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Word-Identification Priming for Ignored and Attended Words

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Three experiments examined contributions of study phase awareness of word identity to subsequent word-identification priming by manipulating visual attention to words at study. In Experiment 1, word-identification priming was reduced for ignored relative to attended words, even though ignored words were identified sufficiently to produce negative priming in the study phase. Word-identification priming was also reduced after color naming relative to emotional valence rating (Experiment 2) or word reading (Experiment 3), even though an effect of emotional valence upon color naming (Experiment 2) indicated that words were identified at study. Thus, word-identification priming was reduced even when word identification occurred at study. Word-identification priming may depend on awareness of word identity at the time of study. © 1998 Academic Press

An important distinction between memory tests is whether they require conscious recollection of the study episode at the time of testing. Direct tests, such as recall or recognition, require explicitly that participants consciously recollect the study phase occurrence of stimuli (Graf & Schacter, 1985). Indirect tests do not require conscious recollection of study phase episodes and measure memory implicitly, by experience-induced changes in performance (e.g., Tulving & Schacter, 1990). For example, repetition priming tasks measure memory as the change in speed, accuracy, or bias in responses to studied relative to baseline items. Priming is often intact in amnesic patients who cannot recollect study episodes (Cermak, Talbot, Chandler, & Wolbast, 1985; Graf, Shimamura, & Squire, 1985; Graf, Squire, & Mandler, 1984; Shimamura, 1986; Vaidya, Gabrieli, Keane, & Monti, 1995; Verfaellie, Cermak, Letourneau, & Zuffante, 1991) and independent of performance on direct tests of recall or recognition in young, healthy participants (e.g., Tulving, Schacter, & Stark, 1982). Thus, different neural systems and memory processes appear to mediate explicit and implicit memory retrieval.

Most studies that compare performance on indirect and direct tests of memory focus on contributions of conscious awareness of study phase experience with stimuli during retrieval, i.e., at the time of test. Less is known about the effects of stimulus awareness at encoding (at the time of study) on subsequent performance on direct versus indirect tests. Awareness can be manipulated in different ways (Greenwald, Draine, & Abrams, 1996). One way of manipulating awareness is by using subthreshold presentation of stimuli, by presenting them very briefly and/or heavily masking the presentation. Under these conditions, full attention is allocated to the stimulus, but the perceptual input is too impoverished to allow stimulus identification. Short-term semantic and/or repetition priming can occur after subthreshold presentation, but only if the priming is measured immediately, within seconds, after the original

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subthreshold presentation (Cheesman & Merikle, 1986; Forster & Davis, 1984; Greenwald et al., 1996; Groeger, 1984; Holender, 1986; Marcel, 1980, 1983; Merikle, 1992; Merikle & Reingold, 1990). Attempts to obtain long-term priming several minutes after subthreshold presentation have not been successful (e.g., Forster & Davis, 1984; Graf & Schacter, 1985; Greenwald et al., 1996; Norman, 1993). The only exception is the mere exposure effect, which measures preference for previously seen stimuli (e.g., Kunst-Wilson & Zajonc, 1980; Mandler, Nakamura, & Van Zandt, 1987). However, this form of priming may differ from other implicit memory measures, because it is affective (Zajonc, 1968). The relationship between this special form of priming and standard implicit memory measures is discussed elsewhere (e.g., Bornstein, 1992; Murphy & Zajonc, 1993).

Another way of manipulating study phase awareness is by dividing or eliminating attention to suprathreshold stimuli at study. Under these conditions conscious stimulus identification is reduced or prevented because attention is allocated to another stimulus or a stimulus dimension unrelated to identity. Explicit memory for stimuli is consistently diminished if attention to stimuli is divided at study (Allport, Antonis, & Reynolds, 1972; Anderson & Craik, 1974; Eich, 1984; Glucksberg & Cohen, 1970; Kellog, 1980; Morray, 1959; Norman, 1969; Parkin, Reid, & Russo, 1990; Parkin & Russo, 1990; Weldon & Jackson-Barrett, 1993).

The role of study phase attention for priming, however, is more variable. Division of attention at study reduces priming in some cases (Eich, 1984; Gabrieli et al., 1995; Mulligan & Hartman, 1996; Weldon & Jackson-Barrett, 1993), but not in other cases (Koriat & Feuerstein, 1976; Parkin et al., 1990; Parkin & Russo, 1990). Mulligan (Mulligan, 1997; Mulligan & Hartman, 1996) has suggested that these variable results reflect the distinction between conceptual and perceptual priming (Roediger, Weldon, & Challis, 1989; Roediger & McDermott, 1993). Conceptual priming is based on stimulus meaning and is enhanced by semantic, relative to nonsemantic, tasks. Perceptual priming is based on stimulus form and is enhanced by the match between stimulus form at study and test (e.g., it is reduced if there is a change in modality from study to test). Mulligan has proposed that conceptual priming demands attention at study, whereas perceptual priming does not.

Word-identification priming is perhaps the best documented example of perceptual priming, because it is reduced by study–test changes of modality or font (Jacoby & Dallas, 1981; Jacoby & Hayman, 1987; Kelley, Jacoby, & Hollingshead, 1989). Conceptual influences upon this test are considered minimal because priming is unaffected by manipulations that vary conceptual encoding (Graf & Ryan, 1990; Jacoby & Dallas, 1981; Roediger & McDermott, 1993, but see Brown & Mitchell, 1994; Thapar & Greene, 1994). In a typical word-identification experiment, participants are exposed to words in a study phase. In a test phase, studied and baseline (unstudied) words are presented near identification threshold. Priming is measured by how much more accurately studied words are identified relative to baseline words (Jacoby & Dallas, 1981). In several experiments (Gabrieli et al., 1995), division of attention at study via auditory shadowing or digit monitoring tasks did not diminish visual word-identification priming, even though it reduced performance on tests of recognition, cued-recall, and conceptual priming.

An earlier experiment, however, established that manipulation of selective attention can eliminate word-identification priming (Hayman & Jacoby, 1989). Unlike divided attention manipulations, selective attention manipulations require that participants ignore word identity all together. This experiment compared three study phase tasks: Letter search with target letters presented either before (precue condition) or after (postcue condition) the letter string and lexical decision (deciding if a string of letters constitutes an English word). To determine whether word encoding occurred in the two letter search conditions, the speed of letter search in words versus nonsense letter strings was examined. The word superiority effect, faster letter search for words than for nonsense letter strings (Reicher, 1969; Wheeler, 1970), was used as evidence for word-level encoding. The word superiority effect was obtained in the postcue, but *not* in the precue, condition. These results provided evidence for word encoding in the postcue, but *not* in the precue, condition. At test, significant priming was observed after postcue letter search and lexical decision tasks, but *no* priming was observed after the precue letter search task. Thus, word-identification priming depended upon processing of word identity and/or awareness of word identity at study.

Other measures of perceptual priming were also shown to be susceptible to the manipulations of attention. For example, selective attention to words was important when priming was measured using a word-clarification procedure in which participants saw words obscured by a mask of random dots that were gradually removed until the participant could identify the word. In a study by Johnston and Dark (1985), participants monitored two of four locations on the screen. On each trial, they saw two words presented foveally, one appearing in a designated location and one appearing in a to-be-ignored location, and reported only the words in the designated location. At test, participants were faster to identify attended rather than new or unattended words. Hawley and Johnston (1991) presented words flanked by digits very briefly during the study phase. Some participants had to report only the words, others reported either words or sums of flanking digits, and others reported only the sums of digits. At test, participants who reported only the words showed priming, whereas participants who reported only the sums of digits showed no priming.

In the above three studies, priming was eliminated for words presented foveally. The foveal presentation and the above-threshold (supraliminal) exposure durations used in these studies ensured that participants were aware of the word presentation, and thus, conscious *detection* of letter strings occurred. This encoding, however, was insufficient to support priming. Perhaps this was because the minimal attention paid to foveally presented but ignored words was sufficient for detection of strings of letters, but not for encoding of the lexical or semantic identity of the letter string. The lack of such encoding was demonstrated directly by the absence of the word superiority effect in one study (Hayman & Jacoby, 1989) and was also likely for the ignored words in the other two studies (Hawley & Johnston, 1991; Johnston & Dark, 1985).

To reconcile the findings of diminished perceptual priming with the claim that perceptual priming has no attentional demands, Mulligan and Hartman (1996) proposed that perceptual priming is reduced or eliminated only when attention prevents processing of word identity at study. Thus, perceptual priming is not reduced by the division of attention per se, but by the lack of identity processing. Divided attention manipulations do not prevent awareness of word identity at study (e.g., Gabrieli et al., 1995). Some selective attention manipulations eliminate all processing of word identity (e.g., Hayman & Jacoby, 1989). However, there are a few selective attention manipulations that eliminate or reduce awareness of word identity, but do not completely eliminate identity processing. The evidence for such processing can be detected via interference or facilitation from stimulus identity on the current trial or priming (positive or negative) on the subsequent trial. Examples include such phenomena as the word superiority effect (Reicher, 1969; Wheeler, 1970), negative priming (Allport, Tipper, & Chmiel, 1985; Fox, 1995; Tipper, 1992), and Stroop interference (Stroop, 1935; MacLeod, 1991). The open question, therefore, is whether identity processing alone, not accompanied by full awareness and/or attention to stimulus identity, is sufficient for perceptual priming.

In present study, we examined this question with respect to word-identification priming. To obtain study phase evidence of word identification, we used short-term priming and interference measures at study that have been previously used to document automatic word identification (i.e., reading) without awareness.

In Experiment 1, words were presented briefly, and study phase negative priming was used as evidence of word encoding of the ignored words. Negative priming refers to slower and/or less accurate responses to studied, relative to novel, stimuli. In a typical negative priming experiment, two items are presented simultaneously, and participants are instructed to attend and respond to only one. On some trials, the ignored items from the previous trials are repeated as to be attended and responded to items. A typical result is the slower response to such items, relative to items that did not appear previously, and little or no conscious awareness of the ignored items, as measured by participants' ability to report the identity of the ignored word immediately after presentation on a small proportion of the ''catch'' trials (Alport et al., 1985; Tipper, 1985; Tipper & Driver, 1988). Thus, the goal of Experiment 1 was to see if preserved word-identification priming can be obtained when this minimal word encoding occurs at study.

Experiments 2 and 3 used the Stroop color naming task at study. Negative priming and color naming tasks are similar in that they both require that the unattended word be actively ignored and thus may involve inhibition. However, negative priming involves diverting attention to a different visual object (another word), whereas color naming involves diverting attention to a different feature (color) of the same object. It is more likely that a task-irrelevant feature of an attended object gets processed than a task-irrelevant feature of an unattended object (e.g., Gordon & Irwin, 1996; Kahneman, Treisman, & Gibbs, 1992; Yantis, 1993). Thus, it is possible that the processing of the unattended (identity) dimension of words in a color naming task is sufficient for perceptual priming later, but that processing of the unattended word in the negative priming paradigm is not. In Experiment 2 the pattern of reaction times in a color naming task was used as evidence of identity processing of the ignored words. The emotional valence rating task was chosen to demonstrate that identity of the words was encoded during color naming task in Experiment

2. Experiment 3 was designed to replicate the findings of Experiment 2 and rule out levels of processing explanation for the reduced word-identification priming in Experiment 2.

EXPERIMENT 1

In Experiment 1, negative priming was the measure of study phase identity encoding, and word-identification priming was the measure of perceptual implicit memory. In a typical negative priming experiment, participants are presented with two overlapping images of different colors (e.g., a red and a green letter). They are instructed to respond to the item of one color (e.g., red) and to ignore the item in the other color (e.g., green). Participants are slower to respond to an attended item on the current trial if it was presented as the ignored item on the previous trial than if it was not presented. Slowing that occurs when an ignored item on one trial becomes attended on the next is referred to as negative priming. The presence of the negative priming effect indicates that the ignored items were identified. Otherwise, their occurrence as ignored items should not affect subsequent processing.

Three different explanations of negative priming have been proposed (Fox, 1995). According to some authors (e.g., Allport et al., 1985; Neumann & DeSchepper, 1991; Tipper, 1985; Yee, 1991), negative priming is an attentional phenomenon resulting from inhibition of responses and/or representations associated with the ignored stimuli. According to others, negative priming is a memory phenomenon resulting from the conflict between the retrieved representation from the previous trial and the perceived stimulus on the current trial. This conflict can be a feature mismatch, such as green A versus red A (Park & Kanwisher, 1994), or mismatch in memory tags (do not respond to A versus respond to A) (e.g., Neill & Valdes, 1992; Neill, Valdes, Terry, & Gorfein, 1992). The two memory accounts differ in that the status of the stimulus (i.e., attended or ignored) is irrelevant to whether negative priming is predicted in the feature mismatching account, but is crucial for the prediction of negative priming in the episodic retrieval (mismatch in memory tags) account. It is possible that negative priming can be attributable to more than one source and that different conditions of presentation and response requirements may lead to negative priming for different reasons. None of the explanations directly addresses the issue of whether and when the representation of the unattended item persists in long-term memory and can support later priming.

Experiment 1 used negative priming effects to validate the study phase encoding of the ignored words. At study, participants saw two overlapping words, one in green and one in red, and read the red word into a microphone. On some trials, the green (ignored) word from the previous trial reappeared as a red (attended) word on the next trial. Negative priming was measured as the increase in latency to respond to such repeated words relative to baseline (no repetition).

The presence of negative priming would indicate that the identity of the ignored words was processed at lexical or semantic level. Because the main goal was to minimize conscious encoding of the ignored words, a relatively short exposure duration (67 ms) and a relatively low proportion of repetition (0.25) were chosen. At test, attended, unattended and baseline words were presented at threshold durations for word identification.

Method

Participants. Forty-two West Valley community college students, 18–36 years old, participated in this experiment and received course credit for their participation. Two participants had to be excluded, 1 due to unusually low performance on the word-identification test (no baseline items identified correctly), and another due to unusually high performance on the word-identification test (all of the baseline items identified correctly). All participants were native English speakers and had normal color vision.

Apparatus. The same apparatus was used in Experiments 1–3. Participants were tested on an Apple Quadra 800 computer. The experimental routines were programmed using PsychLab software package.

Materials. Experimental stimuli were 112 names of concrete objects from Snodgrass and Vanderwart (1980), 3–10 letters long, and 4 filler items from the same set. Each experimental stimulus was randomly assigned to one of the eight possible stimulus sublists, with each sublist containing 14 items.

Eight study lists were generated, together with eight corresponding test lists by counterbalancing the eight possible sublists of items across the eight possible roles, such that each item on the list served in one of the eight possible roles (unattended-control, negative priming, attended-prime, unattended-probe, unattended-plain, attended-plain, baseline-set 1, and baseline-set 2) equally frequently across participants. The negative priming items were used to assess the negative priming during the study phase and were excluded from the test phase, because they were presented both as attended (red) and as unattended (green) items. The unattended-control and unattended-prime items appeared as ignored (green) during the study phase, paired with the negative priming items on either control or probe negative priming trials. The attended-probe items appeared as attended (red) with negative priming items as ignored (green) on the prime trials preceding the probe negative priming trials. The unattended-plain items appeared as ignored (green) items and were paired with the attended-plain (red) items and not used to measure negative priming in the study phase. Finally, the baseline-set 1 and baseline-set 2 items did not appear in the study phase at all and appeared only in the test phase as baseline items. Figure 1 illustrates how the items were used to construct study and test trials.

All study lists were arranged in a pseudo-random order, with the constraints that the first and the last item on the list was a filler, the control trial for the corresponding probe negative priming trial was separated by at least seven trials, and the prime negative priming trial always immediately preceded the corresponding probe negative priming trial. In this sequence of trials, half of the negative priming words appeared in the control trial first, and the remaining half appeared in the prime-probe negative priming trial pairs first. The entire list was then repeated, with the ignored word used in control versus probe trial and the order in which these two trials appeared for each item switched. All study lists were 116 trials long. Control negative priming (unattended-control–negative priming-red) trials constituted 0.25 of the trials, prime negative priming trials (negative priming-green–attended-prime'') constituted another 0.25, the probe negative priming trials (unattended-probe–negative priming—red) constituted 0.25, and finally the (unattended-plain–attended-plain) trials consti-

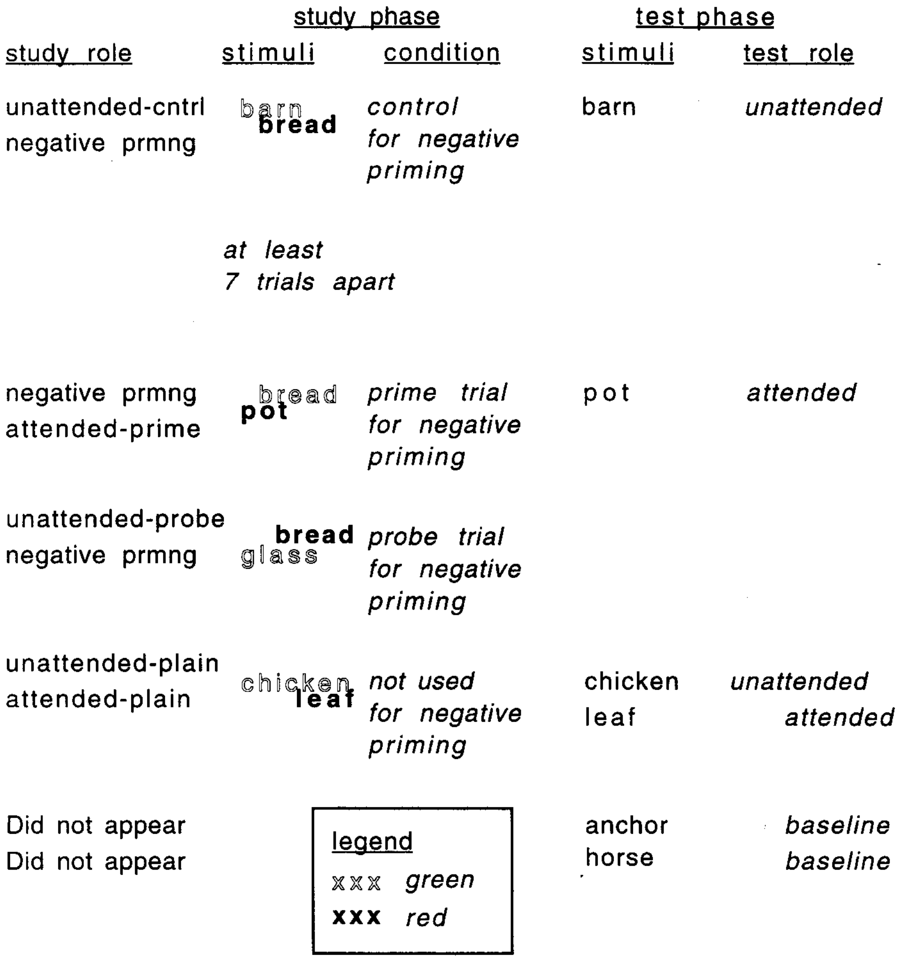

FIG. 1. Study and test phase conditions in Experiment 3. The words in black represent the words that were presented in red (i.e., attended), and outlined words represent the words that were presented in green (i.e., unattended) during study.

tuted the remaining 0.25 of the trials. Thus, only 0.25 of trials contained immediate repetitions. To generate test lists, items baseline-set 1 and baseline-set 2 (baseline), items unattended-control and unattended-plain (ignored), and items attended-prime and attended-plain (attended) were combined in pseudo-random order, with the constraint that no more than four items of the same kind occurred in a row. Negative priming items were excluded from the test phase, because they appeared both as attended and as unattended items at study, and unattended-probe items were excluded to maintain a 1:1:1 ratio of baseline to ignored to attended items. The first 4 trials on each test list were fillers, followed by 84 experimental trials. Five participants were randomly assigned to each of the eight possible study–test combinations.

Design. The test phase design was within subjects, with the status of the test stimulus (attended, unattended, baseline) as the independent variable and accuracy of word identification as the dependent variable. The study phase design was also within subjects, with the status of the primed item (control vs. negatively primed) as the independent variable and reaction time (RT) as the dependent variable.

Procedure. During the study phase, each trial began with a fixation cross presented for 900 ms. Then, two words were presented for 67 ms, overlapping and in the center of the screen. One word appeared shifted slightly to the upper left and another to the bottom right of the central fixation. The to-be-attended word appeared in red and the to-be-ignored word appeared in green on a computer. The location of the red word (top left or bottom right) was randomly determined on each trial, with the constraint that the top and the bottom locations were occupied by a red word equally often. The words were replaced by a backward mask that consisted of beige X's and remained on the screen until the participant responded. Participants were asked to read the red word into the microphone as quickly and as accurately as possible. After an intertrial interval, the next trial began with the presentation of the fixation cross.

The test phase immediately followed the study phase. At test, participants saw a black fixation cross for 500 ms, followed by a single word, presented centrally in black for 16 ms, and replaced by a backward mask of black X's. Participants attempted to identify the word; responses were entered into the computer by the experimenter. After the responses were entered, the computer advanced to the next trial following a 100-ms intertrial interval.

Results

Study phase negative priming. Only trials on which participants responded correctly, with reaction times in the range between 100 and 3000 ms, were included in the analysis. Fewer than 1% of the trials fell outside the acceptable range. Overall, 14% of the trials were excluded from the baseline condition and 13% of the trials were excluded from the negatively primed condition either because of the errors or because they fell outside of the acceptable range.

Median reaction times were computed for the control trials and the probe negative priming trials. Participants were slower on the negative priming trials ($M = 503$ ms, $SD = 94$) than on the control trials ($M = 491$ ms, $SD = 94$, $t(39) = 1.97$, $p < .05$, one-tailed). This negative priming effect indicates that ignored words were identified at study.

Test phase word-identification priming. For each participant, the percentage of items identified correctly was computed separately for baseline, ignored, and attended items. Study-phase errors were excluded from the analysis (Table 1). An analysis of variance (ANOVA) was performed with item type (attended, unattended, or baseline) as a within-participants variable. There was a significant effect of study condition ($F(2, 78) = 54.71$, $MS_e = 120.00$, $p < .0001$). Participants identified significantly more attended than unattended items ($t(39) = 7.96$, $p < .0001$) and marginally more unattended than baseline items ($t(39) = 1.73$, $p < .10$). The same pattern of results was obtained when error trials were included in the analysis.

TABLE 1
Mean Percentages (Standard Deviations in Parenthesis) of Words Identified Correctly in the Word-Identification Task in Experiment 1

Study condition	*M* (*SD*)	Priming
Attended	74 (21)	24
Unattended	53 (28)	3
Baseline	50 (29)	—

Discussion

Negative priming at study indicated that at least some word-specific information was encoded at study. This, however, did not result in intact word-identification priming. Thus, identity processing that supports negative priming was not sufficient for later perceptual priming. Alternatively, it is possible that the negative priming associated with the response to the word and the positive priming associated with the identity representation of the word, respectively, cancel each other out and result in no net priming. We believe that the first of the two possibilities is more likely. First, the negative priming effect observed in our study was very small and therefore unlikely to equal the robust positive priming effect obtained for attended words. Second, previous studies demonstrate that negative priming is short-lived and observed only when there is need for response selection at the probe trial (that is, two items are presented at the probe trial). When only one item is presented, no priming or positive priming is usually observed (Allport et al., 1985; Lowe, 1979; Tipper, Brehaut, & Driver, 1990; Tipper & Cranston, 1985, but see Neill, Terry, & Valdes, 1994; Neill & Westberry, 1987). Since at test, words were presented one at a time, the negative priming component is unlikely to have played a role. Thus, we conclude that word-identification priming relies on a memory trace that depends on more identity processing than is afforded to an ignored word in the negative priming paradigm.

EXPERIMENT 2

Color naming has been used frequently to demonstrate unwanted, ‘‘automatic’’ reading of ignored words (see MacLeod, 1991; Stroop, 1935). In a typical Stroop experiment, participants are presented with words in colored ink and asked to name the color of the ink while disregarding the identity of the words. Color naming is typically slowed by words (such as DOG) relative to nonsense strings of letters (such as POG) and even more so by the incongruent color names (such as RED printed in green letters) relative to neutral words (such as DOG) (Dalrymple-Alford, 1972; Klein, 1964; MacLeod, 1991). These effects establish that both lexical and semantic processing of a word occurs during color naming.

This unintentional reading of the word during color naming can lead to long-lasting priming. Szymanski and MacLeod (1996) required participants to either read words or name the colors of words at study and then administered either a recognition test or a lexical-decision test. A lexical-decision test requires participants to decide as quickly as they can whether or not a string of letters constitutes a legitimate English word. Lexical-decision priming was the same after color naming and reading, even though recognition was severely impaired after color naming relative to reading. These results are different from the results of Experiment 1, and two different reasons can be suggested. First, it is possible that lexical-decision priming relies on different representations and/or processes than perceptual priming. Second, it is possible that color naming results in lasting encoding of word identity, whereas ignoring the words in the presence of other words does not. This can be because the color naming task involves diverting attention within the same visual object, whereas the negative priming task involved diverting it to a different visual object (Gordon & Irwin, 1996; Kahneman et al., 1992; Yantis, 1993). Experiment 2 examined whether word-identification priming was preserved after color naming.

To establish word identification at study, we relied on the finding that emotionally charged words produce different amounts of interference in a color naming task (Pratto & John, 1991). Slower RT's to name the color of negative relative to positive words and emotionally charged relative to neutral words are frequently observed. We used this finding to establish that participants performing color naming have processed word identity. A control group of participants rated the same words on a 9-point emotional-valence scale, to ensure full semantic processing of the words. At test, some of the participants performed a word-identification task (perceptual implicit memory test), and some performed a recognition task (explicit memory test).

Method

Participants. Eighty West Valley College students, 18–35 years old, participated and received course credit for their participation. All participants had normal color vision and were native English speakers.

Materials. One hundred and eighty words were selected from Pratto and John (1991). To determine word valence, 30 students rated the words on a 9-point scale (1 = extremely negative, 2 = very negative, 3 = moderately negative, 4 = slightly negative, 5 = neutral, 6 = slightly positive, 7 = moderately positive, 8 = very positive, 9 = extremely positive). None of the words referred to the physiological drive states of hunger, thirst, or sex. Ratings were lower for negative ($M = 2.23$, $SD = .69$) than neutral ($M = 5.13$, $SD = .37$) words ($t(59) = 29.58$, $p < .0001$) and higher for positive ($M = 7.45$, $SD = .68$) than neutral ($t(59) = 23.89$, $p < .0001$) words. The degree of word valence intensity (i.e., the difference between a word's rating and a neutral rating of 5) was computed for each word. The mean degree of valence intensity did not differ for negative ($M = -1.54$, $SD = .19$) and positive ($M = 1.45$, $SD = .17$) words. Negative, positive, and neutral words were matched for length (range: 5–8 letters, $M = 6.43$ letters, $SD = 1.06$ for negative words; $M = 6.5$, $SD = .97$ for neutral words; $M = 6.7$, $SD = .97$ for positive words), and frequency (range: 1–133 per million, $M = 26.67$ per million, $SD = 24.41$ for negative words; $M = 28.95$, $SD = 24.62$ for neutral words; $M = 30.48$, $SD = 29.13$ for positive words, Kucera & Francis, 1967).

Two 90-word study lists (Lists A and B) and one 180-word test list composed of all the words from the two study lists were generated, with each study list containing equal numbers of neutral, positive, and negative words. In each study list, 18 words were assigned to one of five colors for presentation (red, orange, blue, pink, green) so that a fifth of the words appeared in each color. Five study forms for each study list were created by changing the color assignment for each word, so that across lists every word appeared in each color. Every test list had 18 studied and 18 unstudied words in each color. Across test lists, every word appeared in every color. The color of a word was always the same at study and at test. Thus, there were 10 unique study–test combinations. The words on each study list were arranged in fixed pseudo-random sequence, with the constraint that no more than three items of the same valence (neutral, negative, or positive) appeared in a row, and no more than three items in the same color appeared in a row. The words on the test list were arranged in fixed pseudo-random order, with the additional constraint that no more than 3 words from the same study list appeared in a row. Each study list also included 2 filler words at the beginning and at the end.

Design. The design was 2 × 2 × 2 × 3 mixed variable, with type of study (color naming or valence rating) and type of test (word identification or recognition) as between-participants variables and item type (studied or new) and word valence (positive, negative, or neutral) as within-participants variables. The dependent variable at study was RT. The dependent variable at test was accuracy of word identification. Ten participants were assigned to each of the four study and test combinations.

Procedure. During study, participants saw a ''+'' fixation for 250 ms that was replaced by a word in colored letters after a 500-ms blank interval. Half of the participants named the color of the word into the microphone, and the other half rated the word on the 9-point scale described above. The words remained on the screen until responses were made, and a 1000-ms intertrial interval was used. In the test phase, participants were either asked to identify briefly presented words or to perform a yes/no recognition test. For the recognition test, words were presented until participants responded ''yes'' to words seen in the study and ''no'' to words not seen in the study phase. For the word-identification test, each trial consisted of a ''+'' fixation for 500 ms, a blank period of 500 ms, a forward mask for 100 ms, the word for 16.7 ms, and a backward mask. Forward and backward masks were identical and consisted of rows of X's. The mask on each trial covered the word completely and was in the same color as the words it preceded and followed. The experimenter recorded the response and initiated the next trial.

Results

Study phase. Participants in the color naming condition were faster to respond than participants in the emotional ratings conditions (M = 704 ms, SD = 86 versus M = 1403 ms, SD = 347, $t(78) = 12.38$, $p < .01$).

Mean median reaction times to name the color of the word were compared for neutral (M = 705 ms, SD = 85), negative (M = 712 ms, SD = 93), and positive (M = 696 ms, SD = 82) words in a repeated measure ANOVA. An overall effect of valence was observed ($F(2, 78) = 7.20$, $MS_e = 361.32$, $p < .01$). Subsequent analyses revealed that reaction times to positive words were significantly faster than reaction times to negative words ($t(39) = 3.62$, $p < .01$), with reaction times to neutral words falling in between. The effect of word meaning on color naming indicates that semantic analysis of the words was performed at study.

TABLE 2
Mean Percentages of Hits and False Alarms (Standard Deviations in Parenthesis) in Recognition Task in Experiment 2

	Study group					
	Color naming			Valence rating		
Word valence:	Negative	Neutral	Positive	Negative	Neutral	Positive
Hits						
M (*SD*)	62 (21)	42 (16)	60 (21)	90 (8)	83 (11)	92 (8)
False alarms						
M (*SD*)	39 (16)	24 (17)	41 (22)	20 (12)	11 (10)	26 (14)

Test phase: Recognition. Proportions of hits and false alarms for neutral, negative, and positive words were computed for each participant. Means and standard deviations are presented in Table 2.

A mixed factors ANOVA was performed with valence (negative, positive, or neutral) and type of response (hit, false alarm) as within-participants variables and type of study task (valence rating, color naming) as a between-participants variable. Participants were more accurate in recognition after valence rating than after color naming ($F(1, 76) = 142.77$, $MS_e = 507.88$, $p < .05$), interaction between type of study task, and response category. Participants were slightly more accurate with positive than with negative or neutral words, but this trend was not significant ($F(2, 76) = 2.77$, $MS_e = 84.34$, $p > .09$); there was no significant interaction between valence and response category. No interaction between valence and encoding was observed ($F(2, 76) = 1.94$, $MS_e = 84.34$, $p > .17$). Thus, besides greater accuracy after valence rating than color naming, no other significant effects were found.

Test phase: Word-identification. The percentage of items identified correctly was computed separately for unstudied and studied items for each participant. These data were first analyzed in three-way mixed design ANOVA with study task (color naming, rating) as a between participants variable and priming condition (baseline, studied) and valence (positive, negative, or neutral) as within-participants variables. Studied words were identified more accurately than baseline words ($F(1, 38) = 61.20$, $MS_e = 125.9$, $p < .0001$). Participants showed greater priming after the rating task than after the color naming task and interaction between study task and priming condition ($F(1, 38) = 10.63$, $MS_e = 125.9$, $p < .0025$). A main effect of valence was observed ($F(2, 76) = 7.6$, $MS_e = 79.8$, $p < .001$), and an interaction between valence and priming condition reached significance ($F(2, 76) = 3.52$, $MS_e = 48.74$, $p < .05$). No other interactions reached significance (F's < 1). Subsequent t tests revealed that the priming effect was smaller for positive words ($M = 8$, $SD = 13$) than for neutral ($M = 14$, $SD = 15$, $t(39) = 2.40$, $p < .05$) or negative ($M = 13$, $SD = 11$, $t(39) = 2.14$, $p < .05$) words. Priming for neutral words did not differ from priming for negative words ($t(39) < 1$) (Table 3).

When the individual participants' data were collapsed across valences (because valence did not interact with study task), significant priming was observed in both groups, ($t(19) = 3.48$, $p < .0025$ for participants in the color naming condition, and $t(19) = 7.34$, $p < .0001$ for participants in the rating condition).

TABLE 3
Mean Percentages (Standard Deviations in Parenthesis) of Words Identified Correctly in the Word-Identification Task in Experiment 2

Word valence: Priming condition	Study group: Color naming: Negative	Color naming: Neutral	Color naming: Positive	Valence rating: Negative	Valence rating: Neutral	Valence rating: Positive
Studied						
M (*SD*)	48 (19)	42 (19)	45 (18)	55 (29)	52 (28)	53 (30)
Baseline						
M (*SD*)	39 (21)	34 (18)	40 (27)	39 (26)	33 (22)	40 (27)
Priming	9	8	5	16	19	13

Discussion

The main result of Experiment 2 was that both recognition and word-identification priming were reduced after color naming, relative to emotional valence rating. The recognition result replicates the earlier finding by Szymanski and MacLeod (1996). The second result is unexpected, given the earlier report of preserved lexical-decision priming. It is unlikely that in our study word-identification priming was contaminated by explicit memory contributions. Word-identification priming has been dissociated from explicit memory measures in studies involving memory-impaired patients as well as normal participants (Jacoby & Dallas, 1981; Vaidya et al., 1995; Vertfaellie et al., 1991). In addition, our data contain a functional dissociation: word valence affected priming, but not recognition performance.

It is also unlikely that the longer exposure duration at study for emotional rating than for color naming was responsible for the observed difference in priming. Word-identification priming is unaffected by exposure durations after the first 100 ms (Hirshman & Mulligan, 1991). Finally, it is unlikely that elaborate processing associated with emotional rating contributed to unusually high priming in this condition, whereas priming after the color naming condition reflected ‘‘normal’’ priming levels. Word-identification priming is only minimally affected by elaborate semantic processing manipulations (Roediger & McDermott, 1993).

However, to conclusively rule out these factors and to replicate the observed effect, we conducted Experiment 3, in which exposure duration at study was controlled, and a reading task was used as the control condition. The reading task avoids the problem of extra processing in the control condition potentially present when a semantic task, such as valence rating, is used.

EXPERIMENT 3

Method

Participants. Forty students from West Valley College, 18–35 years old, participated for course credit. All participants had normal color vision and were native English speakers

TABLE 4
Mean Percentages (Standard Deviations in Parenthesis) of Words Identified Correctly in the Word-Identification Task in Experiment 3

	Study group	
Priming condition	Word naming	Color naming
Studied		
M (*SD*)	47 (25)	42 (21)
Baseline		
M (*SD*)	32 (21)	38 (21)
Priming	15	4

Materials. The stimuli were 80 words, four to eight letters long, with an average frequency of 41 per million (Kucera & Francis, 1967). The words were randomly assigned to one of the two 40-word study lists (Lists A and B) and the 80-word test list comprised all the words from the two study lists. The color of presentation was counterbalanced, as in Experiment 2. Across test lists, every word appeared in every color. The color of a word was always the same at study and at test. Each test list was arranged in pseudo-random order with the same constraints as those in Experiment 2. Thus, there were 10 unique study–test combinations, and four participants were assigned randomly to each combination. Each study list also included 2 filler words at the beginning and at the end, and participants practiced for the word-identification test with 10 additional words.

Design. The design was mixed, with study group (reading, color naming) manipulated between subjects and the status of test item (studied, baseline) manipulated within subjects. The dependent variable was accuracy of word identification at test. Participants were randomly assigned a study task of word reading or color naming, and all participants received the word-identification test.

Procedure. The sequence of events on each trial of study phase was identical to the one used in Experiment 2, except that the words remained on the screen for 1000 ms, instead of disappearing as soon as responses were made. Participants in the word-reading condition were instructed to read each word aloud. Participants in the color naming condition were instructed to name aloud the color that each word appeared in. The test phase was identical to the word-identification test used in Experiment 2.

Results

Test phase. Percentages of correctly identified studied and unstudied words were computed for each participant (Table 4).

Words that were misread or misnamed in the study phase were excluded from analysis in the test phase (less than 1%). The data were analyzed in a mixed design ANOVA with study (word reading, color naming) as a between-participants variable and priming (studied, unstudied) as a within-participants variable. Studied words were identified more accurately than unstudied words ($F(1, 38) = 21.98$, $MS_e = 77.77$, $p < .001$). Participants in the word-reading condition showed more priming than participants in the color naming condition and interaction between priming and study ($F(1, 38) = 7.14$, $MS_e = 77.77$, $p = .01$). Participants in the word-reading condition showed significant priming ($t(19) = 4.36$, $p < .01$, two-tailed), but participants in the color naming condition did not ($t(19) = 1.57$, $p > .12$, two-tailed).

Thus, reduction in word-identification priming after color naming was observed in Experiment 3, where exposure duration was controlled and conceptual elaboration was minimal in the control condition.

Discussion

Experiment 3 replicated the main finding of Experiment 2, reduced word-identification priming after color naming. The reduction in this case cannot be attributable to potential hyperpriming in the control condition due to semantic processing, as it could be in Experiment 2. Thus, the unintentional word reading that occurs in color naming does not lead to preserved word-identification priming.

These findings are important not only for understanding the relationship between study phase awareness and implicit memory (the issue we will revisit under *General Discussion*), but also for the interpretation of the Stroop effect itself. Stroop interference is frequently interpreted as demonstrating obligatory and automatic word identity processing. Our findings add to an accumulating body of evidence (Henik, 1996) suggesting constraints on this interpretation of the Stroop effect. The processing of word identity that occurs during color naming is limited relative to the processing of word identity under full attention conditions (e.g., word reading).

GENERAL DISCUSSION

In three experiments, word-identification priming was reduced for words whose identities were ignored at study, relative to words that were fully attended at study, despite study phase evidence of the unintended identification of the ignored words. The evidence of word identification was demonstrated via the presence of negative priming (Experiment 1) and valence effects on color naming (Experiment 2). Experiments 1 and 2 indicate that word identification at study will not lead to preserved word-identification priming if conscious awareness of the word identity is compromised by the division of attention.

Explicit memory retrieval is described often as memory with awareness. Indeed, reducing study phase awareness of the words reduced recognition memory in Experiment 2. In contrast, implicit memory retrieval is often described as memory without awareness. At a minimum, it implies lack of awareness of the study phase experience at the time of test phase retrieval. Some researchers extend this claim and state that attention and awareness of stimulus identity at study are not important for implicit memory (e.g., Parkin et al., 1990; Parkin & Russo, 1990; Koriat & Feuerstein, 1976; Szymanski & MacLeod, 1996). Yet others claim that study phase attention and awareness may be important for conceptual, but not for perceptual, implicit memory (Mulligan & Hartman, 1996). The results of our experiments are problematic for both accounts, because a perceptual form of memory was greatly affected by the division of attention at study.

The relationship between awareness of the stimuli at study and subsequent implicit memory may depend on the severity with which the awareness of the stimuli at study is affected. The most severe limitations on awareness can be produced with subliminal presentation. Most forms of repetition priming cannot be obtained with subliminal presentation (Forster & Davis, 1984; Graf & Schacter, 1985; Norman, 1993), except for cases when priming is measured immediately following the subliminally presented stimulus (Forster & Davis, 1984; Greenwald et al., 1996) or when it is measured via preference for the previously presented items (Kunst-Wilson & Zajonc, 1980; Mandler et al., 1987).

For stimuli presented supraliminally, the degree of stimulus awareness could determine the magnitude of memory for the stimulus. By this unitary view, the severity of division of attention determines the amount of priming. Such an interpretation would account for the elimination of word-identification priming when word identity is ignored (Hawley & Johnston, 1991; Jacoby & Hayman, 1987; Johnston & Dark, 1985) and the reduced presence of such priming when word identity is processed but to only a limited extent (Experiments 1–3). Such a unitary view would posit that word-identification priming is intact after auditory division of attention (Gabrieli et al., 1995) because the division of attention is simply less severe than that which occurs in letter-search or color naming tasks. Indeed, a unitary view need not distinguish between implicit and explicit or perceptual and conceptual forms of memory. In all cases, the degree of stimulus awareness simply determines how much is remembered.

The main limitation of such a unitary view is that it does not account for attentional or awareness-driven dissociations between various forms of memory. These include dissociations between explicit and implicit memory (Gabrieli et al., 1995; Mulligan & Hartman, 1996; Parkin et al., 1990; Parkin & Russo, 1990), between perceptual and conceptual priming (Gabrieli et al., 1995; Mulligan & Hartman, 1996), between identification and production priming (Gabrieli et al., 1995), and between immediate and delayed priming (Forster & Davis, 1984; Greenwald et al., 1996). The unitary view would have to explain all dissociations as measurement artifacts (e.g., ceiling effects due to differential attentional demands of various memory tasks).

An alternative possibility is that there are multiple relations between specific kinds of attention and specific kinds of memory. For example, auditory–verbal division of attention may reduce conceptual priming (Gabrieli et al., 1995; Mulligan & Hartman, 1996) because that division of attention interferes with conceptual processing at study. It may also reduce priming on those tests that require response production and/or have multiple possible answers (Gabrieli et al., 1995), because the studied stimulus was either not activated sufficiently or did not cause sufficient inhibition of competing responses at study. Auditory–verbal division of attention, however, may not reduce visual–perceptual priming (Gabrieli et al., 1995; Mulligan & Hartman, 1996; Parkin et al., 1990; Parkin & Russo, 1990) because it does not interfere with visual–perceptual processes at study that mediate priming on word-identification, picture-identification, and word-fragment-completion tasks.

Visual attention, furthermore, may be divided in a number of different ways that relate to the specific encoding processes necessary for different forms of priming. For example, color naming reduced word-identification priming in Experiments 2 and 3, but did not affect lexical-decision priming (Szymanski & MacLeod, 1996).

Color naming may interfere with one kind of identity processing (e.g., whole word identification directly from visual letter string representation), but leave another kind of identity processing (e.g., access to word identity via the phonological code for the word) intact. Whole word identification may support word-identification priming, whereas lexical-decision priming may be supported primarily by the indirect access to word identity via the phonological code for the word. Other visual tasks (e.g., postcue or simultaneous cue letter search) may leave word-identification priming intact because they do not interfere with the whole word identification, but reduce or eliminate lexical-decision priming because they interfere with the indirect access to word identity via the phonological code.

The relationship between awareness of stimuli at study and subsequent implicit memory for them is poorly understood. It may be that all forms of memory, implicit or explicit, require some level of awareness at study. While awareness and the degree of processing are correlated, processing can occur in the absence of awareness. It may be that awareness at study is important for explicit memory, and the degree and type of processing may be important for implicit memory. Division of attention at study invariably reduces awareness. In addition, each manipulation of attention may selectively impair one or more aspects of word processing.

At present, it is not clear whether attention affects implicit memory because it affects study phase awareness of the words or because it also impairs some specific aspects of word processing. Our results indicate that when word processing is not accompanied by full awareness at study, later perceptual implicit memory for the words is impaired. One theoretical account of these findings would assume that study phase awareness must be needed for implicit memory. The curious exceptions are lexical-decision priming (Szymanski & MacLeod, 1996) and preference judgments (Kunst-Wilson & Zajonc, 1980; Mandler et al., 1987). These exceptions, along with other dissociations, suggest that there may be specific attentional resources that are required for specific forms of implicit memory.

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