Feature mismatch effects in auditory negative priming: Interference as dependent on salient aspects of prior episodes

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A handful of studies have revealed that withholding a response to a sound causes impaired responding to that sound when subsequently presented (Buchner & Steffens, 2001; Mondor, Leboe, & Leboe, 2005). In the present study, we investigated whether a switch in the location of a repeated sound might represent an additional source of this auditory negative priming effect. In all three of our experiments, participants performed a series of trials in which they withheld a response to a dichotic pair of *prime* sounds presented to each ear. A dichotic pair of *probe* sounds was then presented to each ear, and the participants were required to categorize one of them. Across these experiments, the participants were slower to categorize only repeated sounds that were presented in opposite locations.

The negative priming effect (Tipper, 1985) occurs when withholding a response to a stimulus impairs responding to an identical or related stimulus in a subsequent display. In the most common procedure used to study this effect in the visual modality, each trial consists of the presentation of a pair of stimuli in two successive displays. The first of these displays is typically referred to as the *prime* event, and the second is usually labeled the *probe* event. At onset of both the prime and the probe events, participants are required to respond to one of the two stimuli presented (the *target*) and to withhold a response to the other (the *distractor*). The critical conditions of this procedure are defined by the relationship between the prime and the probe stimuli. On target repetition trials, participants respond to the same stimulus in both prime and probe displays, whereas the prime distractor becomes the probe target on ignored repetition trials. Performance in both of these conditions is measured relative to performance on baseline trials, in which neither the probe target nor the probe distractor was presented during the prime event. Evidence of a negative priming effect is apparent in this procedure when responses to probe targets are slower and/or less accurate on ignored repetition trials than on baseline trials. This result is also often accompanied by a corresponding *positive priming effect*, reflected in faster and more accurate responses to probe targets on target repetition trials than on baseline trials.

Tipper (1985) provided a famous demonstration of the negative priming effect by presenting the participants with overlapping red and green line drawings in each of a series of displays. The participants' task upon presentation of each pair of line drawings was to identify the red drawing and to ignore the green drawing. For example, the participants might be asked to identify a red piano and to withhold a response to a green violin. As in the procedure described above, each trial consisted of a prime and a probe event that differed in the relationship between prime and probe stimuli. To illustrate, on target repetition trials, the participants might be asked to identify the drawing of a piano in response to both prime and probe events. In contrast, in the ignored repetition condition, the participants might be required to identify a red violin during the probe event after withholding a response to that same picture when it appeared in green during the prime event. On baseline trials, there was no overlap between prime and probe stimuli. For example, after identifying a red piano and ignoring a green violin, the participants might be asked to identify a red kite in the presence of a green dog. Not surprisingly, relative to performance on baseline trials, the participants were faster at identifying probe targets on target repetition trials (e.g., a piano was the target for identification in both displays). This observation replicated a host of prior demonstrations of *positive priming* in which prior exposure to a stimulus was shown to facilitate perception of that stimulus on a subsequent occasion (e.g., Jacoby & Dallas, 1981; Posner & Snyder, 1975). The more novel result was that the participants were slower to identify probe targets on ignored repetition trials than on baseline trials. To differentiate this result from earlier demonstrations of positive priming, Tipper (1985) coined the term *negative priming* to refer to instances of impaired responding to a repeated stimulus.

In the visual domain, the negative priming effect has been observed across a wide variety of tasks, such as

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picture identification (Tipper, 1985; Tipper & Cranston, 1985), word naming (Milliken, Joordens, Merikle, & Seifert, 1998), lexical decision (Yee, 1991), shape matching (DeSchepper & Treisman, 1996), and spatial localization (Tipper, Brehaut, & Driver, 1990). In contrast, there have been relatively few investigations of this effect in the auditory domain. Banks, Roberts, and Ciranni (1995) provided the first demonstration of negative priming with auditory stimuli, reporting slower identification of spoken words that had been previously ignored than for words that had not been presented in a preceding prime event. Similarly, Buchner and Steffens (2001) observed that the participants were especially slow to categorize a probe sound as having been played on a wind or a string instrument when it had been ignored during the prime event. More recently, Mondor, Leboe, and Leboe (2005) observed a negative priming effect when a set of nonverbal, nonmusical auditory stimuli were used.

Overt Prime Selection and Auditory Negative Priming

For present purposes, what is most noteworthy about Mondor et al.'s (2005) findings is their observation of a particularly large negative priming effect when participants were not required to identify a prime target. In their first experiment, the participants identified target sounds presented in both the prime and the probe events. The outcome was that relative to a baseline condition, the participants were slower and less accurate at identifying probe targets that had been presented as the distracting prime sound. In contrast, each prime event in Experiment 2 consisted of a single sound presented in isolation. The participants were instructed not to respond to this sound but to identify the sound presented to their left ear in the probe presentation that followed. This modification effectively eliminated any need for the participants to actively ignore a prime sound. Relative to the magnitude of negative priming observed in Experiment 1 with the more conventional procedure, in Experiment 2 the participants were significantly more impaired at identifying probe sounds that were identical to the prime sound.

Requiring participants to overtly select a prime target is typical of the procedure used to study negative priming in the visual domain. That is, participants are usually required to generate a response to a prime stimulus, while simultaneously ignoring a prime distractor. Indeed, this feature of the conventional negative priming procedure has been central to the development of theoretical accounts of the phenomenon (Milliken et al., 1998). Although some controversy remains over the specific process that gives rise to negative priming, there is a common assumption that the effect is an outcome of selective attention processes operating at the time of the prime display (for reviews, see Fox, 1995; May, Kane, & Hasher, 1995; Tipper, 2001). The essence of this attention-based account of negative priming is that selectively responding to one stimulus is seen as achieved, in part, by selecting against distracting stimuli. To illustrate, in Tipper's (1985) procedure, the participants' task of identifying drawings presented in red

was made somewhat challenging by the presentation of a different drawing in green. Thus, identifying the correct red drawing might partly require allocating attention away from the green distractor. The negative priming effect might, then, be a direct consequence of this prior act of ignoring the prime distractor. Failure to attend to the distracting green drawing might carry over to interfere with identification of that stimulus when it is presented in red during the probe event. Applied more generally, this attention-based account predicts that negative priming should occur to the extent that participants are forced to allocate attention away from a prime stimulus that subsequently becomes the probe target.

Given the findings reported by Mondor et al. (2005), the dominant view that visual negative priming occurs as an outcome of selecting against a prime distractor may not apply to the auditory version of the effect. Instead, their results reveal that eliminating the need for participants to allocate attention away from a prime sound actually enhances negative priming. Thus, it appears that mere exposure to a prime sound can impair future responding to that stimulus. Similar results have also been observed in visual investigations of negative priming (Milliken & Joordens, 1996; Milliken et al., 1998; Milliken, Lupiáñez, Debner, & Abello, 1999; Moore, 1994; Neill & Kahan, 1999; Ortells & Tudela, 1996), raising similar questions about whether an attention-based explanation is adequate to account for negative priming in the visual modality. Still, Mondor et al.'s (2005) results are unique because they demonstrate that overtly selecting against a prime sound can actually *weaken* negative priming for auditory stimuli.

Negative Priming as a Phenomenon of Memory Retrieval

Despite questions about whether traditional assumptions about the role of overt prime selection apply to auditory negative priming, Mondor et al.'s (2005) results are still quite consistent with the growing consensus that a memory retrieval process underlies negative priming effects. This use of memory principles to account for negative priming was pioneered by Neill and his colleagues (Neill, 1997; Neill & Valdes, 1992; Neill, Valdes, Terry, & Gorfein, 1992). Borrowing from Logan's (1998) instance theory of automaticity, this episodic retrieval approach relies on the assumption that performance of any task is driven by the faster of two processes: an automatic episodic retrieval process and a more controlled algorithmic process. On each trial of a negative priming experiment, Neill et al. (1992) assumed that a representation of the prime event is stored in memory and may be retrieved by the onset of the probe event. They further assumed that whether or not a response was made to a prime stimulus can be stored as part of the memory representation of the prime event. That is, the episodic trace for the prime event in memory would contain a representation of both the prime target and the distractor stimulus, with a response tag indicating whether each stimulus was attended or ignored. After a participant withholds a response to a prime

sound, presentation of the same sound as the probe target may cue retrieval of the memory representation for the prime event more quickly than it does the independent generation of a response by the algorithmic process. In turn, retrieval of a prior episode of having not responded to that stimulus would interfere with the present need to generate a response to that item.

As has been indicated above, the dominant view has been that negative priming is the consequence of actively ignoring a prime stimulus that the participants must respond to during the probe event. Thus, in its original form, Neill's (1997) episodic retrieval account focused primarily on how the act of ignoring a prime stimulus might impair subsequent responding. Similarly, the earliest demonstrations of negative priming led some researchers to propose that ignoring a stimulus inhibits abstract mental representations associated with that stimulus (Neill, 1977; Tipper, 1985). By this distractor inhibition account, presentation of a previously ignored item as the probe target leads to impaired performance because this inhibition must be overcome before response selection can occur. This proposal that an inhibitory attentional mechanism lies at the root of negative priming has been the source of much controversy (e.g., May et al., 1995; Milliken et al., 1998). Even among proponents of this view, however, there is acknowledgment that negative priming effects do rely on an episodic retrieval process. From this perspective, although inhibition of a prime distractor is considered an important cause of negative priming effects, the observation of negative priming is thought to depend on retrieval of an episodic representation of that prior inhibitory process at the time of the probe event (Tipper, 2001). Therefore, we consider it appropriate to emphasize the influence of memory retrieval processes in producing negative priming effects, leaving aside concerns about whether or not such effects may be caused by the retrieval of an inhibitory process.

Following Neill's (1997) episodic retrieval approach, our assumption is that the memory representation for the prime event preserves processes engaged in during that experience. Furthermore, we assume that negative priming occurs when the processes stored in a memory representation for the prime event conflict with processes that are necessary for responding to the probe event. Applied to the observation of more pronounced negative priming for a single prime sound, retrieving a representation for not responding to a sound ought to have greater impact when that process is the sole component of the prime episode. This condition holds for Mondor et al.'s (2005) Experiment 2, in which the only demand on the participants was to withhold response to a single prime sound. Conversely, this condition does not hold either for Mondor et al.'s (2005) Experiment 1 or for most previous studies of either visual or auditory negative priming. In those studies, the main requirement of the prime task has been to identify the prime target. At least in the auditory modality, we propose that requiring overt selection of a prime sound serves to minimize the role of withholding a response to the distractor during the prime episode. The consequence is that not responding to the prime distractor

forms a less prominent aspect of the memory representation for that episode. In turn, failure to respond to the prime distractor represents a less potent source of interference when the probe event cues retrieval of that episode from memory. The purpose of the present study was to further investigate the possibility that the occurrence of auditory negative priming depends on the combination of two factors: (1) whether there is a source of incongruence between the prime and the probe events and (2) whether that source of incongruence represents a salient feature of the prime episode.

Feature Mismatch Approaches to Negative Priming

As an alternative to attention-based accounts of negative priming that emphasize the role of ignoring a prime distractor, other theorists suggest that negative priming might occur because perceptual aspects of ignored primes often differ when they are later presented as the probe target (e.g., Park & Kanwisher, 1994). Consider Tipper's (1985) classic demonstration of negative priming for previously ignored line drawings. In this case, the participants were instructed to respond to red line drawings in the presence of green distractor drawings. Thus, on ignored repetition trials, green line drawings not only were ignored, but also were presented in a different color than the probe target. This raises the possibility that negative priming occurred because presentation of a line drawing in red mismatches its prior presentation in green. Since demonstrations of negative priming often involve analogous feature mismatches on ignored repetition trials, it is possible that failure to attend to a prime stimulus is not the central cause of many observations of the phenomenon.

The results of several experiments have shown that this type of mismatching can produce negative priming effects (Lowe, 1985; MacDonald & Joordens, 2000; MacDonald, Joordens, & Seergobin, 1999; MacLeod, Chiappe, & Fox, 2002; Park & Kanwisher, 1994; Milliken, Tipper, & Weaver, 1994). Demonstrations that such mismatches may impair responding to previously *attended* stimuli provide particularly convincing support for this approach. For example, in one study, MacDonald et al. (1999) presented participants with pairs of animal names (*lion*, *elephant*, *turtle*, and *mouse*), requiring the participants to identify the word representing the larger of the two animals in each display. This task made it necessary for the participants to attend to both stimuli in the prime display in order to determine which word was the target. Nevertheless, the requirement to treat a word as referring to a relatively small animal in the prime event produced substantial costs in identifying that same word when the participants were later required to treat it as relatively large. To illustrate, when the words *lion* and *elephant* were paired during a prime display (requiring identification of *elephant*), the participants were much slower at identifying the repeated word, *lion*, when it was paired with the word *turtle* in a probe display. The authors interpreted their results as evidence that negative priming effects can arise from a mismatch in the way the participants perceive the features of a repeated stimulus.

This type of evidence has motivated an explanation of negative priming based on the broader memory principle of transfer-appropriate processing (TAP). This principle, which has a long history in the memory literature (Jacoby, 1983; Kolers & Roediger, 1984; Morris, Bransford & Franks, 1977; Roediger, Weldon, & Challis, 1989; Tulving & Thomson, 1973), refers to the idea that performance on a task is determined by the overlap between current processing requirements and processes engaged in during similar prior experiences. When applied to priming, this principle leads to the expectation that impaired responding to a repeated stimulus will occur whenever processing of a prime display is inconsistent with the requirements of the probe task (Leboe, Whittlesea, & Milliken, 2005; Neill & Mathis, 1998; Wood & Milliken, 1998). The advantage of this perspective is that negative priming effects are not viewed as solely a consequence of ignoring a prime distractor, as was proposed by earlier episodic retrieval and distractor inhibition accounts of the phenomenon. Even when a response to a stimulus is impaired when that stimulus has been ignored during a prime event, such instances of negative priming are merely representative of a broader class of negative transfer effects. In this way, application of the TAP principle to negative priming reflects a broadening of Neill's (1997) original episodic retrieval account to also encompass observations of the effect when it arises from feature mismatching.

One obstacle in applying this broader memory-based account of negative priming, however, is that the evidence does not unequivocally support a role of feature mismatches in generating negative priming effects. A number of studies in the visual domain have revealed that negative priming may occur even when there is no mismatch between successive presentations of a repeated stimulus (Baylis, Tipper, & Houghton, 1997; Milliken et al., 1994; Tipper, Weaver, & Houghton, 1994). More important for present purposes, in the auditory modality, there have been at least two previous failures to confirm that feature mismatching contributes to negative priming. In both of these cases, withholding a response to a prime sound led to the same magnitude of negative priming whether that sound was repeated in the same or a different location.

In Mondor et al.'s (2005) study, the participants were required to categorize probe sounds presented to their left ear. When the participants withheld a response to a single, preceding prime sound (Experiment 2), equal negative priming was observed whether that sound was presented to the left or the right ear. On the basis of this result, the authors suggested that a location-based feature mismatch was not an important contributor to the negative priming effects they observed.¹ In an earlier study, Buchner and Steffens (2001) reached a similar conclusion. In their Experiment 1, participants categorized a musical sound presented to either the right or the left ear, as produced by either a wind or a string instrument. For every presentation, the participants responded to the sound presented to one ear and withheld a response to a sound presented to the opposite ear. Just prior to the presentation of each pair of sounds, the location of the to-be-categorized target was

cued by the onset of a metronome click in one ear. Thus, the location of attended and ignored sounds for both the prime and the probe events varied across trials. This procedure allowed the researchers to compare negative priming for previously ignored sounds that either switched locations or were presented in the same location during both presentations. Buchner and Steffens obtained no evidence in this experiment that negative priming was greater on different- than on same-location trials.

Thus, evidence from the two studies of auditory negative priming that have addressed the issue is not consistent with the idea that feature mismatches contribute a source of negative priming. Still, it is possible to overgeneralize these results. For example, Buchner and Steffens (2001) used their findings as grounds to claim that "feature mismatching does not play an important role in negative priming" (p. 1138). Such a broad conclusion may be premature. In keeping with TAP, whether a change in some property of a repeated stimulus contributes a source of interference may depend on the extent to which that feature was encoded during the prime episode. In Mondor et al.'s (2005) study, withholding a response to a single prime may have discouraged processing of its location. Without the contrast provided by another sound presented to the opposite location, the participants might have treated the location of the prime sound as an irrelevant feature of the prime episode. It is possible that presentation of different sounds to each ear might have been more effective in encouraging the participants to encode location information. In that case, presentation of a sound in the left ear would provide a context for the participants to think of another sound as presented to the right.

Buchner and Steffens (2001) may have failed to find that feature mismatching plays a role in auditory negative priming for a similar reason. In their procedure, categorization of the prime target may have meant that the location of the prime distractor was not processed to any significant degree. As a consequence, there was little opportunity for a mismatch in location to influence performance on ignored repetition trials. Interestingly, Buchner and Steffens did observe slower and less accurate categorization of probe sounds following categorization of prime sounds presented to the opposite ear. In the response time (RT) data, this effect was especially pronounced when the probe target was the same sound as the prime target. In other words, a location-based feature mismatch did give rise to a form of negative priming in their experiment, but this effect did not selectively impair performance on ignored repetition trials. Thus, there is reason to be hesitant in accepting their results as revealing that a location switch does not contribute to negative priming. Instead, we suspect that their experiment might be an example of how the need to categorize one sound minimizes location processing of an unattended sound presented to the opposite ear. Buchner and Steffens's observation of a cost of responding to identical sounds presented to opposite locations is consistent with this idea. In that case, categorization of the prime sound makes all of its features a more prominent aspect of the prime episode, including its location. Indeed, the prime

target was defined by its location in their study, given that a precue to the right or left ear informed the participants where the target sound would be presented.

EXPERIMENT 1

In Experiment 1, we tested the idea that a location-based feature mismatch could be a source of auditory negative priming by making that feature a more salient aspect of the prime event. Mondor et al. (2005) required listeners to identify abstract sounds, corresponding to the categories *buzz*, *croak*, *noise*, and *tone*. We used the same stimuli in the present experiment. However, in contrast to the single-prime procedure used by Mondor et al. (2005) in their second experiment, in the present study different prime sounds were dichotically presented to the participants' left and right ears on every trial. We expected that presentation of two sounds in opposite locations would encourage the participants to experience sound location as a relevant feature of the prime stimuli. The participants were also required to withhold a response to both prime sounds. This procedure was meant to ensure that the participants would have about equal opportunity to process the features of both of these sounds. We reasoned that allowing more equal processing of the prime sounds might reveal a feature mismatch basis for auditory negative priming.

On each trial, after withholding a response to the prime sounds, the participants responded to one of two sounds presented during the probe event. Specifically, the participants were instructed to identify the probe sound presented to their left ear as quickly and accurately as possible and to withhold a response to the probe sound presented to their right ear. Three repetition conditions served as the independent variable for this experiment. On baseline trials, the probe target sound differed from both prime sounds. On repeated same-location trials, the probe target sound presented to the left ear was identical to the sound presented to that same ear during the prime event. In contrast, on repeated different-location trials, the probe target sound presented to the left ear matched the sound that was presented to the right ear during the prime event. If this procedure does reveal the contribution of a location-based feature mismatch to negative priming, the participants should be particularly slow at identifying probe targets in the repeated different-location condition.

Method

Participants

Thirty undergraduate students enrolled in an introduction to psychology course participated in Experiment 1 for course credit. None of the participants reported any uncorrected auditory or visual impairments.

Materials

Computer and sound system. The experiment was controlled by the E-Prime 1.0 software system (Psychology Software Tools, 2001) running on a Dell Pentium desktop workstation. The sounds were presented over Sony MDR V600 headphones at an intensity of approximately 70 dB SPL.

Sounds. The sounds were synthesized using CoolEdit 2000 (Syntrillium Software, 2000) at a sampling rate of 44100 Hz. Four sounds

were used. These sounds, labeled *buzz*, *croak*, *noise*, and *tone*, differed markedly from one another in spectral composition. The *buzz* sound was based on a square wave and included a fundamental frequency of 200 Hz plus the first (400 Hz), second (600 Hz), third (800 Hz), and fourth (1000 Hz) harmonics. Relative to the intensity of the fundamental, the intensities of each of the four harmonics was set to 40%, 30%, 20%, and 10%, respectively. The *croak* sound was based on a sine wave with a fundamental frequency of 500 Hz. The frequency of this sound was modulated randomly between 450 and 550 Hz at a rate of 40 times per second. The *tone* sound was also based on a sine wave, had a fundamental frequency of 2000 Hz, and included the first (4000 Hz), second (6000 Hz), and third (8000 Hz) harmonics. Relative to the fundamental, the intensities of the three harmonics were set at 30%, 20%, and 10%, respectively. The *noise* sound was a burst of white noise filtered to include only frequencies between 0 and 10000 Hz. All the sounds were 250 msec in duration, including 10-msec onset and offset amplitude ramps to eliminate clicks associated with abrupt intensity changes. The four sounds could be easily discriminated from one another.

Procedure

Prior to each experimental session, the participants were presented with the four sounds in isolation and were informed of the verbal label assigned to each. The experimental session consisted of a practice session followed by 192 experimental trials. Two pairs of sounds were presented in succession on each trial. Each pair was composed of two of the four possible sounds, one presented to each ear. The participants were instructed to initiate each trial by pressing any of the four response keys. After they did so, a fixation cross (+) was presented at the center of the computer screen for 500 msec, followed by dichotic presentation of two prime sounds for 250 msec, with one sound presented to the right ear and the other sound presented to the left ear. The participants were instructed not to respond to this initial pair of sounds. After a 1,250-msec silent period, two probe sounds were presented dichotically (i.e., one sound presented to each ear) for 250 msec, and the participants were asked to identify the sound presented to their left ear as quickly and accurately as possible. The participants identified target sounds by pressing one of four keys on a PST serial response box. Figure 1 provides an example of the sequence of events that occurred on each trial.

During the practice session, the participants were allowed 1,500 msec to make a response, and accuracy feedback was provided following each response. Blocks of 24 practice trials continued until the participants were successful at correctly identifying at least 75% of the targets. For all three of the experiments reported here, the large majority of the participants required two practice blocks before beginning the experimental session. On rare occasions, the participants required up to four practice blocks before they were ready to proceed to the experimental blocks. Experimental trials were identical to practice trials, except that the participants were allowed 1,000 msec to respond and no accuracy feedback was given.

As was described above, there were three principal types of trials in the experiment, each defined by the relation between the prime and the probe pairs. On baseline trials, which comprised 50% of all the trials, the two prime sounds were different from the two probe sounds. Since there was no overlap between the prime and the probe displays on these trials, performance in this condition provided a means of evaluating the effect of sound repetition on responses to the probe target. On repeated same-location trials, which comprised 25% of trials, the probe target sound presented to the participants' left ear was identical to the sound that had been presented to their left ear during the prime event. On these trials, the sounds presented to the participants' right ear during the prime and probe events were always different. The remaining 25% of the trials consisted of repeated different-location trials, in which the sound presented to the participants' right ear in the prime display matched the probe target sound presented to their left ear. On these trials, the prime sound presented to the participants' left ear always differed from the sound

Figure 1. Graphic display of the sequence of events that occurred on baseline trials in Experiment 1. Participants identified the sound presented to their left ear during the probe event, which is displayed in capital letters in the figure. Note that on repeated same-location and repeated different-location trials, one of the prime sounds matched the probe target.

presented to their right ear. Examples of the relationship between prime and probe sounds for each of the three repetition conditions are provided in Figure 2.

Trials for each of the three repetition conditions were presented in a different random order for each participant. Moreover, for each of these conditions, each sound was presented equally often to the left and right ears, and all possible pairings of the four sounds were used equally often.

Results and Discussion

Mean correct RTs and error rates for each condition, averaged across participants, are displayed in Table 1.

Both mean RTs and error rates were submitted to a repeated measures ANOVA, treating repetition condition (repeated same location vs. repeated different location vs. baseline) as a within-participants factor. The analysis of error rates yielded no significant effects ($p > .05$ in all cases). In the analysis of RTs, there was a main effect of repetition condition [$F(2,29) = 4.20$, $MS_e = 3,565.7$, $p <$

$.05$]. On repeated different-location trials, the participants were about 20 msec slower at identifying targets, relative to baseline trials [988 vs. 968 msec; $F(1,29) = 4.54$, $MS_e = 1,449.3$, $p < .05$]. In contrast, the participants were about 24 msec faster at responding on repeated same-location trials than on baseline trials [944 vs. 968 msec; $F(1,29) = 1.90$, $MS_e = 4,441.5$, $p = .18$]. In a separate analysis, we also tested whether the priming effect observed on repeated same-location trials reliably differed from that observed on repeated different-location trials. We first calculated priming effects for each participant by subtracting their mean RTs on repeated same-location trials and repeated different-location trials from their mean RT on baseline trials. These difference scores were then submitted to a repeated measures ANOVA, treating location match/mismatch as a within-participants factor. This analysis yielded a reliable difference in priming effects depending on whether the probe sound matched a

Figure 2. Graphic display providing examples of the relationship between the prime and the probe sounds for each repetition condition (repeated same location, repeated different location, and baseline) in Experiment 1.

Table 1
Mean Identification Response Times (RTs, in Milliseconds) and Error
Proportions (ERRs) Observed in Experiment 1 as a Function of Repetition
Condition (Repeated Same Location vs. Repeated Different Location vs. Baseline)

Repetition Condition	RT			ERR		
	<i>M</i>	Difference	<i>SE</i>	<i>M</i>	Difference	<i>SE</i>
Repeated same location	944	+24	17.2	.099	-.002	.011
Repeated different location	988	-20	9.8	.111	-.014	.012
Baseline	968			.097		

Note—Difference scores represent the mean difference between repeated and baseline trials; *SE* refers to between-participants standard errors of these difference scores.

prime sound presented to the same versus the opposite ear [$F(1,28) = 6.30$, $MS_e = 4,935.8$, $p < .05$].

In Experiment 1, two prime sounds were presented on every trial, and the participants were not required to respond to either of them. Even though responding was withheld for both prime sounds, the effect of repetition was found to depend on prime location. Presentation of a repeated sound as the probe target slowed responding when that sound was presented to the nontarget location (right ear). This negative priming effect was not observed when the repeated sound was presented to the target location (left ear) during the prime display. On the basis of this result, we concluded that an identity–location mismatch can be a source of auditory negative priming. Indeed, the priming effect on repeated same-location trials was nominally positive. This result suggests that a mismatch in the location of a repeated sound contributed the primary source of negative priming in our experiment. This finding contrasts with the results of both Buchner and Steffens (2001) and Mondor et al. (2005), which suggested that failure to attend to a prime sound was the sole cause of auditory negative priming.

Our best explanation of the discrepancy between these previous results and those in our Experiment 1 is that withholding a response to prime sounds represented a more central aspect of the prime episode in those studies. When Buchner and Steffens (2001) and Mondor et al. (2005, Experiment 1) used the conventional procedure common to visual investigations of negative priming, ignoring distracting prime sounds might have been made quite prominent by the need to avoid processing of those sounds while generating a response to the prime target. Similarly, as was suggested above, withholding a response to a single prime sound (Mondor et al., 2005, Experiment 2) appeared to further enhance the salience of this aspect of the prime episode, leading to an especially large negative priming effect when there was a match between the prime sound and the probe target. It appears that failure to respond to two dichotically presented prime sounds, as in the present experiment, minimized the role of response suppression in the participants' memory representation for the prime episode.

Similarly, we propose that the observation of location-based negative priming in Experiment 1 occurred because the location of the repeated sound was a more salient aspect of the prime episode than in previous studies of auditory negative priming. During the prime display, processing of the location of the sound presented to the right ear

was supported by presentation of a different sound to the left ear. In addition, the participants were not required to categorize primes presented to the left ear, leaving more resources available for processing the location of primes presented to the right ear. The purpose of Experiment 2 was to further test the possibility that it is the prominence of location within the prime episode that determines whether a mismatch on that dimension will contribute a source of negative transfer.

EXPERIMENT 2

In Experiment 2, we manipulated the salience of location as an aspect of the prime episode by presenting an abrupt onset cue to either the right or the left ear just prior to the onset of the prime display. A number of studies have demonstrated that attention is involuntarily or exogenously drawn to the location of an abrupt visual (Gibson & Egeth, 1994; Yantis, 1996; Yantis & Jonides, 1984) or auditory (Mondor, 1999; Mondor & Breau, 1999) event. If the participants' attention is preferentially drawn to the location of a prime sound that later appears as the probe target, we expected that location would provide a more potent source of negative priming.

In some ways, this is an unusual prediction, on the basis of the historical view of negative priming. Our suggestion is that exogenously cuing the location of a prime sound should increase negative priming for that stimulus when it appears as the probe target, so long as the matching prime and probe occur in opposite locations. Obviously, it is difficult to resolve this prediction with the conventional view that negative priming involves impaired responding to a previously unattended stimulus. Our assumption, however, is that negative transfer may arise from any number of sources other than failure to attend to a prime stimulus. In the context of the present study, we predict that making location a more central feature of the prime event will trump other potential sources of negative transfer. As was discussed above, this notion is inspired by the broader principle of TAP. According to this principle, presentation of a probe stimulus following an identical prime stimulus cues the retrieval of processes that were engaged in during the prime event. In turn, efficiency in responding to the probe target depends on whether processing that occurred during the prime episode is appropriate for performing the probe task. Consequently, the features most capable of

producing a cost owing to the repetition of a sound should be those that contribute most to the participants' processing of the prime display.

In addition to the repetition conditions used in Experiment 1, we added an additional independent variable in Experiment 2. In the left ear cued condition, the onset of the prime sounds was immediately preceded by presentation of a cue sound to the participants' left ear. In the right ear cued condition, a cue sound to the participant's right ear preceded presentation of the prime sounds. On every trial, as in Experiment 1, the participants withheld a response to both prime sounds and were required to identify the probe sound presented to their left ear. We reasoned that exogenously directing the participants' attention toward the location of a prime sound should enhance processing of that feature. Consequently, we expected that a larger negative priming effect would occur on repeated different-location trials in the right ear cued condition than in the left ear cued condition.

Method

Participants

Twenty-nine undergraduate students enrolled in an introduction to psychology course participated in Experiment 2 for course credit. None of the participants reported any uncorrected auditory or visual impairments.

Materials

The materials for Experiment 2 were identical to those in Experiment 1, except for the generation of a sound for use as the abrupt onset cue prior to presentation of the prime sounds. The cue consisted of two frequency components at equal intensity (10000 and 11000 Hz) and was 25 msec in duration, with 2-msec onset and offset amplitude ramps.

Procedure

The procedure in Experiment 2 was identical to that in Experiment 1, except for the insertion of an abrupt onset cue for 25 msec, followed by a 100-msec silent interval immediately prior to the onset of the prime display. For each of the three repetition conditions (baseline, repeated same location, and repeated different location), the cue was presented to the left ear on half of the trials (left ear cued condition) and to the right ear on the other half of trials (right ear cued condition). The participants also completed 384 experimental trials in Experiment 2, or twice as many as the 192 trials the participants completed in Experiment 1. The purpose of this modification

was to ensure a sufficient number of observations for each condition, given the addition of prime cue location as a factor.

Note that this design required an evaluation of the effect of sound repetition against two different baseline conditions. On both repeated same-location and repeated different-location trials, when the cue preceding the prime display was presented to the same location as the probe target (left ear cued trials), the baseline for comparison was performance on trials in which the prime cue was presented to the left ear and no sounds were repeated between the prime and the probe events. Similarly, when the prime cue was presented to the location opposite to that of the probe target (right ear cued trials), the baseline for comparison was performance on trials in which the prime cue was presented to the right ear and the two prime sounds were different from both probe sounds.

Results and Discussion

Mean correct RTs and error rates for each condition, averaged across the participants, are displayed in Table 2.

Both mean RTs and error rates were submitted to a 3×2 repeated measures ANOVA, treating repetition condition (repeated same location vs. repeated different location vs. baseline) and prime cue location (left ear cued vs. right ear cued) as within-participants factors. The analysis of error rates produced no significant results ($p > .05$ in all cases). In the analysis of RTs, there was a reliable interaction between the repetition and the prime cue conditions [$F(2,56) = 10.72$, $MS_e = 2,474.3$, $p < .001$], owing to higher negative priming for repeated different-location trials in the right ear cued condition than in the left ear cued condition. When a repeated prime sound was presented to the right ear, opposite from the location of the probe target, and the cue sound was presented at that location, the participants were approximately 36 msec slower to respond, relative to baseline, right ear cued trials [846 vs. 810 msec; $F(1,28) = 11.36$, $MS_e = 1,657.2$, $p < .005$]. In contrast, when the cue sound was presented to the left ear on repeated different-location trials, the participants were only 4 msec slower to respond, in comparison with the baseline, left ear cued trials (823 vs. 819 msec; $F < 1$).

On repeated same-location trials, the magnitude of priming did not reliably depend on whether or not the prime cue was presented at the location of the repeated prime sound (repetition $\times$ prime cue location interaction, $F < 1$). On these trials, drawing attention to the location

Table 2
Mean Identification Response Times (RTs, in Milliseconds) and Error Proportions (ERRs)
Observed in Experiment 2 as a Function of Repetition Condition (Repeated Same Location
vs. Repeated Different Location vs. Baseline) and Prime Cue Location
(Left Ear Cued vs. Right Ear Cued)

Repetition Condition	Prime Cue Location	RT			ERR		
		<i>M</i>	Difference	<i>SE</i>	<i>M</i>	Difference	<i>SE</i>
Repeated same location	Right ear cued	775	+35	15.3	.125	+.010	.016
	Left ear cued	772	+47	14.4	.121	+.017	.021
Repeated different location	Right ear cued	846	-36	10.7	.161	-.026	.015
	Left ear cued	823	-4	11.9	.147	-.009	.014
Baseline	Right ear cued	810			.135		
	Left ear cued	819			.138		

Note—Difference scores represent the mean difference between repeated and baseline trials; *SE* refers to between-participants standard errors of these difference scores.

of a repeated prime sound occurred when the cue sound was presented to the participants' left ear, whereas cuing the location opposite to that of a repeated prime sound involved presentation of the cue to the right ear. In the left ear cued condition, responses on repeated same-location trials were 47 msec faster than those on baseline, left ear cued trials (772 vs. 819 msec). Similarly, in the right ear cued condition, responses on same-location trials were about 35 msec faster than those on baseline, right ear cued trials (775 vs. 810 msec). Combined, these results revealed that sound repetition significantly facilitated the speed of identification responses in the repeated same-location condition [$F(1,28) = 9.38$, $MS_e = 5,398.8$, $p < .005$].

These results provide compelling support for our suggestion that a location-based feature mismatch will give rise to auditory negative priming, depending on whether the participants experience location as a central aspect of the prime episode. It appears that the participants had greater opportunity to encode the location of a prime sound when their attention was drawn to that location prior to its onset. Consequently, a reliable negative priming effect occurred in Experiment 2 only when the prime sound presented to the right ear matched the probe target presented to the left ear *and* attention was cued to the location of that sound prior to its presentation during the prime event. There was no reliable repetition cost on repeated different-location trials when the participants' attention was cued to the opposite location of the repeated sound.

As in Experiment 1, we also observed no evidence of negative priming on repeated same-location trials in Experiment 2. Indeed, performance was reliably faster on these trials, relative to baseline trials in the present experiment. This finding further strengthens our position that having participants withhold a response to two prime sounds minimizes the importance of response suppression in the participants' experience of the prime episode. Still, reducing the role of response suppression as a source of negative priming cannot explain why performance would be significantly faster in the repeated same-location condition. It is also unclear as to why the location of the cue sound would fail to significantly modulate this positive priming effect, when it did reliably impact the magnitude of negative priming on repeated different-location trials.

One possibility is that the participants' strategy in preparing to identify the probe target often involved maintaining their attention to their left ear, even while they were withholding a response to the prime sounds. If so, the way the participants performed repeated same-location trials might have been functionally similar to the type of processing that occurs on attended-repetition trials using the conventional negative priming procedure. In that case, attending to a prime stimulus facilitates responses to an identical stimulus when it appears as the probe target. With attention already biased to receive sounds presented to the left ear, cuing that location would not be expected to influence performance. Moreover, this bias might be only temporarily influenced by presentation of an exogenous cue to the right ear. On right ear cued trials, some attentional resources must be drawn to that location

for performance to be influenced on repeated different-location trials. Still, there might be minimal impact on the participants' processing of prime sounds presented to their left ear, because of the strength of their bias to attend to stimuli presented at that location.

Of greater concern, however, is the implication that this type of bias might have for our interpretation of the location mismatch effects we observed in Experiments 1 and 2. In the likely event that the participants did preferentially attend to prime sounds presented to their left ear, it may not have been the presentation of the probe target in an opposite location during the prime event that caused auditory negative priming *per se*. Instead, these negative priming effects might reflect the participants' efforts to actively ignore prime sounds presented to their right ear. We conducted Experiment 3 to explore this possibility.

EXPERIMENT 3

In combination, the results of Experiments 1 and 2 strongly support a contribution of location-based feature mismatches to auditory negative priming. Indeed, we obtained no evidence that any other influence contributed to negative priming in those two experiments. Repetition of a prime sound as the probe target gave rise to negative priming only on repeated different-location trials. Even on those trials, when the participants' attention was not exogenously drawn to the location of repeated prime sounds in Experiment 2, performance was not significantly slower than baseline. We interpreted these results as revealing that location mismatches will cause negative priming to the extent that location is a salient aspect of the prime episode.

Nevertheless, as was indicated above, we were concerned about one aspect of the procedure used in our preceding two experiments. Since probe targets were always presented to the left ear, it is reasonable to expect that the participants were naturally biased to attend preferentially to sounds presented to that location and to treat sounds presented to the opposite location as a source of distraction. If so, it is possible that this bias accounts for the negative priming effects observed in these two experiments. In Experiment 1, the participants' efforts to avoid attending to sounds on the right might explain why negative priming occurred only when the probe target followed presentation of an identical prime sound to the opposite location. Similarly, in Experiment 2, we observed negative priming exclusively for repeated primes presented to the location opposite that of the probe target. More important, this negative priming effect was enhanced by presentation of an abrupt onset cue at the location of the repeated prime sound. In this case, it is possible that negative priming was enhanced in the right ear cued condition because attentional capture to the right ear conflicted with the participants' strategy to allocate attention to the left ear. By making it more challenging for the participants to maintain attention to sounds presented to their left ear, a cue to the right ear might have compelled the participants to more aggressively direct attention away from sounds presented to that location. The greater effort necessary for ignoring

sounds presented to the right ear might then have carried over and impaired responding to an identical sound in the probe display. In other words, rather than being caused by a mismatch in location, the negative priming effects observed in our first two experiments might have arisen from the participants' active suppression of sounds presented to their right ear.

In Experiment 3, we attempted to rule out this *active suppression* alternative to our location mismatch account. The procedure of this experiment was highly similar to that in Experiment 1. The same three repetition conditions (repeated same location, repeated different location, and baseline) as those used in Experiment 1 represented the critical independent variable in this experiment as well. A critical difference, however, was that the participants identified probe sounds presented to either their left or right ear, depending on a cue that followed offset of the prime display and preceded onset of the probe display. This modification led to the addition of a second independent variable, defined by the location of the probe target. On half of the trials corresponding to each repetition condition, the participants identified the probe sound presented to their left ear (left-target condition), whereas they identified the probe sound presented to their right ear on the remainder of trials (right-target condition).

For one group of participants, the location of the probe target was *endogenously* cued by the presentation of a visual arrow that pointed to either the left or the right (arrow cue condition). Another group of the participants was *exogenously* cued by a metronome click (click cue condition), following the procedure for investigating auditory negative priming developed by Buchner and Steffens (2001). Regardless of the nature of the cue, the advantage of this procedure is that the participants did not have foreknowledge about the location of the probe target until after the prime event. As a result, there should be no consistent bias to attend to one location or the other on presentation of the prime pair. Therefore, any effect of a location mismatch under these conditions could not arise from a bias to allocate attention away from the location of a repeated prime sound. Instead, if the cost of repetition is found to depend on a location mismatch, this finding would provide convergent support for the idea that feature mismatching can play a significant role in auditory negative priming.

Method

Participants

Thirty-one undergraduate students enrolled in an introduction to psychology course participated in Experiment 3 for course credit (16 in the arrow cue condition and 15 in the click cue condition). None of the participants reported any uncorrected auditory or visual impairments.

Materials

The materials for Experiment 3 were identical to those used in the preceding two experiments, except that two arrow stimuli (one pointed to the left and the other to the right) were created to signal the location of the probe target to one group of the participants and a 15-msec metronome click was created to serve the same purpose for another group of the participants.

Procedure

The procedure in Experiment 3 was identical to that in Experiment 1, except that the participants were required to identify probe sounds that were presented to either the left or the right ear. To accommodate for the addition of this factor to the design, we also increased the experimental session from 192 trials in Experiment 1 to 384 trials in Experiment 3. For one group of the participants, a visual arrow that pointed to either the left or the right indicated which probe sound was the target. This cue appeared on the computer monitor immediately following offset of the prime display and remained on the screen for 1,250 msec. After this delay, the arrow disappeared, and the presentation of the probe display immediately followed. For another group of the participants, a metronome click presented to either the left or the right ear cued the location of the probe target. The click was presented 618 msec after the offset of the prime display for 15 msec. Presentation of the probe display began 618 msec after the offset of the click. Across the experimental session, probe targets were presented to the left ear on one half of the trials and to the right ear on the remaining trials. Other than this constraint, the presentation of probe targets to either the left or the right ear was determined at random prior to each trial.

Results and Discussion

Both mean RTs and error rates were submitted to a $2 \times (3 \times 2)$ mixed-design ANOVA, treating cue type (arrow cue vs. click cue) as a between-participants factor and probe target location (left ear vs. right ear) and repetition condition (repeated same location vs. repeated different location vs. baseline) as within-participants factors. Table 3 displays mean correct RTs and error rates, averaged across participants.

The analysis of error rates yielded no significant effects ($p > .05$ in all cases). In the analysis of RTs, the type of cue used to signal the location of the probe target had no significant effect on the results, either as a main effect or in interaction with other factors ($F < 1$ in all cases). There was a reliable main effect of repetition [$F(2,60) = 9.05$, $MS_e = 5,206.6$, $p < .001$]. Overall, the participants were about 46 msec slower at identifying targets on repeated different-location trials than on baseline trials [1,011 vs. 965 msec; $F(1,30) = 20.85$, $MS_e = 3,239.9$, $p < .001$]. On repeated same-location trials, however, speed of responding was nearly identical to performance in the baseline condition (962 vs. 965 msec; $F < 1$).

We confirmed the contribution of location mismatching to negative priming by conducting a separate analysis on priming effects observed for the repeated same-location and repeated different-location conditions, collapsing across probe target location. In particular, we subtracted each participant's mean RT on both repeated same- and repeated different-location trials from their mean RT on baseline trials. We then submitted these difference scores to a repeated measures ANOVA, treating repetition condition as a within-participants factor. This analysis revealed a significant difference in priming effects, depending on whether the repeated sound appeared in a same versus a different location during the prime event [$F(1,30) = 7.98$, $MS_e = 9,244.4$, $p < .01$].

For repeated different-location trials, there was also significantly greater negative priming when the probe target was presented to the left than when it was presented to the

Table 3
Mean Identification Response Times (RTs, in Milliseconds) and Error Proportions (ERRs) Observed in Experiment 3 As a Function of Repetition Condition (Repeated Same Location vs. Repeated Different Location vs. Baseline), Cue Type (Arrow Cue vs. Click Cue), and Probe Target Location (Left Ear vs. Right Ear)

Cue Type	Probe Target Location	Repetition Condition									
		Baseline		Repeated Same Location				Repeated Different Location			
		RT	ERR	M	Difference	M	Difference	M	Difference	M	Difference
Arrow	Left ear	957	.129	960	-3	.132	+.003	1,030	-73	.149	-.020
	Right ear	954	.106	969	-15	.148	+.042	986	-32	.095	+.011
Click	Left ear	973	.069	961	+12	.059	+.010	1,026	-53	.098	-.029
	Right ear	975	.057	959	+16	.065	-.008	1,002	-27	.071	-.014
Overall difference											
M					+2		+.011		-46		-.013
SE					10.1		.010		10.2		.007

Note—Difference scores represent the mean difference between repeated and baseline trials; *SE* refers to between-participants standard errors of these difference scores.

right. When the probe target presented to the left ear was the same as the sound presented to the right ear in the prime display, responses were about 63 msec slower, relative to the baseline condition [1,028 vs. 965 msec; $F(1,30) = 33.36$, $MS_e = 1,883.9$, $p < .001$]. In contrast, when the probe target presented to the right ear matched the preceding prime sound presented to the left ear, responses were only 30 msec slower than those in the baseline condition [994 vs. 964 msec; $F(1,30) = 4.30$, $MS_e = 3,177.7$, $p < .05$]. It is unclear why negative priming would be greater when the same sound switched locations from right to left than when the location switch was from left to right. Other research, however, has demonstrated that right-handed participants are biased to attend to stimuli presented to their right ear in the context of dichotic listening tasks (Mondor, 1994). Although we did not require the participants to report their dominant hand, we assume that most of our participants were right-hand dominant. If so, a general bias to process stimuli presented to the right ear might have enhanced location processing for those stimuli. By the TAP approach adopted here, heightened processing of the location of sounds presented to the right ear would be expected to enhance the cost of a location-based mismatch. Indeed, this notion formed the rationale for our cuing the location of prime sounds in Experiment 2.

More important for present purposes, Experiment 3 allowed us to rule out an *active suppression* explanation of the results of Experiments 1 and 2. By this account, the location mismatch effects observed in the preceding two experiments might have merely reflected the participants' bias to allocate attention away from sounds presented to their right ear. In contrast with the preceding experiments, the participants had no motive to preferentially attend to sounds presented to their left ear in Experiment 3. Nevertheless, as in Experiments 1 and 2, the occurrence of negative priming was dependent on whether or not the probe target had been presented in the same location or in a different location in the prime display. Indeed, sound repetition was costly to performance only on location mismatch trials in all three of our experiments. Thus, it appears that a mismatch in the location of an identical prime and probe

sound can serve as an important source of auditory negative priming as long as location forms a salient aspect of the participants' memory representation for the prime episode. Otherwise, information about the location of a prime sound will not be available to interfere with responding to a probe target that appears in the opposite location.

Interestingly, in contrast with the results of Experiment 2, there was no evidence of positive priming on repeated same-location trials. Our explanation for observing positive priming in Experiment 2 relied on the idea that the presentation of probe targets to the left ear on every trial biased the participants to attend to all sounds presented to their left ear, including prime sounds. If the participants had employed this strategy, it would be sensible to expect facilitated responses on repeated same-location trials. Consistent with this view, having eliminated the motive for the participants to preferentially attend to sounds presented to their left ear in Experiment 3, we also eliminated positive priming for repeated prime sounds presented to the same location as the probe target.

GENERAL DISCUSSION

Recently, there have been a number of attempts at applying TAP to explain short-term priming effects (Leboe et al., 2005; Neill & Mathis, 1998; Wood & Milliken, 1998). From this perspective, processing that occurs during a prime event generates a representation in memory. The presence of a stimulus in the probe display that is identical or related to a prime stimulus then cues retrieval of processes engaged in during the prime episode. In turn, the consequence of stimulus repetition depends on the appropriateness of processing during the prime event for performing the probe task. Responses will be facilitated if the probe task requires processing that is similar to processing that occurred at the time of the prime event. On the other hand, stimulus repetition will impair performance when processing of prime stimuli conflicts with the processing requirements of the probe task.

The episodic retrieval account offered by Neill and colleagues (Neill et al., 1992) represents an example of how

inappropriate transfer might give rise to a negative priming effect. In this view, failure to respond to a prime stimulus conflicts with the subsequent requirement to respond to that stimulus during the probe event. Similarly, retrieving an episode of having inhibited processing of an irrelevant prime stimulus might also slow a response to that item when it appears as the probe target (Tipper, 2001). Common to both of these approaches is their emphasis on a prior act of ignoring a prime stimulus in giving rise to negative priming effects. Until the present study, the weight of evidence suggested that this source of interference provides the sole basis for auditory negative priming effects. For example, Mondor et al. (2005) demonstrated a particularly large negative priming effect when participants withheld a response to a prime sound presented in isolation that was later presented as the probe target. In contrast, withholding a response to a prime sound produced a much smaller negative priming effect when it was accompanied by another prime sound that the participants were required to identify. The authors proposed that greater negative priming for a single prime sound occurred because withholding a response to an isolated sound represents a more prominent aspect of the prime episode. As a consequence, retrieving the memory representation for the prime episode contributes a more potent source of interference when the participants are later required to identify the same sound as the probe target.

Prior investigations have provided little evidence that other sources of interference can also contribute to auditory negative priming. In particular, studies by Mondor et al. (2005) and Buchner and Steffens (2001) revealed no evidence of impaired responding to a probe target due to its presentation in an opposite location during the prime event. The present study contradicts these earlier findings. In Experiments 1 and 2, negative priming occurred only when the participants withheld a response to a prime sound when that same sound was presented in the opposite location as the probe target. No reliable negative priming effects were observed on repeated same-location trials. These results are consistent with demonstrations in the visual domain, revealing that some instances of negative priming may be explained entirely by a mismatch in the features of a repeated stimulus (e.g., MacLeod et al., 2002). Also, our findings raise the possibility that mismatches on other auditory dimensions, such as loudness or pitch, may also give rise to negative priming effects. Nevertheless, it is important to consider why a mismatch in the location of repeated sounds provided the primary source of negative priming here but played no role in previous investigations of auditory negative priming.

When applied to short-term priming, the principle of TAP predicts that performance of a probe task should depend on the appropriateness of the specific processing operations made available by retrieval of the prime episode. The mere presence of a feature mismatch may not be sufficient to contribute a source of negative transfer if that feature was not central to processing that occurred at the time of the prime event. We propose that withholding a response to a single prime sound in Mondor et al.'s (2005)

study discouraged processing of the location of that item. Without a basis for comparison, the participants experienced where the prime sound occurred as an irrelevant aspect of the prime event. In the present study, however, the participants withheld a response to two different prime sounds that were presented to opposite locations. We suspect that this dichotic presentation of two different prime sounds stimulated comparison of their relative spatial origins. The outcome was that across our three experiments, identification responses were impaired when a location switch accompanied presentation of the prime sound as the probe target.

In Buchner and Steffens's (2001) study, the participants always categorized one prime sound at the same time as they withheld a response to a sound in the opposite location. In this case, the participants might have been less likely to encode the location of unattended primes, given that they were engaged in the primary task of responding to some other sound. In our Experiment 1, although two sounds were presented in opposite locations in the prime display, we attempted to minimize the possibility that the participants would devote more resources to one of the sounds by not requiring a response to either of them. Allowing the participants more opportunity to process the location of both prime sounds revealed a central role for location-based mismatches in generating negative priming. Even so, we were concerned that requiring the participants to categorize probe sounds presented to the left ear encouraged them to devote more attention to prime sounds presented to that location. To remove this possibility, probe targets were presented randomly to either the left or the right ear in Experiment 3. This experiment replicated the results of Experiment 1, in that we observed a negative priming effect only when repeated sounds were presented to opposite locations.

Thus, whether a mismatch in location produces a negative priming effect appears to depend on the degree to which the participants process location at the time of the prime event. The results of Experiment 2 provide particularly compelling support for this idea. In that experiment, an exogenous cue preceded the prime sound presented to either the participants' right or left ear. Given that probe targets were always presented to the left ear, repeated different-location trials occurred when the prime sound presented to the right ear subsequently became the probe target. On these trials, negative priming occurred when the participants' attention was cued to the right ear prior to the prime display, but not when a cue directed their attention to the opposite location. This finding provides a clear illustration that stimulus repetition will impair performance to the extent that there is a mismatch in the processing associated with the prime and probe events. In the absence of a processing mismatch, a mismatch in the nominal features of prime and probe stimuli will not contribute a source of negative priming. Drawing attention to the prime sound presented to the right ear enhanced processing of that sound and its location. The outcome was that the participants experienced more interference when responding to that same sound when it was presented to

the opposite location. Presentation of the cue to the left ear minimized processing of the sound presented to the right ear. The result was that performance on repeated different-location trials was not reliably different from baseline.

Together, the results of the present study provide convincing evidence that auditory negative priming can originate from a mismatch in the perceptual features of a repeated stimulus. Moreover, we offer the present results as an illustration of how the principle of transfer-appropriate processing, which is already applied broadly to explain other memory phenomena, can also provide a valuable framework for understanding short-term priming effects.

REFERENCES

- BANKS, W. P., ROBERTS, D., & CIRANNI, M. (1995). Negative priming in auditory attention. *Journal of Experimental Psychology: Human Perception & Performance*, **21**, 1354-1361.
- BAYLIS, G. C., TIPPER, S. P., & HOUGHTON, G. (1997). Externally cued and internally generated selection: Differences in distractor analysis and inhibition. *Journal of Experimental Psychology: Human Perception & Performance*, **23**, 1617-1630.
- BUCHNER, A., & STEFFENS, M. C. (2001). Auditory negative priming in speeded reactions and temporal order judgements. *Quarterly Journal of Experimental Psychology*, **54A**, 1125-1142.
- DESCHÉPPER, B., & TREISMAN, A. (1996). Visual memory for novel shapes: Implicit coding without attention. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **22**, 27-47.
- FOX, E. (1995). Negative priming from ignored distractors in visual selection: A review. *Psychonomic Bulletin & Review*, **2**, 145-173.
- GIBSON, B. S., & EGETH, H. (1994). Inhibition of return to object-based and environment-based locations. *Perception & Psychophysics*, **55**, 323-339.
- JACOBY, L. L. (1983). Remembering the data: Analyzing interactive processes in reading. *Journal of Verbal Learning & Verbal Behavior*, **22**, 485-508.
- JACOBY, L. L., & DALLAS, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General*, **110**, 306-340.
- KOLERS, P. A., & ROEDIGER, H. L., III (1984). Procedures of mind. *Journal of Verbal Learning & Verbal Behavior*, **23**, 425-449.
- LEBOE, J. P., WHITTLESEA, B. W. A., & MILLIKEN, B. (2005). Selective and nonselective transfer: Positive and negative priming in a multiple-task environment. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **31**, 1001-1029.
- LOGAN, G. D. (1988). Toward an instance theory of automatization. *Psychological Review*, **95**, 492-527.
- LOWE, D. G. (1985). Further investigations of inhibitory mechanisms in attention. *Memory & Cognition*, **13**, 74-80.
- MACDONALD, P. A., & JOORDENS, S. (2000). Investigating a memory-based account of negative priming: Support for selection-feature mismatch. *Journal of Experimental Psychology: Human Perception & Performance*, **26**, 1478-1496.
- MACDONALD, P. A., JOORDENS, S., & SEERGOBIN, K. N. (1999). Negative priming effects that are bigger than a breadbox: Attention to distractors does not eliminate negative priming, it enhances it. *Memory & Cognition*, **27**, 197-207.
- MACLEOD, C. M., CHIAPPE, D. L., & FOX, E. (2002). The crucial roles of stimulus matching and stimulus identity in negative priming. *Psychonomic Bulletin & Review*, **9**, 521-528.
- MAY, C. P., KANE, M. J., & HASHER, L. (1995). Determinants of negative priming. *Psychological Bulletin*, **118**, 35-54.
- MILLIKEN, B., & JOORDENS, S. (1996). Negative priming without overt prime selection. *Canadian Journal of Experimental Psychology*, **50**, 333-346.
- MILLIKEN, B., JOORDENS, S., MERIKLE, P. M., & SEIFFERT, E. (1998). Selective attention: A reevaluation of the implications of negative priming. *Psychological Review*, **105**, 203-229.
- MILLIKEN, B., LUPIÁÑEZ, J., DEBNER, J., & ABELLO, B. (1999). Automatic and controlled processing in Stroop negative priming: The role of attentional set. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **25**, 1384-1402.
- MILLIKEN, B., TIPPER, S. P., & WEAVER, B. (1994). Negative priming in a spatial localization task: Feature mismatching and distractor inhibition. *Journal of Experimental Psychology: Human Perception & Performance*, **20**, 624-646.
- MONDOR, T. A. (1994). Interaction between handedness and the attentional bias during tests of dichotic listening performance. *Journal of Clinical & Experimental Neuropsychology*, **16**, 377-385.
- MONDOR, T. A. (1999). Predictability of the cue-target relation and the time-course of auditory inhibition of return. *Perception & Psychophysics*, **61**, 1501-1509.
- MONDOR, T. A., & BREAU, L. M. (1999). Facilitative and inhibitory effects of location and frequency cues: Evidence of a modulation in perceptual sensitivity. *Perception & Psychophysics*, **61**, 438-444.
- MONDOR, T. A., LEBOE, J. P., & LEBOE, L. C. (2005). The role of selection in generating auditory negative priming. *Psychonomic Bulletin & Review*, **12**, 289-294.
- MOORE, C. M. (1994). Negative priming depends on probe-trial conflict: Where has all the inhibition gone? *Perception & Psychophysics*, **56**, 133-147.
- MORRIS, C. D., BRANSFORD, J. D., & FRANKS, J. J. (1977). Levels of processing versus transfer-appropriate processing. *Journal of Verbal Learning & Verbal Behavior*, **16**, 519-533.
- NEILL, W. T. (1977). Inhibitory and facilitatory processes in selective attention. *Journal of Experimental Psychology: Human Perception & Performance*, **3**, 444-450.
- NEILL, W. T. (1997). Episodic retrieval in negative priming and repetition priming. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **23**, 1291-1305.
- NEILL, W. T., & KAHAN, T. A. (1999). Response conflict reverses priming: A replication. *Psychonomic Bulletin & Review*, **6**, 304-308.
- NEILL, W. T., & MATHIS, K. M. (1998). Transfer-inappropriate processing: Negative priming and related phenomena. In D. L. Medin (Ed.), *The psychology of learning and motivation* (Vol. 38, pp. 1-44). San Diego: Academic Press.
- NEILL, W. T., & VALDES, L. A. (1992). Persistence of negative priming: Steady state or decay? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **18**, 565-576.
- NEILL, W. T., VALDES, L. A., TERRY, K. M., & GORFEIN, D. S. (1992). Persistence of negative priming: II. Evidence for episodic trace retrieval. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **18**, 993-1000.
- ORTELLS, J. J., & TUDELA, P. (1996). Positive and negative priming of attended and unattended parafoveal words in a lexical decision task. *Acta Psychologica*, **94**, 209-226.
- PARK, J., & KANWISHER, N. (1994). Negative priming for spatial locations: Identity mismatching, not distractor inhibition. *Journal of Experimental Psychology: Human Perception & Performance*, **20**, 613-623.
- POSNER, M. I., & SNYDER, C. (1975). Attention and cognitive control. In R. L. Solso (Ed.), *Information processing and cognition: The Loyola Symposium* (pp. 55-85). Hillsdale, NJ: Erlbaum.
- PSYCHOLOGY SOFTWARE TOOLS (2001). E-Prime 1.0 [Computer software]. Pittsburgh: Author.
- ROEDIGER, H. L., III, WELDON, M. S., & CHALLIS, B. H. (1989). Explaining dissociations between implicit and explicit measures of retention: A processing account. In H. L. Roediger III & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honour of Endel Tulving* (pp. 3-41). Hillsdale, NJ: Erlbaum.
- SYNTRILLIUM SOFTWARE (2000). CoolEdit 2000 [Computer software]. Scottsdale, AZ: Author.
- TIPPER, S. P. (1985). The negative priming effect: Inhibitory priming by ignored objects. *Quarterly Journal of Experimental Psychology*, **37A**, 571-590.
- TIPPER, S. P. (2001). Does negative priming reflect inhibitory mechanisms? A review and integration of conflicting views. *Quarterly Journal of Experimental Psychology*, **54A**, 321-343.
- TIPPER, S. P., BREHAUT, J. C., & DRIVER, J. (1990). Selection of moving

- and static objects for the control of spatially directed action. *Journal of Experimental Psychology: Human Perception & Performance*, **16**, 492-504.
- TIPPER, S. P., & CRANSTON, M. (1985). Selective attention and priming: Inhibitory and facilitatory effects of ignored primes. *Quarterly Journal of Experimental Psychology*, **37A**, 591-611.
- TIPPER, S. P., WEAVER, B., & HOUGHTON, G. (1994). Behavioral goals determine inhibitory mechanisms of selective attention. *Quarterly Journal of Experimental Psychology*, **47A**, 809-840.
- TULVING, E., & THOMSON, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review*, **80**, 352-373.
- WOOD, T. J., & MILLIKEN, B. (1998). Negative priming without ignoring. *Psychonomic Bulletin & Review*, **5**, 470-475.
- YANTIS, S. (1996). Attentional capture in vision. In A. F. Kramer, M. G. H. Coles, & G. D. Logan (Eds.), *Converging operations in the study of visual attention* (pp. 45-76). Washington, DC: American Psychological Association.
- YANTIS, S., & JONIDES, J. (1984). Abrupt visual onsets and selective attention: Evidence from visual search. *Journal of Experimental Psychology: Human Perception & Performance*, **10**, 601-621.
- YEE, P. L. (1991). Semantic inhibition of ignored words during a figure classification task. *Quarterly Journal of Experimental Psychology*, **43A**, 127-153.

NOTE

1. In two other experiments, Mondor et al. (2005) provided additional demonstrations of negative priming for auditory stimuli. However, neither of those experiments was capable of revealing (or ruling out) a contribution of location-based mismatching to these effects. In both cases, the participants always responded to a prime sound presented to their left ear, while withholding a response to a different prime sound presented to their right ear. At onset of the probe display, the participants were again required to categorize the sound presented to their left ear. In one experiment, this probe target was accompanied by a distracting sound presented to the participants' right ear (Experiment 1), whereas in another experiment it was presented in isolation (Experiment 3). Although negative priming for a previously ignored sound was observed in both of these experiments, repetition of ignored primes always involved a switch in location from the ignored right ear to the attended left ear. Thus, any negative priming effects observed could have been caused either by having not responded to the probe target when it was presented previously in the prime display or by presentation of the probe target in a different location from that in which it had been presented during the prime event.

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