which is now the target. Resolving this conflict takes time.

Park and Kanwisher (1994) suggested an alternative explanation. In their view the negative priming effect resulted from a mismatch in the representation of the repeated object between the prime and probe displays. Using a spatial selection

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task they asked participants to indicate at which of four marked positions a target symbol (o) occurred while ignoring a distractor symbol (+) at another location. In ignored repetition trials the probe target appeared at the location of the prime distractor. In control trials the probe target appeared in a previously unoccupied position. Park and Kanwisher argued that slower reactions in ignored repetition than in control trials were caused by a symbol location–identity mismatch between prime and probe displays because the probe target (o) differed from the item that occupied the same position in the prime display (+) in ignored repetition trials. No negative priming was observed when the prime distractor had the same identity as the probe target (prime: “respond to the location of the +, ignore the o”; probe: “respond to the location of the o, ignore the +”) and both “o”s appeared at the same location. This is consistent with the feature mismatch hypothesis because there was no prime-to-probe symbol change at the probe target location.

Location–identity mismatches in spatial priming tasks are equivalent to other mismatches in identity priming tasks in which participants respond to the identity (and not the location) of a target stimulus. For example, there can be colour–identity mismatches in a visual identity priming task in which participants use the colour as a selection cue (e.g., the blue object in an array of a blue and a red object) to respond to the identity of a target (e.g., classify it as an object from one of two categories). A colour–identity mismatch takes place when the colour of the repeated object in an ignored repetition trial changes between prime and probe. This is usually the case when the selection colour stays the same throughout prime and probe trials (e.g., “name the red object, ignore the blue object”). Then, the repeated object is blue in the prime but red in the probe. Following the feature mismatch hypothesis this mismatch in colour–identity combination results in confusion.

Whereas feature mismatch probably does play a role in spatial negative priming tasks (Park & Kanwisher, 1994; but for exceptions, see Milliken, Tipper, & Weaver, 1994; Tipper, Weaver, & Milliken, 1995), available evidence until recently suggested that this is not true for identity priming tasks. For instance, Tipper and Cranston (1985, Exp. 4) changed the target selection criterion between prime and probe displays (name the red letter in the prime, name the green letter in the probe), thereby avoiding a colour–identity mismatch between prime and probe displays. Negative priming was nevertheless found, which would not be expected if only feature mismatch caused negative priming. In contrast, this finding can be explained by both distractor inhibition and episodic retrieval. This basic finding has been replicated many times using different tasks and both visual and auditory stimuli¹ (Buchner & Mayr, 2004, Exp. 2; Buchner, Zabal, & Mayr, 2003; Mayr & Buchner, 2006; Mayr, Niedeggen, Buchner, & Orgs, 2006; Mayr, Niedeggen, Buchner, & Pietrowsky, 2003). What is more, we know from studies with feature match and mismatch manipulations within a single experiment (Buchner & Mayr, 2004; Buchner & Steffens, 2001; Mondor, Leboe, & Leboe, 2005) that the size of the negative priming effect is indeed independent of this manipulation. We may thus conclude that feature mismatch is irrelevant for identity negative priming (but see Leboe, Mondor, & Leboe, 2006; MacLeod, Chiappe, & Fox, 2002, for exceptions).

Recently, however, MacDonald and Joordens (2000) extended the concept of a “mismatch”. First, mismatches were no longer restricted to the level of perceptual features (such as location–identity, colour–identity mismatches) but they were also considered possible at the level of semantic features. Second, mismatches at the dimension of the selection criterion were thought to be critical for negative priming. For example, if selection is based on a perceptual feature such as colour, a colour–identity mismatch should cause negative

¹ In auditory identity priming tasks target and distractor sounds are usually presented dichotically to the left and right ear, respectively. The target is signalled by a location cue. A location–identity mismatch takes place when the repeated stimulus appears on one side as the prime distractor but on the other side as the probe target.

priming. If selection is based on a semantic feature (e.g., “select the larger of two depicted animals”), a mismatch in semantic features should lead to negative priming. Note that Park and Kanwisher (1994, p. 618, Footnote 6) already touched on the idea of an extended mismatch definition by stating that it was not clear whether “the matching or mismatching of exact shapes, symbol identities abstracted across letter case, or more abstract response categories” was the critical factor.

Most important for the present purposes is that MacDonald and Joordens’s (2000) redefinition of the “mismatch” concept can be extended even further. This extension, if valid, would pose serious problems for the interpretation of many past negative priming experiments, including a number of experiments from our laboratory. Using the above-mentioned experiments from our laboratory as examples, all of them may have included a mismatch at the dimension of the selection criterion, which has been overlooked to date. Specifically, we always assumed that the relevant selection criterion in visual identity priming tasks was an object feature such as the colour (blue vs. red) of the to-be-attended stimulus. For example, we thought that given a red colour cue participants would select the “red object” and that a feature mismatch occurred when this object had just been presented in blue. However, this reasoning ignores that a coloured cue always preceded the prime and the probe displays to indicate the colour of the to-be-attended object. This coloured cue can also be conceived as the relevant selection criterion in a different sense. Specifically, participants may not have selected the “red object” (as intended by the experimenter), but they may have selected “the object of the *same* colour as the preceding cue”, regardless of the colour itself. If this “sameness” in colour of object and cue (rather than colour of the object per se) were the relevant selection feature, then cue mismatches would be inevitable in all ignored repetition trials.

To illustrate, assume that the prime display contains one red object *X* and one blue object *Y*. A red prime cue indicates that the red object *X* must be selected, and the blue object *Y* must be ignored. Next, a blue cue indicates that in the

subsequent probe trial the blue object *Y* must be attended whereas the red object *Z* must be ignored. In this ignored repetition trial, the blue prime distractor *Y* becomes the blue probe target *Y*. Hence there is no feature–identity mismatch in the sense of Park and Kanwisher (1994). Importantly, however, there may have been a mismatch in a different sense. Consider that in the ignored repetition trial just mentioned, the (blue) prime distractor was the object that *differed* in colour from the (red) prime cue, whereas the identical object appearing as probe target had the *same* (blue) colour as the (blue) probe cue. Thus, there is a cue mismatch (the object *Y* *differs* in colour from the cue in the prime, but has the *same* colour as the cue in the probe) in ignored repetition trials even when there is no colour–identity mismatch in terms of Park and Kanwisher (1994). If this novel variant of the mismatch hypothesis were valid, then the negative priming effects in many experiments—for instance, in all experiments mentioned above—could be explained by a cue mismatch (different from cue in the prime—same as cue in the probe).

A valid test of this *cue mismatch hypothesis* requires a comparison of two conditions, one with a cue mismatch and one without. In the present experiment participants received prime–probe pairs of line drawings printed in different colours (blue or red). Participants classified the prime and probe targets as either animals or musical instruments. In the cue mismatch condition, a coloured square indicated the colour of the to-be-attended object. Participants were to select the object that had the same colour as the cue and to ignore the object that differed in colour. They also knew that the prime target always appeared in one particular colour (e.g., blue), and the probe target appeared in the other colour (e.g., red). Two small static squares in the upper half of the screen served as memory aids, indicating the colour of the to-be-attended object in the prime (upper square) and probe displays (lower square). The control condition without a cue mismatch was parallel except that the colour cue was replaced by a black analogue. Therefore, “sameness” in colour of the cue and

the repeated object could not occur on principle. The decision as to which object to select was entirely based on the learned sequence of colours.

For the cue mismatch condition, the prime distractor *differed* in colour from the prime cue, but had the *same* colour as the probe cue when it became the target in the probe display. Therefore, this condition included a cue mismatch if participants indeed used the “sameness” attribute to select the target (select the target that has the *same* colour as the cue). Note that there was no feature mismatch in its original form because the colour of the prime distractor did not change when it became the probe target. In the no mismatch condition, the cue was always black so that no cue mismatch could occur. If cue mismatch played a role in identity negative priming tasks, the negative priming effect should be larger in the cue mismatch than in the no mismatch condition.

Method

Participants

Participants were 184 adults, 116 of whom were female. They ranged in age from 18 to 43 years ($M = 25$). All participants were tested individually and were paid for their participation.

Materials

The stimuli were six line drawings (between 159 and 198 pixels wide and 111 and 198 pixels high), which could be categorized unambiguously as “musical instruments” (piano, guitar, and cornet) or “animals” (hen, lamb, and frog). Of each line drawing, one version was blue, and one was red. The colour (blue or red) indicated the to-be-attended drawing. Participants reacted to the attended drawing by pressing the “instrument” or “animal” response key. The response keys were aligned sagittally on a response box. Participants pressed the distal key with the index finger of their right hand and the proximal key with the index finger of their left hand.

Each experimental trial consisted of a prime and a probe display. Each display consisted of a target object in one colour and a simultaneously presented, superimposed distractor object in the

other colour. The prime and probe displays of the ignored repetition and control trials were constructed to be parallel. First, an ignored repetition trial was constructed by randomly combining prime and probe targets and distractors with two restrictions: The ignored prime had to be identical to the attended probe, and the target and distractor had to be from different categories. Next, a control trial was constructed by replacing the ignored prime with a different stimulus but from the same category. The response category of the ignored prime was thus always the same on an ignored repetition and its corresponding control trial. Furthermore, the probe stimulus pair was identical for an ignored repetition and its respective control trial.

Using all possible combinations of line drawings yields 36 different ignored repetition trials but 72 different control trials. This imbalance is due to the fact that from a set of three category exemplars there are always two possibilities to replace the to-be-ignored prime stimulus in an ignored repetition trial when creating a parallel control trial. Therefore, two sets of stimuli were generated. Control trials that belonged to the same ignored repetition trial were systematically assigned to different sets.

With only ignored repetition and control trials, the required probe response always would have been different from the prime response and thus would have been perfectly predictable. Therefore, filler trials were added in which the required prime and probe responses were the same. Filler trials were created by exchanging, in the control trials, the to-be-attended and the to-be-ignored primes. In order to arrive at an equal probability of a response change versus no response change from prime to probe displays, the filler trials were duplicated.

Overall, there were 36 ignored repetition trials, 36 control trials, and 72 filler trials in each set. Sets were completely parallel with respect to the absolute frequencies of the different drawings within and between trial types and the frequencies of the combinations of attended and ignored drawings, both within the prime and within the probe pairs. Participants were randomly assigned to the sets.

The colour of the attended object always changed between prime and probe displays (blue–red or red–blue). The cueing to the to-be-attended colour was manipulated between participants. For participants assigned to the cue mismatch condition, a 48×48 -pixel colour square was presented 700 ms before the prime and the probe displays. The cue colour (blue or red) indicated the colour of the to-be-attended drawing. The sequence of the to-be-attended colours (blue–red vs. red–blue) stayed constant for the first half of the experiment and was reversed for the second half. The order of these sequences (blue–red, red–blue vs. red–blue, blue–red) was counterbalanced across participants. The instructions also specified which colours would be used consistently for the prime and probe targets. In addition, two small sagittally aligned coloured squares were presented as memory aids in the upper half of the screen that indicated the to-be-attended colour in the prime display (upper square) and the to-be-attended colour in the probe display (lower square). Participants in the no mismatch condition received the same cueing information except for the coloured cue, which was replaced by a black square of the same size that was presented 700 ms before the prime and probe displays. The entire set of 144 experimental stimuli was presented twice, once in the first half and once in the second half of the experiment. Within the halves of the experiment the sequence of trials was random.

Procedure

Participants were familiarized with the six drawings before they were introduced to the set-up of a complete prime–probe trial. All participants knew that the to-be-attended colour would always change between prime and probe display, and they learned that of the two static colour squares the upper and lower squares indicated the to-be-attended colour of the prime and probe display, respectively.

Participants then received training trials composed of randomly selected experimental trials from the first half of the experiment. The

experiment began only after participants had responded correctly in 70% of the past 15 trials of at most 50 trials.

Each of the 144 experimental trials in the first half of the experiment began with the presentation of the centrally located prime cue for 200 ms, followed by a 500-ms cue–target interval and the prime pair of drawings, which disappeared when the participant responded. After a 1,000-ms blank interval, the probe cue was presented for 200 ms, followed by a 500-ms cue–target interval, after which the probe pair of drawings was presented until the participant's response. Next, participants received feedback about the correctness of their responses.

After the first half of the experiment, participants learned that the sequence of the to-be-attended prime and probe colours would be reversed, from blue–red to red–blue, or vice versa. After 10 training trials, participants completed the 144 trials of the second half of the experiment.

Prime or probe reactions faster than 100 ms and slower than 3,000 ms were counted as invalid, and the entire trial was repeated after a brief warning. After every 12th trial, participants received a summary feedback about their error percentage and average reaction time, but correctness was emphasized. After the final trial, all participants were informed about the purpose of the experiment.

Design

The data were collapsed over the *sequence* variable (blue–red vs. red–blue) because this manipulation was irrelevant to the hypothesis at stake (and did not influence the results in any way). The experiment comprised a 2×2 design with *trial type* (ignored repetition vs. control) as within-subject variable and *cue mismatch* (mismatch vs. no mismatch) as between-subjects variable. The primary dependent variable was participants' average reaction time, but error rates were also analysed.

The difference of the negative priming effect (ignored repetition – control) between the cue mismatch and the no mismatch condition was relevant for our a priori power considerations. In order to detect effects as small as “small”

(as defined by Cohen, 1988)—that is, of size $f = 0.10$, given a population correlation of $\rho = .7$ between the reaction time variables ignored repetition and control, and desired levels of $\alpha = \beta = .05$ —data had to be collected from a sample of at least $N = 198$ participants (Faul, Erdfelder, Lang, & Buchner, 2007). We were able to collect data from $N = 184$ participants so that the power was slightly smaller at $1 - \beta = .94$. The level of alpha was maintained at .05 for all statistical decisions.

Results

Probe reactions were evaluated only for trials in which both the prime and the probe reactions were correct. Figure 1 (upper panel) shows that the mean reaction times were higher in the no mismatch than in the cue mismatch condition. The same was true for the ignored repetition condition compared to the control condition. Most interestingly and contrary to what the cue mismatch hypothesis predicts, the negative priming effect was descriptively even larger in the no mismatch than in the cue mismatch condition.

A 2×2 multivariate analysis of variance (MANOVA) of the reaction time data with trial type (ignored repetition vs. control) as within-subject variable and cue mismatch as between-subjects variable (mismatch vs. no mismatch) showed a significant main effect of trial type, $F(1, 182) = 50.32$, $p < .01$, $\eta^2 = .22$, and of cue mismatch, $F(1, 182) = 10.27$, $p < .01$, $\eta^2 = .05$. The interaction between trial type and cue mismatch missed the preset level of statistical significance, $F(1, 182) = 3.25$, $p = .07$, $\eta^2 = .02$. Negative priming was significant at both levels of the cue mismatch variable, as is shown by follow-up tests using the Bonferroni–Holm method of protecting against α -error accumulation, $t(91) = 4.08$, $p < .01$, $\eta^2 = .16$ for the cue mismatch condition, and $t(91) = 5.84$, $p < .01$, $\eta^2 = .27$ for the no mismatch condition. In order to take into account the generally slower response time level in no mismatch trials than in cue mismatch trials, we also computed proportional slowing in the ignored repetition condition relative to control. In the cue mismatch

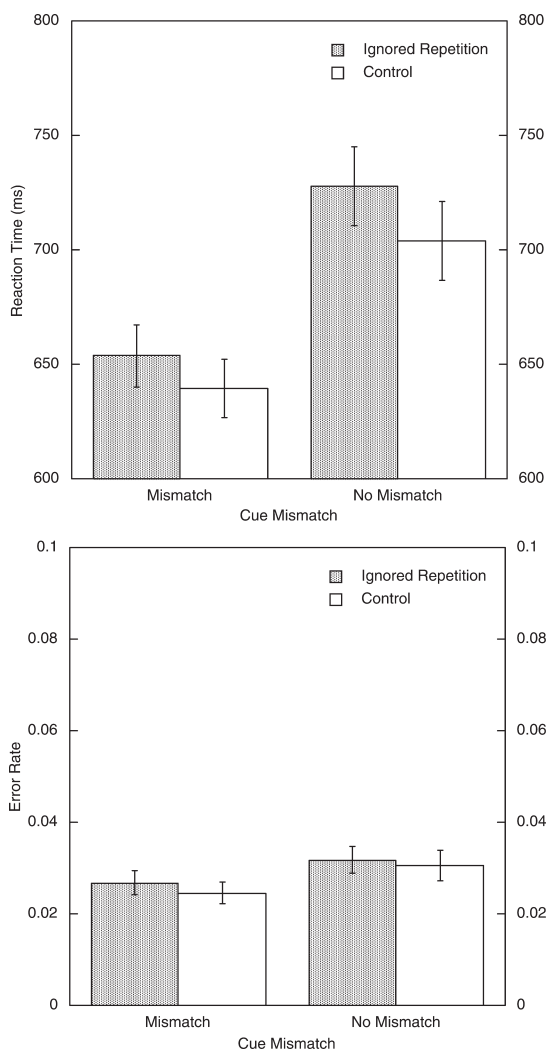


Figure 1. Reaction times (upper panel) and error rates (lower panel) as a function of cue mismatch and trial type. The error bars depict the standard errors of the means.

condition responses were slower by a factor of 1.022 in the ignored repetition than in the control condition whereas the slow-down factor was 1.037 in the no mismatch condition. The slow-down was significantly smaller in the cue mismatch than in the no mismatch condition, $t(182) = 2.04$, $p = .04$, $\eta^2 = .02$.

An analogous analysis of the error data (lower panel of Figure 1) showed no significant main

effects of trial type, $F(1, 182) = 0.72$, $p = .40$, $\eta^2 < .01$, and cue mismatch, $F(1, 182) = 2.56$, $p = .11$, $\eta^2 = .01$, and no interaction between these variables, $F(1, 182) = 0.06$, $p = .80$, $\eta^2 < .01$.

Discussion

We tested a novel variant of the mismatch hypothesis of negative priming: the cue mismatch hypothesis. The possibility that cue mismatches (the repeated object in ignored repetition trials *differs* in colour from the cue in the prime, but has the *same* colour as the cue in the probe) have an influence on the size of the negative priming effect in identity priming tasks has not yet been considered. If cue mismatches played a role in identity negative priming, the negative priming effect should have been larger in the cue mismatch than in the no mismatch condition. This was not observed. In fact, the negative priming effect was even smaller in the cue mismatch than in the no mismatch condition. Thus, we can exclude cue mismatch as cause of the negative priming effect, at least in the type of negative priming task used here.

An important assumption in the present experiment is that participants in the cue mismatch condition really processed the selection cue; if they did not (for instance, because they solely relied on remembering the correct prime and probe target colours), then the lack of a larger negative priming effect in the cue mismatch condition could not be interpreted as evidence against the cue mismatch hypothesis. Fortunately, the present experiment allows us to conclude that the selection cue was used. Response times were significantly faster (about 60 ms) in the cue mismatch than in the no mismatch condition, which means that participants benefited from the additional colour information and, hence, must have processed the selection cues.

The fact that the negative priming effect was smaller in the cue mismatch than in the no mismatch condition is at odds with the cue mismatch hypothesis but is entirely consistent with the episodic retrieval account. According to this account the size of the negative priming effect depends on successful retrieval of the prime episode.

Successful episodic retrieval is facilitated by the contextual similarity between prime and probe (see Mayr & Buchner, 2007). The colour change of the prime and probe cues in the cue mismatch condition reduced the contextual similarity between episodes and, hence, lowered the probability of successful prime episode retrieval so that negative priming should be smaller than in the no mismatch condition in which a black square preceded the prime and the probe and thereby increased the contextual similarity between both episodes. This is what was observed.

In sum, the present experiment shows that cue mismatches do not increase identity negative priming. If anything, these mismatches reduce the contextual similarity and, in turn, the negative priming effect as predicted by the episodic retrieval account. Earlier conclusions that feature mismatch can be excluded from the list of possibly valid accounts of negative priming can be maintained (Buchner & Mayr, 2004; Buchner & Steffens, 2001; Buchner, Steffens, & Berry, 2000; Buchner et al., 2003; Mayr & Buchner, 2006; Mayr et al., 2006; Mayr et al., 2003; Tipper & Cranston, 1985).

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