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Change in perceptual form attenuates the use of the fluency heuristic in recognition

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Four experiments (total $N = 295$) were conducted to determine whether within-modality changes in perceptual form between the study and the test phases of an experiment would moderate the role of the fluency heuristic in recognition memory. Experiment 1 showed that a change from pictures to words reduced the role of fluency in recognition memory. In Experiment 2, the same result was found using counterfeit study lists that supposedly consisted of pictures or words. Experiments 3 and 4 showed that changes in the font used to present the study and test words also attenuated the contribution of fluency to the recognition decision when font change was manipulated between subjects, but not within subjects. Results suggest that the fluency heuristic is subject to metacognitive control, since participants' attributions of perceptual fluency depend on the perceived usefulness of fluency as a cue to recognition.

In their seminal paper, Tversky and Kahneman (1974) described several heuristics that are often adopted when decisions are made under conditions of uncertainty. For instance, when the probability that a particular event will occur is judged, the ease with which relevant examples of that event can be brought to mind has been found to influence the judgments that are made. Heuristics that are based on ease of processing have also been found to play a role in memory judgments (e.g., Kamas & Reder, 1995; Koriat & Levy-Sadot, 2001; Schacter, Israel, & Racine, 1999; Whittlesea & Leboe, 2000). A well known example is the use of the *fluency heuristic* in recognition memory (Jacoby & Dallas, 1981). Recognition memory judgments are influenced by the ease and speed (or fluency) with which a stimulus is processed on a recognition test. As compared with stimuli that are processed less fluently, stimuli that are perceived fluently relative to other stimuli presented in the same context are more likely to be judged as *old* on a recognition task (e.g., Higham & Vokey, 2000; Jacoby & Dallas, 1981; Jacoby & Whitehouse, 1989; Johnston, Hawley, & Elliott, 1991; Whittlesea, 1993; Whittlesea & Williams, 1998, 2000). The role of processing fluency as a heuristic in recognition memory is presumed to stem from participants' knowledge that stimuli that have been experienced previously are perceived more fluently when they are reencountered, as compared with novel stimuli (e.g., Jacoby & Dallas, 1981; Murrell & Morton, 1974; Neisser, 1954). It is theorized that, because prior experience facilitates later perceptual processing, a high level of processing fluency is used to infer past experience with a stimulus.[1]

The results of numerous perceptual priming experiments have shown that the degree to which the perceptual processing of a stimulus is facilitated by its previous presentation varies as a function of the perceptual match between its first and its second presentations (e.g., Clarke & Morton, 1983; Craik, Moscovitch, & McDowd, 1994; Durso & Johnson, 1979; Rajaram & Roediger, 1993; Srinivas, 1993). That is, the perceptual fluency of a stimulus is enhanced to a much greater degree when it is presented in the same sensory modality on both occasions than when it appears in a different modality on each occasion. Changes from an auditory to a visual presentation of a word results in an attenuated priming effect, as compared with situations in which both primes and targets are presented visually (e.g., Clarke & Morton, 1983; Ellis, 1982; Jacoby & Dallas, 1981; Rajaram & Roediger, 1993; Roediger & Blaxton, 1987).

There is some recent evidence that the *interpretation* of fluency as a sign of recognition memory is also sensitive to a match in sensory modality. Westerman, Lloyd, and Miller (2002) conducted a series of experiments in which a repetition priming procedure was used to enhance the fluency of recognition test items—a manipulation that typically leads to an illusion of recognition memory (e.g., Higham & Vokey, 2000; Jacoby & Whitehouse, 1989; Rajaram, 1993; Westerman, 2001). Replicating previous experimental results, Westerman et al. found that the prime increased positive recognition responses to test words that followed it, as long as the study phase had been presented in the same sensory modality as the priming and recognition test phase. When the study and the test phases were in different modalities (i.e., an auditory study list and visual priming and recog-

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nition phases), recognition responses were not affected by the priming phase that preceded test words.

Westerman et al.'s (2002) finding that the sensory match between the study and the test phases of the experiment moderates the role of fluency in recognition suggests that the fluency heuristic may depend on whether participants consider fluency to be relevant to the recognition decision. Because there is a greater increment in processing fluency when stimuli are repeated in the same sensory modality than when they are repeated in different modalities (e.g., Ellis, 1982; Jacoby & Dallas, 1981; Rajaram & Roediger, 1993), the attenuated role of fluency in Westerman et al.'s experiments may reflect an attributional process that is sensitive to the relevance of fluency to the recognition decision. That is, participants may discount the fluency of test items when their prior experience with the recognition targets do not lead them to expect more fluent processing of these items upon reoccurrence.

The results of Westerman et al. (2002) showed that a cross-modality change in perceptual form (a shift from an auditory to a visual presentation) reduces the role of perceptual fluency in recognition memory, a finding that suggests that participants may consider the relevance of fluency as a sign of previous experience when interpreting an enhanced sense of fluency for a test item. Research on perceptual priming effects has demonstrated that there are also within-modality changes in perceptual form that reduce the relevance of fluency as a sign of prior experience with a stimulus. For example, a switch from pictures to words in perceptual priming studies typically results in no or only negligible priming effects (e.g., Durso & Johnson, 1979; Rajaram & Roediger, 1993; Weldon, 1991). Reduced perceptual priming has also been found with changes in typography (Jacoby & Hayman, 1987; Roediger & Blaxton, 1987), although the reduction appears to be less robust than that which results from modality changes or from a change from pictures to words (e.g., Rajaram & Roediger, 1993). Because participants' use of fluency as a cue to recognition memory is presumed to stem from their knowledge that previously experienced stimuli are perceived more easily than are novel stimuli (e.g., Jacoby & Dallas, 1981; Whittlesea & Williams, 2001), the use of the fluency heuristic may vary depending on the perceptual match between the study and the test phases of a recognition memory experiment. That is, participants may be less likely to interpret fluency as a sign of prior experience when the study and the test phases include stimuli in different perceptual forms.

The question that is addressed in this study is whether the attribution of perceptual fluency to recognition memory is moderated by factors that influence the degree to which a previous presentation of a stimulus enhances its later perceptual processing. The variables that are considered in this study are within-modality perceptual changes that are known to moderate perceptual priming effects. The question at hand is whether these variables will also influence participants' reliance on the fluency heuristic in recognition memory. In each experiment, the surface forms of the stimuli were varied to create a perceptual match or a perceptual mismatch between the study and the test phases of the experiment. The recognition test and the priming phase consisted of words, and the test procedures were identical across all the experiments reported here. In Experiment 1, the perceptual match between the stimuli used in the study and the test phases was manipulated by showing either pictures or words during the study phase. In Experiment 2, a counterfeit list was shown, and the participants were told that the list consisted of either pictures or words. Experiments 3 and 4 used words as stimuli in both the study and the test phases but varied the font used to present the words. In each experiment, the fluency of half of the test items was enhanced by using a repetition priming technique that has been used in much previous work on this topic (e.g., Higham & Vokey, 2000; Jacoby & Whitehouse, 1989; Rajaram, 1993; Westerman, 2001; Westerman et al., 2002).

EXPERIMENT 1

The results of many priming studies have established that the amount of perceptual priming that occurs when a stimulus is reencountered is greatly diminished when pictures are used to prime word targets (e.g., Durso & Johnson, 1979; Rajaram & Roediger, 1993; Weldon, Roediger, Beitel, & Johnston, 1995; Weldon, Roediger, & Challis, 1989). In Experiment 1, we attempted to determine whether a switch from pictures during the study phase to words during the recognition phase would reduce the likelihood that participants would interpret fluency as a sign of previous experience with a test stimulus.

In Experiment 1, the participants studied either words or line drawings of objects during the study phase of the experiment. Later, they were given a recognition test that consisted of words. Half of the test words were primed just prior to their appearance on the test, a manipulation that typically produces an increase in positive recognition responses (e.g., Bernstein & Welch, 1991; Gellatly, Banton, & Woods, 1995; Jacoby & Whitehouse, 1989; Westerman, 2001). The question that was addressed was whether the shift from pictures to words would result in participants' being less likely to use fluency as a heuristic when making recognition judgments, as compared with a condition in which words appeared in both the study and the test phases.

Method

Design. Experiment 1 was conducted as a 2 (test item status: target or lure) × 2 (prime type: matching word or mismatching word) × 2 (type of stimuli presented on the study list: pictures or words) mixed factorial design. Test item status and prime type were manipulated within subjects, and the type of stimuli presented on the study phase was manipulated between subjects.

Participants. Eighty-eight students from the State University of New York at Binghamton participated to fulfill a course requirement. The participants were tested individually.

Materials. The stimuli were 126 pictures of objects that were obtained from the pool of line drawings supplied by Snodgrass and Vanderwart (1980). The word labels of the objects were also used, as well as an additional 60 labels from objects in the same pool. The study list consisted of either 66 pictures or 66 word labels. Sixty items were targets, which appeared on a subsequent recognition test, and 6 were buffers, which occupied the first and the last three serial positions of the study list. The order of the targets was freshly randomized for each participant. The recognition test consisted of 120 words; 60 were targets, which were the word labels of the 60 presented objects, and 60 words were lures, which were the labels of 60 nonpresented items from the same pool. The order of targets and lures was freshly randomized for each participant. Each recognition word was preceded by a briefly presented masked word. Either this word was the same as the test word that followed it (matching prime), or it was a word that did not match or bear any obvious relationship to the test word that followed it (mismatching prime). The status of the test word (target or lure) and the prime type (matching or mismatching) were counterbalanced so that, across participants, each item appeared equally often as a target and as a lure and each test item was preceded by a matching word and a mismatching word equally often. The words that were used as mismatching primes were the same for all the participants; however, the words that followed each type of prime varied depending on the counterbalancing condition.

Procedure. The participants were assigned randomly to either the picture list condition ($n = 40$) or the word list condition ($n = 48$). The experiment was conducted on a computer. The stimuli were presented on a 17-in. monitor, and the participants made their responses with a keyboard. Prior to the presentation of the study list, the participants were informed that they were in an experiment on human memory and were instructed to try to remember the items on the study list in preparation for a future memory test; however, the exact nature of the memory test was not disclosed. The participants saw a study list that consisted of 66 items. Each item was presented individually in the center of the computer screen and remained on the screen for 0.5 sec, with a 1-sec interval between items.

A recognition test was given immediately following the study phase. Both groups of participants were given identical recognition tests, and the procedures for the recognition test were explained to each participant before beginning the test. The recognition test consisted of words; therefore, the participants who saw the word list during the study phase experienced a perceptual match between study and test, whereas the participants who saw pictures during the study phase experienced a perceptual mismatch between study and test. The recognition test was self-paced. Each test consisted of 60 targets and 60 lures. Before each recognition test item appeared, a word was presented briefly in the center of the screen. The word was masked by a row of number signs that appeared immediately before and after it. The briefly presented prime was one of two types: It either matched the test word that followed it or did not match the test word that followed it. Each prime was presented for 34 msec and was masked by a row of number signs (############) that appeared for 250 msec immediately before and after the prime. After the presentation of the masked prime, the screen was cleared for 1 sec, and then the test item appeared. The participants were instructed to press the "y" key if they thought that the word had been on the study list and to press "n" if they thought that the word had not been on the study list. After the participants made a recognition decision, the screen cleared for 2 sec, and then the next prime and recognition trial began.

Results

The data (expressed as the proportion of *yes* [*old*] responses) are summarized in Table 1. A 2 × 2 × 2 (status [target or lure] × prime type [matching or mismatching] × study list stimuli [pictures or words]) mixed analysis of variance (ANOVA) was conducted on the proportion of *yes* responses to each type of test item. A .05 significance criterion was used in interpreting the results of all the statistical analyses. There was a main effect for test item status; targets were more likely to be classified as targets than were lures [$F(1,86) = 1{,}019.16$, $MS_e = 0.02$]. There was a main effect for prime type; test items in the matching prime condition received more *yes* responses than did test items in the mismatching prime condition [$F(1,86) = 16.76$, $MS_e = 0.01$]. There was not a main effect for the type of stimuli on the study list [$F(1,86) < 1$, $MS_e = 0.04$]. There was no interaction between test item status and prime type [$F(1,86) = 1.23$, $MS_e = 0.001$] or between item status, prime type, and stimuli [$F(1,86) < 1$, $MS_e = 0.01$].

Table 1
Mean Proportions of *Yes* Responses by Test Item Status and Prime Type for Experiments 1 and 2

Test Item	Prime Type: Matched *M*	Matched *SE*	Control *M*	Control *SE*	Priming Effect
Experiment 1					
Studied words					
Target	.69	.02	.63	.02	.06
Lure	.23	.02	.16	.02	.07
Studied pictures					
Target	.73	.02	.73	.02	.00
Lure	.15	.02	.14	.02	.01
Experiment 2					
Type of counterfeit list					
Words	.61	.03	.40	.03	.21
Pictures	.40	.04	.34	.03	.06

The analysis most important for the question addressed by this experiment is the interaction between the type of stimuli presented on the study list and the type of prime that preceded test words. This interaction was significant [$F(1,86) = 11.62$, $MS_e = 0.01$]. To interpret the interaction, the proportions of *yes* responses were collapsed across targets and lures, and separate planned comparisons were carried out for the group that experienced a perceptual match between the study and the test phases (i.e., the participants who saw words during both phases) and for the group that experienced a perceptual mismatch between the study and the test phases (i.e., the participants who saw pictures during the study phase and words on the recognition test). When words occurred on the study list, the matching prime had the effect of increasing *old* responses to test words preceded by a matching prime [$t(47) = 5.56$, $SE = 0.01$]. However, the prime did not have a reliable effect on recognition when there was a mismatch in the perceptual form of the stimuli presented at study and at test [$t(39) = 0.51$, $SE = 0.01$, $p > .60$].

The signal detection estimates of sensitivity and bias, d_L and C_L were also analyzed (see Table 3 for a summary). This analysis revealed that there was not a difference in sensitivity depending on the priming condition or on the composition of the study list. Because the priming manipulation led to an increase in both hits and false alarms, it influenced the response bias measure. The results replicated those found when the proportion of *yes* responses was used as the dependent variable, since there was a significant prime × modality interaction [$F(1,86) = 7.68$, $MS_e = 0.75$]. The interaction revealed that the degree to which the priming manipulation lowered the participants' response criterion depended on whether pictures or words were presented on the study list.

We see two possible interpretations for the present results. One interpretation is that the participants discounted perceptual fluency as a cue to recognition memory when there was not a perceptual match between the study and the test phases. In other words, even though the study and the test phases were presented in the same sensory modality, the shift from pictures to words may be analogous to the effect of a shift in sensory modality between the study and the test phases (Westerman et al., 2002). Because the study phase included only pictures, the fluency of recognition test words was not regarded as a sign that the corresponding picture had appeared earlier. A second possible interpretation of the interaction found in Experiment 1 stems from the distinction between familiarity and recollection that is advocated by dual-process models of recognition memory (e.g., Jacoby, 1991; Mandler, 1980; Yonelinas, 1999; for a review, see Yonelinas, 2002). Specifically, experimental work on the contribution of recollection to recognition decisions has shown that the probability of recollection-based retrieval is higher when pictures are targets than when words are targets (e.g., Dewhurst & Conway, 1994; Rajaram, 1996; Wagner, Gabrieli, & Verfaellie, 1997). Therefore, it may be that the greater contribution of recollection to recognition decisions reduces participants' reliance on the fluency heuristic. A recent study by Westerman (2001) offers some support for such an interpretation. Using the same priming technique as that used in the present experiment, Westerman (Experiment 1) found that enhanced fluency did not affect associative recognition, a task that is theorized to be largely dependent on recollection (e.g., Clark, 1992; Hockley & Consoli, 1999; Yonelinas, 1997). Given that the fluency heuristic is not used on recognition tests that are based largely on recollection, it is possible that the null effect of the prime that occurred when pictures were studied is the result of a greater reliance on recollection for the group that studied pictures. In Experiment 2, we attempted to determine which explanation is a more fitting account of the results of Experiment 1 by using a counterfeit study list to eliminate the possibility that participants were basing their responses on their recollection of the study list.

EXPERIMENT 2

The results of Experiment 1 showed that the priming manipulation had a greater effect on recognition responses when words were presented during the study phase than when pictures were presented during the study phase. Experiment 2 was conducted to determine whether the results were due to a greater reliance on recollection for the participants who saw pictures during the study phase. Experiment 2 was similar to Experiment 1. The primary difference was that a counterfeit study list was used in place of a real study list (similar methods have been used recently by Frigo, Reas, & LeCompte, 1999, Verfaellie & Cermak, 1999, and Westerman et al., 2002). The purpose of the counterfeit list was to make the recollection of the study list impossible. The participants were told that they were in an experiment investigating subliminal perception and its effect on memory. The participants were randomly assigned to one of two groups; one group was told that their subliminal list consisted of words, and the other group was told that their subliminal list consisted of pictures. In actuality, the "word" and "picture" lists were identical displays of visual noise. Later, the participants were given a memory test that was identical to that given in Experiment 1, except that the participants were asked to judge the words as being familiar or not familiar. As in Experiment 1, half of the test words were preceded by a matching word prime in order to enhance the processing fluency of these items.

If the interaction between stimulus type and the priming manipulation that was observed in Experiment 1 was due to participants' discounting perceptual fluency when it was irrelevant to the recognition decision, the interaction should occur even when a counterfeit list is used. On the other hand, if the interaction was due to the greater use of recollection for the group that studied pictures, it should not persist when a counterfeit list is used, since it seems unlikely that participants would adopt a recollection-based recognition strategy when only visual noise was presented in the study phase.

Method

Design. Experiment 2 was conducted as a 2 (prime type: matching word or mismatching word) × 2 (counterfeit list instructions: pictures or words) mixed factorial design. Prime type was manipulated within subjects, and the instructions about the nature of the counterfeit list were manipulated between subjects. The dependent variable was the proportion of *yes* responses in each condition.

Participants. Sixty students from the State University of New York at Binghamton participated to fulfill a course requirement. The participants were tested individually.

Materials and Procedure. The materials and procedure were similar to those in Experiment 1. The primary difference was that there were no words or pictures presented during the study phase. The participants were told that the study list was subliminal. The supposed physical form of the items on the study list was manipulated between subjects. Approximately half ($n = 32$) of the participants were told that they were presented with a list of words that were the names of common objects, and approximately half ($n = 28$) of the participants were told that they were presented with a list of pictures of common objects. All the participants were actually presented with identical lists of static. To encourage the participants to believe that we were actually presenting meaningful material during the study phase, a pseudocalibration phase preceded the counterfeit list. The calibration phase consisted of eight trials in which a word or a picture (depending on whether the participant was in the word list or the picture list group) was presented in a heavy visual mask. Each participant was instructed to read the word aloud or to name the picture aloud. With successive calibration trials, the word was presented more briefly, and the mask got heavier. After five calibration trials, there were no words that were actually presented, only visual noise. Nevertheless, the participants were encouraged to try to name the "words" or the "pictures." We told each participant that the timing and the masking level of the subliminal list would be the same as those on the last trial of the calibration phase. The study list consisted of the same sort of visual mask as that presented in the calibration phase. The study list consisted of 60 briefly presented 15.5 × 11.5 cm visual masks. To give the masks a dynamic appearance, each mask consisted of a trio of slightly different rectangular displays of static; the first static display was presented for 255 msec, the second for 34 msec, and the third for 255 msec. Each trio of masks was separated by a 1-sec interstimulus interval. There were four slightly different static displays, which were presented in a random order. The purpose of having slightly different masks appear on the counterfeit list was to try to increase the participants' belief that the information (i.e., the word or the picture) that was embedded in the mask was different on each trial. The participants were told that the target stimulus was embedded in the visual mask and would appear so quickly that they probably would not be aware of its presence. They were asked to keep their eyes on the screen and to watch the subliminal list.

A recognition test immediately followed the presentation of the counterfeit study list. The recognition test was identical to that described in Experiment 1, with two exceptions. First, they were instructed to keep the ratio of old and new test words in mind and to respond *yes* to approximately half of the words on the recognition test even if they felt that they were guessing. Second, the participants were told that when information is presented subliminally, it might seem familiar if it appears again, even if the person is not aware of having seen the information previously. Therefore, they were encouraged to respond *yes* to a word if it "seemed familiar" even if they did not feel as though they had a memory for that item. Each recognition test word was preceded by a priming phase identical to that described in the Procedure section of Experiment 1. After the recognition test, the participants were fully debriefed as to the true nature of the experiment.

Results

The purpose of Experiment 2 was to determine whether the type of stimulus that was supposedly presented in the study phase would influence the role of perceptual fluency on the memory test. The participants complied with the instructions to respond *yes* on approximately half of the test trials, since they responded *yes* to 45% of the test items. There were 3 participants who responded *no* to every single test item; their data were omitted from the analyses. In addition, one extreme outlier was identified in the picture list condition (the priming effect for this individual was 3.2 standard deviations from the mean, and the elimination of this individual's data improved the normality of the data). A summary of the data is presented in Table 1. A 2 × 2 (prime type [matched or mismatched] × instructions [subliminal picture or subliminal words]) mixed-factor ANOVA was conducted on the proportion of *yes* responses to test items. This analysis revealed a main effect for prime type [$F(1,54) = 16.70$, $MS_e = 0.03$]; test words preceded by a matching word prime were more likely to be called *old* than were test words that were preceded by a mismatching word prime. There was also a main effect for the instructions given to the participants about the nature of the study list [$F(1,54) = 21.90$, $MS_e = 0.02$]; the participants were more likely to respond *yes* when they were told that the subliminal list consisted of words ($M = .50$) than when it consisted of pictures ($M = .37$). The main effect for type of counterfeit study list appears to be a result of the interaction between prime type and the nature of the stimuli that was supposedly on the study list. This interaction was significant [$F(1,54) = 4.87$, $MS_e = 0.03$]. As can be seen in Table 2, the priming effect was much larger for the group that was told that the subliminal list consisted of words than for the group that was told that the study list consisted of pictures (.21 and .06, respectively). Planned comparisons on the effect of the prime on each group of participants showed that the priming manipulation had a significant effect when the participants were told that the stimuli were words, but not when they were told that the stimuli were pictures [$t(28) = 3.75$, $SE = 0.05$, for the word study group, and $t(26) = 1.60$, $SE = 0.04$, for the picture study group].

Despite the difference in the study phases, the results of Experiment 2 mimic those of Experiment 1, since the type of stimuli that was supposedly presented on the study list moderated the influence of the prime on recognition judgments. This result suggests that the interaction between supposed study form and priming effects is due to participants' expectations about the relevance of fluency to the recognition decision, rather than to a differential contribution of recollection to recognition decisions when pictures and words are studied. Indeed, the results of Experiment 2 show that stimulus change between the study and the test phases will attenuate the use of the fluency heuristic even in the complete absence of memory for the study list.

Consistent with previous research (Westerman et al., 2002), a larger priming effect was observed with the counterfeit word list than with the real word list that was used in Experiment 1. We suspect that the priming ma-

Table 2
Mean Proportions of Positive Responses by Status, Font, and Prime Conditions for Experiments 3 and 4

Status	Prime Type: Matched *M*	*SE*	Control *M*	*SE*	Priming Effect
Experiment 3					
Same font at study and test					
Target	.78	.02	.69	.02	.09
Lure	.31	.03	.20	.02	.11
Different font at study and test					
Target	.75	.02	.74	.02	.01
Lure	.24	.02	.17	.02	.07
Experiment 4					
Same font target	.70	.02	.64	.02	.06
Different font target	.73	.02	.68	.03	.05
Lure	.36	.02	.25	.02	.11

nipulation had a larger effect when a counterfeit list was presented than when a real list was presented because participants who study a real list can rely on their memory for the study list, whereas participants who study a counterfeit list cannot. Because the relative contribution of fluency to recognition increases as the probability of recollection decreases (Johnston et al., 1991; Lloyd, Westerman, & Miller, 2003; Verfaellie & Cermak, 1999; Westerman, 2001; Westerman et al., 2002; Whittlesea, 1993; for a recent review, see Kelley & Rhodes, 2002), it is not surprising that a larger priming effect would be found in situations in which recollection is impossible. A similar explanation may be applied to the finding that in a typical recognition memory experiment that includes targets and lures, the effect of the priming manipulation is often greater for lures (which cannot be recollected) than for targets (which sometimes can be recollected).

EXPERIMENT 3

In Experiment 3, we investigated whether the attribution of perceptual fluency to recognition memory would be affected by a more subtle change in perceptual form between study and test. The experiment was identical to the visual study list group in Experiment 1, except that the appearance of the words was manipulated by varying the font used to present the study list and the stimuli were drawn from a different word pool. Past research on the effect of typography changes on perceptual priming effects has produced mixed results, with some researchers finding that priming effects are attenuated as a result of font changes (e.g., Jacoby & Hayman, 1987; Roediger & Blaxton, 1987) and others observing no reduction in priming effects as a result of font changes (e.g., Rajaram & Roediger, 1993). Because of the mixed results found on tests of perceptual priming after changes in typography, we changed the font dramatically in order to provide a strong test of the hypothesis that changes in typography would attenuate the role of fluency in recognition memory. The size, color, and typography were varied between the study and the test phases of the experiment to create a dramatic difference in the perceptual form of the words presented in the study and the test phases for participants in the font change condition. The central question of this experiment was whether the participants who saw the test word in a particular font during the initial study phase would use perceptual fluency as a cue to memory when the recognition test words were presented in a font that was very different from that used in the study phase.

Method

Design. Experiment 3 was conducted as a 2 (test item status: target or lure) × 2 (prime type: matching word or mismatching word) × 2 (font: change or no change) mixed factorial design. Test item status and prime type were manipulated within subjects, and font change was manipulated between subjects.

Participants. Ninety students from the State University of New York at Binghamton participated to fulfill a course requirement. The participants were tested individually.

Materials and Procedure. The materials and procedure were identical to those for the word list group in Experiment 1, with two exceptions. First, the stimuli were 126 eight- and nine-letter words obtained from the pool supplied by Kučera and Francis (1967; mean word frequency was 70 per one million). Second, the font used to present the words on the study list was manipulated between subjects. Approximately half (n = 48) of the participants saw words presented in a different font during the study and the test phases of the experiment. The other group of participants (n = 42) saw words in the same font during the study and the test phases. The group that saw the words in a different font at study were presented with a study list that consisted of words printed in large (56 point) red Comic Sans MS font and a test list of words in small (14 point) black Arial font. The participants who saw the same font at study and at test saw all the words in the small black Arial font. In all other respects, Experiment 3 was identical to the word study list condition in Experiment 1.

Results

The results of Experiment 3 are summarized in Table 2. A 2 × 2 × 2 (status [target or lure] × prime type [matching or mismatching] × font [changed or not changed]) mixed-factor ANOVA was conducted on the proportions of *yes* responses given to test items. There was a main effect for the actual status of test items; targets were given more positive responses than were lures [$F(1,88) = 738.98$, $MS_e = 0.03$]. There was also a main effect for the type of prime that preceded test items. Test words that were preceded by a matching prime were more likely to be called *old* than those that were preceded by a mismatching prime [$F(1,88) = 35.45$]. There was not a main effect for the type of font used to present words on the study list [$F(1,88) = 1.16$, $MS_e = 0.03$]. The interaction between status and font approached statistical significance [F(1,88) = 3.16, 8, $MS_e = 0.03$, $p < .08$], as did the interaction between test item status and prime type [$F(1,88) = 2.82$, $MS_e = 0.01$, $p < .09$]. The three-way interaction of status, prime, and font change was not significant [$F(1,88) < 1$, $MS_e = 0.03$].

The goal of this experiment was to compare the effect of the prime on recognition responses when words were presented in the same or a different font during the study and the test phases. Therefore, the result most relevant to the question is the interaction between the type of font used for the study list and the type of prime that preceded the test words. This interaction was significant [$F(1,88) = 6.216$, $MS_e = 0.08$]. There was a larger priming effect for the group that experienced the experimental stimuli in the same font during both the study and the test phases than for the group that experienced the stimuli in a different font during the study and the test phases (.10 and .04, respectively). Separate 2 × 2 (priming condition × status) repeated measures ANOVAs carried out on the results from the same-font group and the changed-font group revealed that the priming phase has a significant effect of recognition responses for both groups [$F(1,47) = 8.87$,

MS_e = 0.01, for the changed-font group, and $F(1,41)$ = 25.41, MS_e = 0.02, for the same-font group]. However, the reliable interaction that was found when both groups were included in the analyses demonstrates that the effect was significantly larger when the same font was used during the study and the test phases, suggesting that, although fluency was used as a heuristic for both groups, it played a greater role in recognition responses when the study and the test words were presented in the same font. This result demonstrates that relatively superficial changes (the color, size, and shape of the letters) in the appearance of the words across the study and the test portions of the experiment will also reduce the use of fluency as a heuristic in memory.

Analyses carried out on the signal detection estimates of sensitivity and bias, d_L and C_L (see Table 3), showed that there was not a difference in sensitivity, depending on the priming condition or the composition of the study list. The priming manipulation did affect the bias measure. The results replicated those found when the proportion of *yes* responses was used as the dependent variable, since there was a significant prime × modality interaction [$F(1,88) = 4.48$, $MS_e = 0.20$]. The interaction revealed that the degree to which the priming manipulation lowered the participants' response criterion depended on whether the words were presented in the same or a different font on the study list.

EXPERIMENT 4

In Experiment 3, changing the font of the words used in the study and the test phases of the experiment reduced the influence of fluency on recognition memory judgments. This result is consistent with the idea that participants are sensitive to the degree to which there is a perceptual match between the stimuli used in the study and the test phases of an experiment and that the attribution of fluency to recognition memory depends on this factor. This supports the notion that the relevance of processing fluency as a cue to recognition memory affects the degree to which fluency will influence recognition judgments, with the relevance being determined by the degree of perceptual match between the study and the test phases of an experiment. Experiment 4 was conducted to find converging evidence for this interpretation. Experiment 4 was identical to Experiment 3, except that font change was manipulated within subjects. The rationale for a within-subjects manipulation was that if some of the words on the study list had appeared in the same font as the words on the recognition test, fluency might be viewed as a relevant cue to recognition. If this is the case, the priming manipulation might lead to an increase in positive recognition responses for all test items, including targets that appeared in a different font during the study phase of the experiment.

A second motivation for the within-subjects manipulation of font type was to rule out the possibility that the results of Experiment 3 were due to some factor related to the presentation of words in a large red font. Because Experiment 3 was unbalanced insofar as there was not a group of participants who saw words in a large red font and had a recognition test with the same type of stimuli, it is possible that the results were due to factors specific to the font and not to the perceptual match between the study and the test phases. For example, perhaps words that were previously presented in large red fonts were not susceptible to priming effects, for reasons not considered here. A within-subjects manipulation of font would help to address this concern.

Method

Design. Experiment 4 was conducted as a 2 (test item status: target or lure) × 2 (prime type: matching word or mismatching word) × 2 (font: change or no change) repeated measures design.

Table 3
Signal Detection Estimates d_L and C_L for Experiments 1, 3, and 4

	Prime Type							
	Matched				Control			
	d_L		C_L		d_L		C_L	
Condition	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Experiment 1								
Studied words	2.22	.17	.26	.10	2.34	.16	.62	.10
Studied pictures	3.03	.19	.48	.11	3.20	.18	.50	.11
Experiment 3								
Same font	2.15	.18	−.22	.09	2.31	.20	.31	.08
Different font	2.38	.17	.01	.09	2.71	.19	.26	.08
Experiment 4								
Same font	1.52	.14	−.12	.08	1.78	.14	.26	.09
Different font	1.68	.16	−.20	.08	1.97	.15	.16	.08

Note—d_L and C_L are signal detection measures of discrimination and bias, respectively, which are based on a logistic distribution, rather than a normal distribution (see Snodgrass & Corwin, 1988, for a comparison with other signal detection measures).

Participants. Fifty-seven students from the State University of New York at Binghamton participated to fulfill a course requirement. The participants were tested individually.

Materials and Procedure. The materials and procedure were identical to those in Experiment 3, with one exception: The presentation font was manipulated within subjects. The participants studied 60 words; 30 were in a large red font, and 30 were in a small black font. The large red and small black words were randomly intermixed on the study list, and each participant received a different random ordering of study words. The recognition test was identical to that in Experiment 3. The participants were instructed to respond *yes* to a word that had been presented in the earlier study phase, regardless of whether it had appeared in a red or a black font. *Old/new* status, priming condition, and font were counterbalanced so that, across participants, each word appeared equally often as a target and a lure, was preceded equally often by a matched and an unmatched prime, and appeared equally often in a small black and a large red font.

Results

The data (expressed as the proportion of *yes* responses) are summarized in Table 2. To analyze the overall effect of the prime on recognition responses, the proportion of *yes* responses to targets was collapsed across font type. A 2 × 2 (status [target or lure] × prime type [matching or mismatching]) ANOVA conducted on the proportion of *yes* responses revealed a main effect for test item status; targets were more likely to be classified as targets than were lures [$F(1,56) = 352.32$, $MS_e = 0.02$]. There was also a main effect for prime type; test items in the matching prime condition received more *yes* responses than did items in the mismatching prime condition [$F(1,56) = 22.49$, $MS_e = 0.02$]. The interaction between the effect of the prime and the status of the test items approached statistical significance [$F(1,56) = 3.12$, $MS_e = 0.01$. $p < .09$].

To determine whether there was a difference in the effect of the prime on recognition responses to old items depending on the form of presentation, the proportion of *yes* responses were analyzed for targets only, using a 2 × 2 (prime type [matched vs. mismatched] × font [same vs. different]) repeated measures ANOVA. This analysis showed a main effect for prime type [$F(1,56) = 4.40$, $MS_e = 0.04$]; words preceded by a matching prime were called *old* more often than those preceded by a mismatching prime. Words that were presented in a large red font during the study phase were more likely to be recognized as targets than were words presented in the small black font [$F(1,56) = 4.60$, $MS_e = 0.01$], probably because the red font made the words very distinctive. In contrast to the results of Experiment 3, there was no difference in the effect of the priming manipulation depending on whether targets had been presented in the same or in a different font than that used to present the word on the study list [$F(1,56) < 1$, $MS_e = 0.02$]. Indeed, as is shown in Table 2, the priming effects were very similar for both classes of items (*M*s = .05 and .06 for the targets presented in red and black fonts, respectively). That is, the participants had a tendency to call old items primed with matching words *old*, and this tendency did not vary according to the font used to present the targets during the study phase. These results suggest that the results of Experiment 3, which showed an attenuated priming effect when the targets were shown in a different font during the study and the test phases, were not due to the font per se, since targets presented in a large red font were judged as being *old* more often as a result of the priming manipulation in this experiment. These results suggest that when fluency was a relevant sign of previous occurrence for half of the target items, the fluency of processing test items was interpreted as a sign of prior occurrence.

The signal detection estimates d_L and C_L were also calculated, and the results replicated those that were found when the proportion of *yes* responses was used as the dependent variable. There was a significant difference in sensitivity as a function of font [$F(1,56) = 5.10$, $MS_e = 0.33$], since discrimination was better for targets that had been presented in the large red font than for targets that had been presented in the small black font. Response bias varied as a function of prime type [$F(1,56) = 17.54$, $MS_e = 0.46$], and there was no significant prime × font interaction [$F(1,56) < 1$, $MS_e = 0.11$]. No other main effects or interactions were significant.

The different effects observed with a between-subjects and within-subjects manipulation are consistent with other recent findings. Experiments conducted by Whittlesea and Williams (1998, 2000, 2001) showed how the attribution of fluency to recognition was greatly attenuated when alternate sources of fluency were made more salient. However, Whittlesea and Williams (2001, Experiments 3a and 3b) also found that this was true only when the salience of the alternate source was manipulated between subjects. When the salience of other sources was manipulated within subjects, participants did not discount fluency on the trials for which an alternate source of fluency was obvious, suggesting that the participants adopted a consistent interpretation of fluency for all the test trials. In their investigation of the effect of modality match on the use of the fluency heuristic, Westerman et al. (2002) also found different effects, depending on whether sensory modality was manipulated between or within subjects. When modality was manipulated between subjects, enhanced fluency did not influence recognition responses for the modality mismatch group; however, when modality was varied within subjects, the fluency manipulation influenced all the test items, regardless of their presentation modality on the study list.

DISCUSSION

The attenuation of perceptual priming effects with changes in perceptual form is well known among memory researchers. The present results suggest that experimental participants may also be knowledgeable (at least tacitly) of this relationship, since the use of the fluency heuristic was attenuated in situations in which the previous presentation of a stimulus would be expected to lead to an attenuated facilitation of processing fluency. The present results highlight the sophistication of the attributional process that mediates the relationship between processing fluency and recognition memory and show how the fluency heuristic is subject to metacognitive control.

The purpose of this study was to determine whether within-modality changes in perceptual form between the study and the test phases of an experiment would moderate the use of the fluency heuristic in recognition memory. The results of the present experiments show that the fluency heuristic is more likely to be used on a recognition test when the stimuli presented in the study and the test phases share the same perceptual form than when the perceptual forms of the stimuli are changed from study to test. In Experiment 1, the participants were less likely to interpret enhanced processing fluency as a sign of recognition memory when there was a change from pictures in the study phase to words in the recognition phase. Similarly, in Experiment 3, a change in the font used to present study and test words also reduced the role of fluency in recognition memory. These results extend the findings reported by Westerman et al. (2002), which showed that changes in sensory modality between the study and the test phases of an experiment reduces the use of the fluency heuristic in recognition memory, by showing that within-modality changes also diminish the role of fluency in recognition memory.

Although changes in perceptual form were found to moderate the role of fluency in recognition, the results also show that it is not the change in perceptual form per se that is the critical factor. One finding that points to this interpretation is that the interaction between the effect of the prime and the change in the font was found only when font change was manipulated between subjects (Experiment 3). When font change was manipulated within subjects (Experiment 4), the priming manipulation had a uniform effect on same-font and different-font targets. This finding suggests that as long as some of the test words had appeared in the same font during the study phase, the enhanced fluency of primed test items was interpreted as a sign of previous occurrence for all test items. The results of font change experiments are consistent with the recent findings of Westerman et al. (2002, Experiments 1 and 2), who found that a change in sensory modality attenuated the role of processing fluency in recognition judgments when modality was manipulated between subjects, but not when it was manipulated within subjects.

The important role that participants' expectations play in the attribution of fluency to recognition memory is further highlighted by the results of Experiment 2. In Experiment 2, the participants' impressions of a perceptual match or mismatch between the study and the test phases was manipulated by changing the instructions given prior to the presentation of the counterfeit study list. In this experiment, the influence of the priming manipulation on the participants' familiarity judgments was much smaller when they were told that the study list consisted of pictures than when they were told that it consisted of words. The interaction between the effect of the priming manipulation and the instructions given to the participants about the contents of the list strongly suggests that the locus of the interaction between perceptual match and processing fluency is at the level of participants' expectations. When participants believe that there is a match between the nature of the stimuli used during the study and the test phases, fluency is more likely to be interpreted as a sense of familiarity; when there is not a match in perceptual form between the study and the test stimuli, participants do not interpret fluency as familiarity with the test item.

The present results bear a resemblance to a recent set of experiments by Dodson and Schacter (2002), who also investigated the use of heuristics in memory judgments. Their paper focused on the *distinctiveness heuristic* (Schacter et al., 1999) in recognition memory. The distinctiveness heuristic has been theorized to be a heuristic used by participants after studying stimuli that are especially distinctive (such as pictures). There is evidence that a participant's ability (or inability) to recollect distinctive details about a test stimulus is used to discriminate between old and new items on a recognition test. Similar to the results of the present study, Dodson and Schacter's study showed that the use of the distinctiveness heuristic is moderated by the degree to which it is relevant to the recognition decision. For example, they found that the distinctiveness heuristic is used on a recognition test as long as some of the targets had been distinctive (i.e., presented as pictures) during the encoding phase. This result is similar to the results of the present study, insofar as the fluency heuristic was more likely to be used on a recognition test when some of the items on the study list had been presented in the same font as the test words (Experiment 4). Dodson and Schacter also manipulated participants' expectations about the relevance of the distinctiveness heuristic by altering the instructions given to the participants and found that the participants' reliance on the distinctiveness heuristic depended on the degree to which they expected target items to be distinctive. The results of the present experiments similarly show that the use of heuristics in memory is not reflexive. Rather, the results suggest that the use of the fluency heuristic depends on the degree to which the participants perceive the heuristic to be a useful aid to recognition.

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NOTE

1. High levels of fluency are not always interpreted as a sign that the stimulus occurred in the past. Rather, enhanced fluency is sometimes attributed to the current processing of the stimulus. For example, fluency can be interpreted as affective preference (Whittlesea & Price, 2001), perceptual clarity (Goldinger, Kleider, & Shelley, 1999; Masson & Caldwell, 1998; Whittlesea, 1993), or fame (Jacoby, Woloshyn, & Kelley, 1989), depending on which source is viewed by the participant as the most likely.

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