
Interactive Visual and Postvisual Processes and Their Roles in Form-Specific Memory

Chad J. Marsolek and David R. Andresen, University of Minnesota

Abstract Effects of depth of encoding on form-specific memory were examined. After viewing words (e.g., “bear”) presented centrally during initial encoding, participants completed word stems (e.g., “BEA”) presented laterally and pattern masked during subsequent test. When the encoding task was perceptual, letter-case specific memory was not observed, unlike in previous experiments without pattern masking. However, when the encoding task required both perceptual and conceptual processing, letter-case specific memory was observed in direct right-hemisphere, but not in direct left-hemisphere, test presentations, like in previous studies without pattern masking. Results were not influenced by whether stems were completed to form the first words that came to mind or words explicitly retrieved from encoding. Depth of encoding may influence form-specific memory through interactive processing of visual and postvisual information.

An important aspect of repetition priming is that it can be form specific under some conditions. Form-specific word priming is measured as greater priming when words are presented in the same format (letter case and font) between the initial encoding of a word (e.g., “bear”) and the subsequent test (e.g., “bear”) compared with when words are presented in different formats between encoding (e.g., “BEAR”) and test (e.g., “bear”). Letter-case specific priming is commonly observed (e.g., Jacoby & Hayman, 1987; Masson, 1986; Roediger & Blaxton, 1987). This effect is found when test items are presented directly to the right cerebral hemisphere, but not when they are presented directly to the left cerebral hemisphere (e.g., Marsolek, Kosslyn, & Squire, 1992; Marsolek, Schacter, & Nicholas, 1996; Marsolek, Squire, Kosslyn, & Lulenski, 1994; see also Marsolek, 1995, 1999, for similar results with objects and unfamiliar shapes), and it is found when serotonin levels in the brain are high, but not when serotonin levels are low (Burgund, Marsolek, & Luciana, 2003). However, many important questions remain un-

answered regarding the experimental conditions that produce or enhance form-specific priming (e.g., see Bowers & Marsolek, 2003). Indeed, a curious aspect of the previous research is that seemingly contradictory results have been observed in studies of the effects of depth of encoding (Craik & Tulving, 1975) on visually specific priming (Graf & Ryan, 1990; Jacoby, Levy, & Steinbach, 1992). In this article, after considering these contradictory results, we test alternative theories of depth of encoding effects on form-specific memory. In doing so, we address important questions about the degree of interactivity between visual and postvisual processes.

Research on depth of encoding and form-specific memory has produced contradictory results. Graf and Ryan (1990) observed greater form-specific word priming when participants performed a relatively shallow encoding task (rating the readability of the prime words) than when they performed a relatively deep encoding task (rating the likeability of the prime words). In contrast, Jacoby et al. (1992) observed greater form-specific word priming when encoding and test involved the relatively deep task of reading and answering short questions than when they involved the relatively shallow task of only reading the questions aloud. (Similarly, Woltz, 1990, also found form-specific priming when the encoding and test tasks involved semantic relatedness judgments for pairs of words, although no comparison was made between priming in this relatively deep task versus a relatively shallow task.) Why are such seemingly discrepant results obtained? These previous studies differed in many ways, but the following analysis highlights important variables that have been implicated by previous research. Potential answers for why seemingly discrepant results have been obtained arise from considerations of the functional and neural processes that may be involved in such memory effects.

Involuntary Explicit Memory

Interactions between the neocortex and the hippocampal formation may be important for helping to

predict depth of encoding effects on form-specific priming. Neocortical areas store well-established, consolidated information. For example, visual areas in neocortex store the visual shapes of familiar printed words. Representations in these areas can suffice to support repetition priming effects, independently of the hippocampal formation; however, these neocortical areas also can interact with the hippocampal formation to form new explicit memory representations (e.g., Cohen & Eichenbaum, 1993; McClelland, McNaughton, & O'Reilly, 1995; Squire, 1992). Hippocampal interactions are needed to bind disparate elements of the encoding context and the to-be-remembered information in order to store new learning events involving the information normally stored in the relevant neocortical areas. For example, visually specific information about the letter case of a word form may be just the sort of information included in a new explicit memory representation (for evidence that the letter case of words can be explicitly remembered, see Kirsner, 1973). Furthermore, some researchers have suggested that such explicit memory representations can be accessed in an involuntary manner (Richardson-Klavehn, Gardiner, & Java, 1994) during presumably implicit memory expression (e.g., Hamann & Squire, 1996; but see also, Richardson-Klavehn & Gardiner, 1998), and that such involuntary access may normally support form-specific priming effects in particular (Curran, Schacter, & Bessenoff, 1996; Schacter, 1994). In line with this possibility, Kinoshita and Wayland (1993) found that form-specific effects were smaller in amnesic patients than in normal control participants in a presumably implicit memory experiment (but for contradictory evidence, see Vaidya, Gabrieli, Verfaellie, Fleischman, & Askari, 1998).

If involuntary explicit memory underlies form-specific priming, it should do so to a greater degree when the encoding task is perceptual in nature than when it is both conceptual/semantic and perceptual in nature. An explicit memory representation should be more likely to include the letter case or font of a prime word (and hence be able to yield greater form-specific priming) when the encoding task calls attention to that perceptual information (e.g., shallow encoding) than when it does not (e.g., deep encoding). This could help to explain the results from the Graf and Ryan (1990) study, in which form-specific memory was greater following shallow encoding than deep encoding and in which explicit and implicit memory effects were not dissociated by this variable.

Interactive Visual-Postvisual Processes

Interactions between different neocortical areas also may be important for helping to predict depth of encoding effects on form-specific priming. Visual and

postvisual processes take place at least relatively independently in neocortex (e.g., Blaxton et al., 1996; Buckner & Koutstaal, 1998; Gabrieli et al., 1996; Schacter, 1990). For example, visual areas store word form information (e.g., the visual structure of a printed word), and postvisual areas store conceptual/semantic information (e.g., the meaningful information associated with a word). However, given that only weak, not strong, modularity/independence is a hallmark of dissociable areas in neocortex (e.g., Farah, 1994; Van Essen & DeYoe, 1995), visual and postvisual processes may interact in important ways despite their spatial separation. For example, the visual-form representation and the conceptual representation for a word, although stored in spatially separated neocortical subsystems, may be interconnected and interactive, as in neural network models that posit separate pools of units for representing visual and postvisual information for words yet also posit a high degree of interactivity between pools when processing words (e.g., see Masson, 1995; Plaut & Shallice, 1993; Rueckl, 1990; Seidenberg & McClelland, 1989; cf. Van Orden, Pennington, & Stone, 1990). Typically, connections between pools of units have weights that are modifiable with experience, thus priming effects from small changes in weights (see Becker, Moscovitch, Behrmann, & Joordens, 1997; Bowers, Damian, & Havelka, 2002; Marsolek & Burgund, 1997; Stark & McClelland, 2000; Rueckl, 2003) may occur both between and within pools of units. If so, the repetition priming supported by such areas may be influenced by the interconnectivity between neocortical subsystems; the greater the degree to which the interactivity is primed, the greater the likelihood of observing effects of conceptual encoding on (presumably perceptual) priming tests.

Interactive visual and postvisual processes should support greater form-specific priming when the encoding task is both conceptual/semantic and perceptual in nature than when it is only perceptual in nature. When both perceptual and conceptual processing occurs during encoding, not only are the representations within perceptual and conceptual areas primed (i.e., via structural changes within pools of units), but the interactivity between areas also can be primed (i.e., via structural changes between pools of units). In other words, recently activated representations within each area will be more likely to be re-activated than unprimed representations within each area, and recently activated associations between the two areas will be more likely to be reprocessed than unprimed associations between the two areas. As an example, a primed visual input may begin to activate a primed perceptual representation, which then may begin to activate its associated conceptual representation, and then feedback from the

conceptual representation to the perceptual representation may bolster the activation of the associated perceptual representation. In this way, priming from within each area and priming from between the two should increase the likelihood that the primed perceptual representation is re-activated.

This could help to explain the results from the Jacoby et al. (1992) study, in which deep tasks produced greater form-specific memory than shallow tasks. During encoding, interactive perceptual-conceptual representations may have been more likely to be used when reading and answering questions than when simply reading questions aloud. When the test task involved reading and answering questions, both perceptual and conceptual information must have been processed. Thus, primed interactive representations could have provided a supporting context that enhanced the priming effects typically supported by the perceptual processing. However, when the tasks involved simply reading questions aloud, only perceptual information may have been processed and primed. Neither conceptual representations nor interactivity between perceptual and conceptual representations may have contributed to priming, causing no enhancement of the priming effects supported by the perceptual processing alone.

Of course, the two theoretical proposals described above are not mutually exclusive; both types of interaction could take place simultaneously. For example, in previous studies, a benefit from deep encoding that may have occurred through interactive visual-postvisual processing could have been greater than a benefit from shallow encoding that may have occurred through involuntary explicit memory in the Jacoby et al. (1992) study, and vice versa in the Graf and Ryan (1991) study. The important consideration for present purposes is that two different explanations can be distinguished, and the two theories lead to different predictions for the following study.

New Predictions

In the following experiments, we directly tested the foregoing potential explanations for depth of encoding effects on form-specific memory. We utilized a procedure that has been shown to produce strong form-specific priming. In particular, we examined letter-case specific memory in word-stem completion, using stems with highly dissimilar lowercase and uppercase visual structures (e.g., *bea/BEA*), and presenting stems directly to the right or left hemispheres. In these conditions, strong form-specific priming effects are observed (Burgund et al., 2003), especially when stems are presented directly to the right hemisphere (Marsolek, 2004). For example, Marsolek observed strong form-

specific priming with dissimilar-case word stems, but only when test stems were presented directly to the right hemisphere and not when they were presented directly to the left hemisphere. This pattern of results was observed following either deep encoding (rating likeability) or shallow encoding (counting vowels) in different experiments. The stimuli and design from that study were used in the present study as well, with the following main exception.

For the present study, we modified the test task in an important way to provide for novel assessments of the two potential explanations for depth of encoding effects. In particular, we presented a backward pattern mask immediately after each word stem (this does not normally happen in word-stem completion experiments). We did this for the purpose of introducing perceptual interference during test processing of the stems. The hypothesized effects of involuntary explicit memory or interactive visual-postvisual processing should help to overcome such perceptual interference in the processing of the stems, but in different ways according to the different theories.

If involuntary explicit memory supports depth of encoding effects on form-specific memory, then form-specific memory should be observed when a shallow encoding task is used but not necessarily when a deep encoding task is used. Presumably, any explicit memory for the case-specific information that is encoded during a shallow encoding task should be useful for supporting a case-specific memory effect. Indeed, explicit-memory retrieval mechanisms may be critical for helping to overcome the perceptual interference produced by the mask during test. Furthermore, the form-specific effect may be greater when cued recall is performed at test than when simple word completion is performed, if the relevant hippocampal interactions are utilized more effectively in cued recall than in word completion.

In contrast, if interactivity between visual and postvisual processes supports depth of encoding effects on form-specific memory, then form-specific memory should not be observed when a shallow encoding task is used but it should be observed when a deep encoding task is used. For a form-specific perceptual subsystem to effectively overcome the perceptual interference from the mask and produce a form-specific memory effect, interactive support from a postvisual conceptual subsystem may be useful for enhancing activation of the degraded perceptual trace. This interactive support should be primed effectively from a deep encoding task but not from a shallow encoding task.

Experiment 1

During initial encoding, complete words were pre-

sented in the central visual field, half in all lowercase letters and half in all uppercase letters, and participants performed a typical shallow encoding task (they counted the number of vowels in each word). During subsequent test, half of the participants completed primed and unprimed word stems to form the first words that came to mind, and the other half used the stems as cues to help them explicitly recall previously presented words. Each stem was presented directly to the left hemisphere (in the right visual field) or directly to the right hemisphere (in the left visual field), and it was immediately followed by a pattern mask.

Method

Participants. Sixty-four students from the University of Arizona or University of Minnesota (half female and half male) volunteered to participate for course credit or cash payment. All participants were right-handed, as assessed through the Edinburgh Handedness Inventory (Oldfield, 1971); the mean laterality quotient was 0.68. All participants had normal or corrected-to-normal vision.

Design. A 3 x 2 x 2 x 2 x 2 mixed factorial design was used. Three within-participants independent variables were type of initial encoding of the critical word completion for a stem (same-case, different-case, or not previously encoded), hemisphere of direct test presentations of stems (left or right), and letter case of test stems (lowercase or uppercase). Between-participants independent variables were test task (word-stem completion or word-stem cued recall) and gender of participant (female or male).

Materials. Ninety-six English words were chosen from Webster's Vest Pocket Dictionary (1989) with the constraints that the three-letter beginnings (i.e., stems) of each word (a) were exclusive with respect to other words used in the experiment, (b) contained only letters with dissimilar uppercase and lowercase structures (A/a, B/b, D/d, E/e, F/f, G/g, H/h, L/l, M/m, N/n, R/r, T/t) according to analyses in Boles and Clifford (1989), and (c) could be completed to form at least 10 common words found in the dictionary. These were labeled "critical words." The mean frequency of occurrence per million for these words was 88 (Francis & Kucera, 1982). Twenty-nine additional words were selected for use as fillers during encoding (5) and for word-stem completion practice trials during test (24). For counterbalancing purposes, the 96 critical words were sorted into lists balanced for word frequency, the total number of words that could be completed from the stem of each word, and the chance (unprimed) probability that the stem would be completed to that word (assessed in

a separate group of participants).

The stimuli were presented on an AppleColor High Resolution RGB Monitor with a Polaroid CP-50 filter placed over the display to reduce glare. A Macintosh II or IIsi computer controlled stimulus presentation. A chin rest was used to keep the participants' eyes approximately 50 cm from the monitor.

The words and word stems were presented in a black 24-point bold Helvetica font inside a 10 x 4 cm white window (surrounded by grey). The window was visible throughout the experiment and helped participants to focus attention on the appropriate area of the monitor. A 2 mm bullet in the same font served as the fixation point (subtending 0.23° of visual angle). The pattern mask was composed of three uppercase "X" figures superimposed on three "&" figures, also in the 24-point bold Helvetica font. During the encoding phase, the fixation point and the words were presented in the centre of the display. During the test phase, the fixation point was always presented at the centre of the display, but word stems and masks were presented laterally such that the centre of each stem or mask was 2.5° to the left or right of the centre of the display, and the inner edge of a stem or mask was never within 1.5° from the centre of the display.

Procedure. Participants were tested individually in a testing room with normal lighting. About six minutes intervened between the initial encoding phase and the subsequent test phase for each participant. During this time, participants read the instructions for the test phase and asked any questions that they had. Also during this time, the experimenter made sure that the instructions were understood and set up the computer program for administering the test phase.

During the encoding phase, participants silently read 48 critical words, presented in a pseudorandom order (no more than three consecutive trials representing one experimental condition), with three filler words presented at the beginning and two filler words presented at the end of each list (to attenuate primacy and recency effects, respectively). Half of the words appeared in all lowercase letters and the other half appeared in all uppercase letters. The entire encoding list was presented twice in succession for each participant to increase memory effects.

Each trial in the encoding phase began with a fixation point displayed centrally for 500 ms. Then, a word was presented centrally for 3 s. Participants were asked to read each word silently and to count the number of vowels in it. They were not instructed in any other way except that they were told that it was very important that they count the number of vowels accurately and they were asked to not count "y" as a vowel no matter

TABLE 1
Critical Word Completion Rates for Experiment 1 (Following Shallow Encoding)

Type of encoding	Word-stem completion task				Word-stem cued recall task			
	Lowercase stem		Uppercase stem		Lowercase stem		Uppercase stem	
	LH	RH	LH	RH	LH	RH	LH	RH
Conditionalized critical-word completion rates								
Same-case encoded	22.4%	29.9%	25.8%	29.3%	34.6%	38.3%	32.7%	39.0%
	(4.2%)	(3.7%)	(3.9%)	(4.3%)	(4.1%)	(4.9%)	(4.9%)	(4.5%)
Different-case encoded	28.9%	33.7%	27.8%	26.3%	36.1%	30.6%	25.3%	32.5%
	(4.3%)	(4.8%)	(3.1%)	(4.1%)	(3.2%)	(3.7%)	(3.4%)	(4.7%)
Not previously encoded	17.8%	18.5%	23.7%	18.4%	21.9%	22.0%	21.8%	25.3%
	(2.6%)	(2.4%)	(2.7%)	(2.4%)	(2.7%)	(2.9%)	(3.0%)	(2.6%)
Unconditionalized critical-word completion rates								
Same-case encoded	17.2%	23.4%	22.9%	26.1%	28.7%	31.3%	25.5%	32.3%
	(3.1%)	(2.9%)	(3.7%)	(3.9%)	(3.8%)	(4.0%)	(4.1%)	(4.0%)
Different-case encoded	22.9%	25.5%	23.4%	20.3%	29.2%	23.4%	20.3%	25.0%
	(3.4%)	(3.6%)	(3.1%)	(2.9%)	(2.6%)	(3.1%)	(2.7%)	(3.5%)
Not previously encoded	13.0%	14.8%	18.7%	14.0%	16.4%	15.4%	16.7%	18.5%
	(1.8%)	(2.0%)	(2.2%)	(1.7%)	(1.9%)	(1.8%)	(2.3%)	(1.8%)

Note. LH = direct stem presentations to the left hemisphere; RH = direct stem presentations to the right hemisphere; standard errors of the mean are in parentheses.

how it was used in a word (they were to count only "a," "e," "i," "o," and "u" as vowels). After each word disappeared, they typed a number key on the keyboard reflecting their count. The next trial began 1 s after a response in the previous trial.

During the test phase, participants completed 96 word stems in four blocks of 24 trials each. Half of the participants (priming group) completed each stem to form the first word that came to mind (excluding proper nouns), and the other half (cued recall group) used each stem as a cue to help them remember a word from the encoding phase that began with those letters (they were informed that some of the stems could not be completed to form such words). In each test block, half of the stems could not be completed to form previously encoded words (half of these in the left visual field, and the other half in the right), and the other half could be completed to form previously encoded words either in the same letter case as during encoding or in the different letter case compared with encoding (again, half of these in the left visual field, and the other half in the right). Letter case of the test stems was also balanced. In addition, an initial block of 24 practice trials was presented before the four blocks of experimental trials.

Each trial in the test phase began with a fixation point displayed centrally for 500 ms. Immediately after the fixation point, a word stem appeared for 183 ms in the left or right visual field, followed immediately by the pattern mask for 500 ms in the same location as the

stem. Participants were instructed to focus their attention on the fixation point the entire time that it was displayed, and not to anticipate which side the subsequent stem would appear. Participants spoke aloud each word completion as soon as they thought of it, and the experimenter recorded their responses. There was a 1-s intertrial interval.

Stimuli counterbalancing lists were rotated through each combination of experimental conditions to assure complete counterbalancing across participants. In this way, each stem represented each experimental condition an equal number of times across participants.

Results

In both experiments reported in this article, a response word was scored as one of the 96 critical word completions only if it was exactly the same as the critical word associated with the stem presented in that trial. Thus, no plural forms, past tense forms, or other changes from a critical word completion were accepted. Also in both experiments, the critical-word completion rates were conditionalized so that only trials in which the stems were accurately perceived by participants were included in the calculations of critical-word completion rates. Identification of the stem in each trial was assessed by whether the first three letters of the word-completion response fit the presented stem. Using these conditionalized completion rates assured that the memory effects reported here were not influenced by trials in which the stems could not be identi-

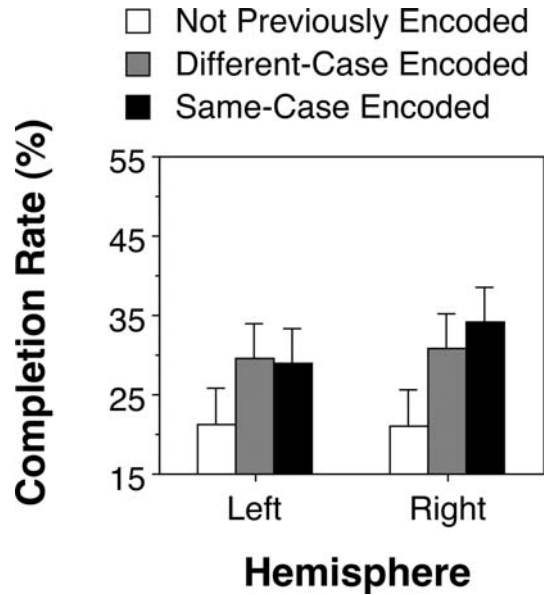


Figure 1. Results from Experiment 1, in which a shallow encoding task (vowel counting) was used. Mean completion rates of masked word stems (to form critical word completions) are depicted as functions of hemisphere of direct test presentation of the stems (left vs. right) and type of initial encoding of the critical words (same-case encoded vs. different-case encoded vs. not previously encoded). The data are collapsed across word-stem completion and word-stem cued recall tasks. Error bars indicate the (95%) “within-subjects confidence interval” (Loftus & Masson, 1994).

fied. Analyses of conditionalized completion rates did not differ qualitatively from analyses of unconditionalized completion rates though, largely because the stems were perceived accurately in large percentages of trials (79.1% for Experiment 1, and 79.2% for Experiment 2). Both conditionalized and unconditionalized completion rates are reported for all conditions in Table 1.

A four-way repeated-measures analysis of variance (ANOVA) was conducted with completion rate as the dependent measure. (A preliminary analysis indicated that gender of participant did not enter into any significant effects, thus it was excluded in the analysis reported below.) The within-participants independent variables were type of encoding (same-case, different-case, or not previously encoded), hemisphere of direct test stem presentations (left or right), and letter case of test stems (lowercase or uppercase). The one between-participants independent variable was test task (word-stem completion or word-stem cued recall).

Figure 1 displays the critical-word completion rates from this experiment. The most important result was that case-specific memory was not observed: Completion rates were not significantly greater for same-case stems than for different-case stems, neither

when stems were presented directly to the right hemisphere (34.1% vs. 30.8%, respectively), $F(1,248) = 1.72$, $MSE = 412.9$, $p > .15$, for the simple effect contrast, nor when stems were presented directly to the left hemisphere (28.9% vs. 29.5%, respectively), $F < 1$, for the simple effect contrast. Thus, unlike in a similar – but unmasked – experiment that also used shallow encoding and dissimilar-case word stems (Marsolek, 2004), type of encoding (same-case, different-case, or not previously encoded) did not interact with test hemisphere, $F(2,124) = 1.53$, $MSE = 334.8$, $p > .20$. Completion rates did differ in a significant main effect of type of encoding (completion rates for same-case, different-case, and not previously encoded items were 31.5%, 30.1%, and 21.2%, respectively), $F(2,124) = 16.4$, $MSE = 491.1$, $p < .001$, but this main effect was not due to the difference between same-case and different-case conditions, $F < 1$, for the appropriate contrast.

The only other significant effects in this analysis were the following (all other $ps > .13$). Completion rates generally were greater in cued recall (30.0%) than in word completion (25.2%), $F(1,62) = 4.69$, $MSE = 933.7$, $p < .05$, for the main effect of test task. However, it is important to note that test task did not interact with any other variable, except in a three-way interaction between test task, hemisphere of direct test presentation, and letter case of test stems that did not lend itself to easy interpretation, $F(1,62) = 7.92$, $MSE = 208.0$, $p < .01$. The pattern indicated an advantage for right-hemisphere presentations over left-hemisphere presentations in cued recall with uppercase stems (32.3% vs. 26.6%, respectively) and in word completion with lowercase stems (27.4% vs. 23.1%, respectively), but not in cued recall with lowercase stems (30.3% vs. 30.9%, respectively) or in word completion with uppercase stems (24.7% vs. 25.8%, respectively).

Discussion

In this experiment, a relatively shallow encoding task was used. The most important result was that form-specific memory was not observed in this masked stem completion experiment, even when test stems were presented directly to the right hemisphere. This finding contrasts with the significant form-specific priming observed (in direct right-hemisphere test presentations, but not in direct left-hemisphere test presentations) in an analogous experiment using unmasked word stem presentations (Marsolek, 2004). It is unlikely that a lack of statistical power is responsible for the lack of significant form-specific priming following right-but not left-hemisphere stem presentations in the present experiment, because the previous experiment had only 32 participants (in the dissimilar-case condition) and the present experiment had 64 participants (and

TABLE 2
Critical Word Completion Rates for Experiment 2 (Following Deep Encoding)

Type of encoding	Word-stem completion task				Word-stem cued recall task			
	Lowercase stem		Uppercase stem		Lowercase stem		Uppercase stem	
	LH	RH	LH	RH	LH	RH	LH	RH
Conditionalized critical-word completion rates								
Same-case encoded	35.5% (4.0%)	43.1% (4.5%)	39.5% (3.9%)	36.4% (4.6%)	39.5% (3.1%)	46.7% (4.8%)	34.0% (4.8%)	50.5% (5.1%)
Different-case encoded	39.0% (4.7%)	34.3% (3.8%)	28.5% (3.4%)	31.7% (4.6%)	48.1% (5.0%)	39.7% (4.6%)	40.1% (4.8%)	42.3% (4.2%)
Not previously encoded	21.6% (2.2%)	20.9% (3.7%)	18.0% (2.4%)	19.4% (2.6%)	25.0% (2.5%)	27.2% (3.0%)	24.5% (2.6%)	23.5% (2.7%)
Unconditionalized critical-word completion rates								
Same-case encoded	28.7% (3.6%)	36.5% (3.9%)	31.8% (3.2%)	31.8% (3.9%)	34.5% (3.4%)	38.3% (4.7%)	29.2% (4.4%)	40.6% (4.5%)
Different-case encoded	31.8% (4.0%)	27.1% (3.2%)	24.0% (3.1%)	24.5% (3.3%)	34.9% (3.8%)	29.9% (3.5%)	35.4% (4.5%)	33.9% (3.7%)
Not previously encoded	16.4% (1.6%)	15.1% (2.5%)	14.3% (2.0%)	15.4% (2.2%)	20.0% (2.5%)	19.6% (2.2%)	19.3% (2.2%)	17.5% (2.2%)

Note. LH = direct stem presentations to the left hemisphere; RH = direct stem presentations to the right hemisphere; standard errors of the mean are in parentheses.

both used the same design and materials, and both used the same number of observations per cell of the design per participant). In fact, the effect size in the previous experiment was $r = .37$ (raw effect = 15.6%), and the power level is .84 for that effect size ($r = .37$) and 64 subjects at $p < .05$ (according to power analysis tables in Cohen, 1988).

Thus, the interactive visual-postvisual processing hypothesis was supported; shallow encoding did not prime the interactive representations needed to help a form-specific subsystem overcome the perceptual interference produced by masking at test. Contrastingly, the involuntary explicit memory hypothesis was not supported; shallow encoding did not allow explicit memory mechanisms (or any other mechanisms) to support a form-specific memory effect (even in explicit-memory cued recall). However, it is important to note that this conclusion assumes that form-specific memory was in fact possible in the face of perceptual interference from masking. If form-specific memory cannot be observed in any masked stem completion experiment, then the failure to find form-specific memory in Experiment 1 may not reflect a failure of explicit memory mechanisms to support such an effect. Experiment 2 was conducted to test whether form-specific memory can be observed in masked stem completion.

Experiment 2

Experiment 2 was conducted in the same manner as

Experiment 1, with the exception that participants performed a deep encoding task (they judged how much they like or dislike each word). As in Experiment 1, the test stems were masked to produce perceptual interference during test processing. If involuntary explicit memory supports form-specific memory effects, then form-specific memory should not be observed, because the encoding task in this experiment provides even less opportunity than in Experiment 1 for attention to be focused on form-specific information. In contrast, if interactive visual-postvisual processes can influence and enhance form-specific memory effects in masked conditions, then form-specific memory should be observed in this experiment. Interactive support from postvisual processing may be needed for form-specific visual processing to effectively overcome the perceptual interference from the mask and produce a form-specific memory effect. Such interactive visual-postvisual processes should be primed effectively during the liking task, which requires perceptual recognition and conceptual assessment of each word during encoding.

Method

Participants. Sixty-four students from the University of Arizona or University of Minnesota (half female and half male) volunteered to participate for course credit or cash payment. All participants were right-handed, according to the Edinburgh Handedness Inventory (Oldfield, 1971), with a mean laterality quotient of 0.74.

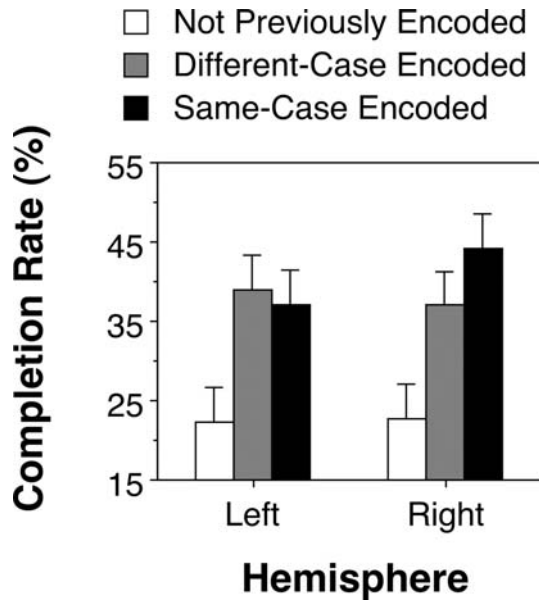


Figure 2. Results from Experiment 2, in which a deep encoding task (like/dislike judgments) was used. Mean completion rates of masked word stems (to form critical word completions) are depicted as functions of hemisphere of direct test presentation of the stems (left vs. right) and type of initial encoding of the critical words (same-case encoded vs. different-case encoded vs. not previously encoded). The data are collapsed across word-stem completion and word-stem cued recall tasks. Error bars indicate the (95%) “within-subjects confidence interval” (Loftus & Masson, 1994).

All participants had normal or corrected-to-normal vision, and none had participated in Experiment 1.

Design, materials, and procedure. This experiment was conducted in the same manner as Experiment 1, with the only exception that participants performed a like/dislike judgment task during initial encoding. They were instructed to rate how much they liked or disliked each encoding word (based on its meaning as opposed to visual appearance or some other criterion) using a 5-point scale (1 = dislike the word very much; 5 = like the word very much). They were not instructed in any other way except that they were told that it was very important that they judge their true feelings about each word. After each word disappeared, they typed a number key on the keyboard reflecting their judgment.

Results

Both conditionalized and unconditional completion rates are reported for all conditions in Table 2. As in Experiment 1, a four-way repeated measures analysis of variance (ANOVA) was conducted with conditionalized completion rate as the dependent measure. (Gender of participant did not enter into any significant

effect in a preliminary analysis, thus it was excluded in the analysis reported below.) The within-participants independent variables were type of encoding (same-case, different-case, or not previously encoded), hemisphere of direct test stem presentations (left or right), and letter case of test stems (lowercase or uppercase). The one between-participants independent variable was test task (word-stem completion or word-stem cued recall).

Figure 2 displays the critical-word completion rates from this experiment. The most important result was that case-specific memory was observed: Completion rates were significantly greater for same-case stems than for different-case stems when they were presented directly to the right hemisphere (44.2% vs. 37.0%, respectively), $F(1,248) = 6.72$, $MSE = 491.2$, $p < .01$, for the simple effect contrast, but not when they were presented directly to the left hemisphere (37.1% vs. 38.9%, respectively), $F < 1$, for the simple effect contrast. Unlike Experiment 1, these results replicate those from similar – but unmasked – experiments that also used deep encoding (Marsolek, 2004; Marsolek et al., 1992, 1994, 1996). In fact, type of encoding (same-case, different-case, or not previously encoded) interacted significantly with hemisphere of direct test presentation (left or right), $F(2,124) = 4.53$, $MSE = 305.1$, $p < .05$.

The only other significant effects in this analysis were the following (all other $ps > .12$). As in Experiment 1, completion rates differed for same-case (40.7%), different-case (38.0%), and not previously encoded stems (22.5%) in a significant main effect of type of encoding, $F(2,124) = 36.2$, $MSE = 677.3$, $p < .001$. Also as in Experiment 1, completion rates in cued recall (36.8%) generally were greater than those in word completion (30.7%), $F(1,62) = 6.28$, $MSE = 1,137.7$, $p < .05$. However, it is important to note that test task did not interact with any other variable.

Combined Results (Experiments 1 and 2)

The most important finding in this study was that significant form-specific memory was observed in right hemisphere presentations in Experiment 2 (see Figure 2) but significant form-specific memory was not observed in right hemisphere presentations in Experiment 1 (see Figure 1). To directly test this difference between the experiments, a final repeated-measures ANOVA was conducted on the combined data from Experiments 1 and 2, with experiment as an additional between-participants independent variable. Within this ANOVA, an a priori interaction contrast confirmed that the difference between completion rates for same-case stems versus different-case stems in right hemisphere test presentations in Experiment 2 (44.2% vs. 37.0%) was greater than that difference in

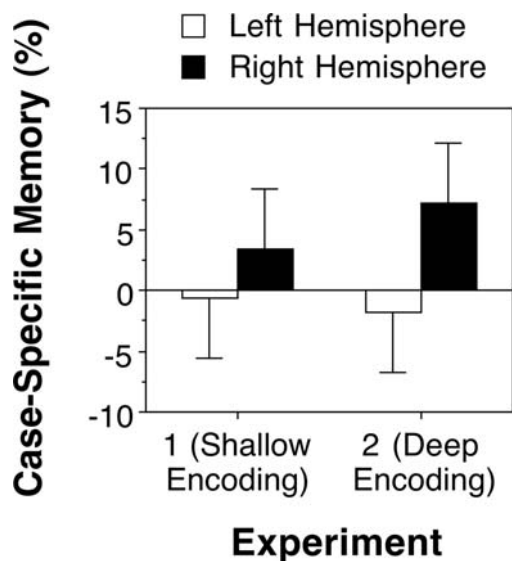


Figure 3. Results from both Experiments 1 and 2. Case-specific memory effects (critical-word completion rates for same-case stems minus critical-word completion rates for different-case stems) are depicted as functions of experiment (1/shallow encoding vs. 2/deep encoding) and hemisphere of direct test presentation of the stems (left vs. right). Error bars indicate the (95%) “within-subjects confidence interval” (Loftus & Masson, 1994).

Experiment 1 (34.1% vs. 30.8%), $F(1,250) = 5.14$, $MSE = 321.0$, $p < .05$. Figure 3 displays the relevant case-specific memory effects (completion rates for same-case stems minus completion rates for different-case stems) for both hemispheres and experiments.

Discussion

In this experiment, a relatively deep encoding task was used. The most important result was that form-specific memory was observed in this masked stem completion experiment, when test stems were presented directly to the right hemisphere. This finding contrasts with the lack of form-specific priming (in either right-hemisphere or left-hemisphere test presentations) in Experiment 1; however, it is in line with the results from an analogous experiment using unmasked word stem presentations and a deep encoding task (Marsolek, 2004).

To summarize the main results, when no mask is used and the encoding task is either shallow or deep, form-specific memory is observed (Marsolek, 2004). We hypothesize that no masking means no perceptual interference at test, thus interactive visual and postvisual processing during encoding is not needed to overcome such interference at test and enable a form-specific memory effect. In addition, form-specific memory is observed when masking is used and the encoding

task is deep (the present Experiment 2). We hypothesize that masking causes perceptual interference at test, thus interactive visual and postvisual processing during encoding is needed to overcome such interference at test and enable a form-specific memory effect. In contrast, form-specific memory is not observed when masking is used and the encoding task is shallow (the present Experiment 1). We hypothesize that masking causes perceptual interference at test, such that the lack of interactive visual and postvisual processing during encoding results in no ability to overcome perceptual interference at test and hence no form-specific memory effect being observed. For these reasons, the interactive visual-postvisual processing hypothesis was supported; in Experiment 2, deep encoding did prime the interactive representations needed to help a form-specific subsystem overcome the perceptual interference produced by masking at test.

General Discussion

Although many important properties of visual memory are being uncovered (e.g., Marsolek, 2003), important issues are still unresolved. For example, previous research indicates discrepant effects of depth of encoding on form-specific memory (Graf & Ryan, 1990; Jacoby et al., 1992). In the present masked stem completion study, letter-case specific memory was observed following a relatively deep encoding task, but not following a relatively shallow encoding task. This finding suggests that priming of interactive visual and postvisual processes is important for explaining depth of encoding effects on form-specific memory. Priming of interactive visual and postvisual processes can provide the support needed for (a) conceptual information to help form-specific perceptual processes to overcome the interference introduced by a masked test stimulus (the present Experiment 2), and (b) conceptual information to help form-specific perceptual processes to effectively contribute to priming during performance of a test task that requires both reading questions and comprehending them well enough to answer them (Jacoby et al.).

Word stem completion was utilized in the present study, and performance in this task can be affected by storage of different kinds of information. Previous studies implicate storage of visual information (Graf, Shimamura, & Squire, 1985; Marsolek et al., 1992), conceptual or semantic information (Bassili, Smith, & MacLeod, 1989; Blaxton et al., 1996; Keane, Gabrieli, Fennema, Growdon, & Corkin, 1991), and phonological information (Badgaiyan, Schacter, & Alpert, 1999; Rueckl & Mathew, 1999; Schacter, Badgaiyan, & Alpert, 1999). A new finding in the present study is that priming in stem completion can be influenced by interactive

visual and postvisual representations, at least when the encoding task involves deep processing. The reason why form-specific memory was observed when stems were presented directly to the right hemisphere but not when they were presented directly to the left hemisphere in Experiment 2 likely is that a form-specific subsystem of visual neocortex operates effectively in the right hemisphere, independently of a more abstract visual subsystem (for further evidence, see Marsolek et al., 1992, 1994, 1996, 2004).

It is important to note that the predictions derived in the present study hold for form-specific memory effects observed in word-stem completion, but not necessarily for memory effects observed in perceptual identification experiments (e.g., Jacoby & Dallas, 1981). Previous experiments indicate that the restrictive nature of the demands of the perceptual identification task creates a situation in which abstract visual representations dominate processing at test, whereas the unrestricted nature of the demands of the stem completion task allow for both specific and abstract visual representations (and others) to contribute to processing at test (for explication and evidence, see Burgund & Marsolek, 1997). The present theory concerns visual-postvisual interactions involving representations in a form-specific subsystem in particular. This may be why, for example, Jacoby and Dallas observed no depth of encoding effects on (same letter case) priming in perceptual identification; presumably, the bulk of the visual priming was supported by abstract visual representations, which should not yield form-specific priming effects of the sort that apparently can be influenced by conceptual representations (Jacoby et al., 1992). However, if memory effects in perceptual identification normally are supported by abstract visual representations, why did Jacoby and Hayman (1997) observe significant levels of case-specific memory using this task? Jacoby and Hayman observed case-specific memory only when the different-case condition involved encoding words presented in a large and visually unusual format. This is important because storage of preexperimentally novel forms (e.g., words in highly unusual fonts, which may not match preexisting representations precisely) appears to require a specific subsystem in the right hemisphere (see Marsolek, 2004). This subsystem can store novel visual forms effectively, because it is effective at processing visual wholes and the novel information in unfamiliar forms is in their holistic configurations (see Marsolek et al., 1996). There may be a limit, however, to the finding that visually unusual words are stored effectively in a specific subsystem when perceptual identification is used. Hunt and Toth (1990) found no significant difference in (same-case) priming effects for orthographically distinctive words (e.g., *czar*) versus

orthographically common words (e.g., *cube*) using perceptual identification. We speculate that, when this task is used, a specific subsystem may store preexperimentally novel forms especially well, but it may not store orthographically distinctive – yet preexperimentally familiar – forms more effectively than orthographically common forms.

The idea that visual and postvisual representations may interact to a high degree is not new. If the visual information and the conceptual information associated with a word are stored in spatially separated areas of neocortex, the representation of that word must include some links between the stores (as well as links to phonological stores). This is an idea inherent in many connectionist models of word processing (e.g., Masson, 1995; Plaut & Shallice, 1993; Rueckl, 1990; Seidenberg & McClelland, 1989; Van Orden et al., 1990). The representation of a word *per se* includes perceptual, conceptual, and phonological information, thus the links between the relevant subsystems are crucial. We suggest that the interactive visual and postvisual processes reflected in the present results are stored through the kind of weakly independent representations posited in such models.

In addition, it may be useful to note that somewhat similar ideas have been proposed by Hirshman, Trembath, and Mulligan (1994), but with a focus on encoding processes. They observed, as Nairne (1988) had before, that pattern masking during encoding enhanced subsequent explicit memory for words (for related results and conclusions, see Tardif & Craik, 1989). To account for these findings, Hirshman et al. (1994) suggested that higher-level representations compensate for the interference to lower-level processing in such a way that leads to improved explicit memory. This appears to be an interesting parallel with our observations and conclusions. At present, however, it is unclear whether such compensatory processing is the same as the interactivity posited in the present theory (e.g., whether the compensatory processing is supported by hippocampal-neocortical interactions or by interactive visual-postvisual neocortical processes of the sort we hypothesize).

The present results are not in line with the hypothesis that form-specific priming relies on involuntary explicit memory (Curran et al., 1996; Schacter, 1994). Although it apparently is possible for involuntary explicit memory to influence form-specific priming effects, at least under certain conditions (e.g., Kinoshita & Wayland, 1993; see also, Badgaiyan et al., 1999; Jacoby, Toth, & Yonelinas, 1993; Schacter et al., 1999), further evidence indicates that representations underlying form-specific priming also can be stored in the neocortex independently of the hippocampal formation

(for reviews and theory, see Marsolek, 2003; Marsolek & Burgund, 1997). For example, amnesic patients with damage to the hippocampal formation can produce normal specificity effects in priming, indicating that hippocampal interactions are not necessary for form-specific priming effects (Vaidya et al., 1998; cf. Hamann & Squire, 1997). Also, in the present study, the cued recall test task did not produce greater form-specific memory than the word completion task. In light of all of these results, form-specific priming may be supported by form-specific neocortical processing without hippocampal mediation, as well as by involuntary explicit memory via hippocampal mediation, but apparently under different conditions.

The present results also are not in line with other hypotheses in this domain. First, Jacoby et al. (1992) suggested that form-specific memory should be observed when unusual typographies are used or when reading is "backgrounded" in the service of some other task required of the participant. However, a typical font was used throughout the present study, and it is difficult to understand how reading may have been more strongly backgrounded in the service of performing liking judgments than in the service of counting vowels. Generally, the notion of backgrounding may require greater specification to be applied unequivocally to new experiments. Second, the transfer-appropriate processing approach (Morris, Bransford, & Franks, 1977) suggests that form-specific memory should be observed when the encoding task requires processing of perceptual information (e.g., Graf & Ryan, 1990). Inconsistent with that prediction, liking judgments, not vowel counting, led to form-specific memory in this study. However, given this result, one may ask why Graf and Ryan found greater form-specific memory following shallow encoding than following deep encoding in their study. Our suggestion would be that it is because they used very unfamiliar fonts and presentation formats (e.g., upside down and backward printed words). We have found in previous research (Marsolek et al., 1996) that preexperimentally novel visual forms are special in that they require attention to perceptual information during encoding for the form-specific representations to be created in the first place. In contrast, familiar forms, such as those used in the present study, are well known and well represented preexperimentally. Hence, they may produce form-specific memory effects even when the encoding task does not require only perceptual processing.

In an unanticipated difference, the memory exhibited in the different-case condition (compared against the baseline stem completion condition) overall was greater in Experiment 2 (with deep encoding) than in Experiment 1 (with shallow encoding; compare Figures

1 and 2). We suspect that this reflects more effective storage of postvisual information associated with the words following deep encoding than following shallow encoding. If so, the effect would be due to postvisual storage of information that was additive with respect to the visual-postvisual interactions of primary concern in this study.

Finally, in both experiments, the effect of test task (cued recall versus word completion) was significant as a main effect, although it did not interact significantly with hemisphere of direct test presentations or with type of encoding (same-case, different-case, or not previously encoded). Thus, memory was generally greater in cued recall than in word completion, but in an effect that did not differ depending on the other important conditions (for similar results and discussion, see Marsolek et al., 1994). One could suggest that the lack of a qualitative difference in results from cued recall and word completion tasks is in line with the possibility that explicit memory was exhibited throughout all conditions of the present study, even in the presumably implicit-memory task of word completion. However, this pattern of results should not be taken as evidence for or against the possibility that one form of memory (explicit or implicit) was exhibited. Different forms of memory supported by different sets of neural subsystems can exhibit similar properties. We suspect that the cued-recall advantage was supported by neocortical-hippocampal interactions involving all relevant neocortical areas (conceptual, form-abstract visual, form-specific visual, etc.). The only significant interaction involving test task was a three-way interaction between test task, letter case of test stems (lowercase vs. uppercase), and test hemisphere in Experiment 1. However, given the unpredicted nature of the effect and the fact that it was not replicated in Experiment 2, we suspect that it may have been a spurious result. Also, it is important to note that type of encoding (same-case, different-case, or not previously encoded) did not influence the result, belying the possibility that the effect should qualify the main conclusions from this study.

To summarize, visual-postvisual interactions appear to be important for helping to explain an intriguing aspect of form-specific memory. In particular, after deep encoding, the interactive support of postvisual processes can help to overcome perceptual interference in visual processes, allowing form-specific memory to be produced. However, after shallow encoding, there is no postvisual support to help overcome perceptual interference, and form-specific memory is not produced. These findings may help to uncover important properties of the architecture and interactive nature of the processes underlying human visual memory.

This work was supported by the National Institute of Mental Health, Grants MH53959 and MH60442; by the McDonnell-Pew Cognitive Neuroscience Center and the Arizona Cognitive Science Program of the University of Arizona; and by the Center for Cognitive Sciences in conjunction with the National Science Foundation (GER 9454163), the Office of the Vice President for Research, and Dean of the Graduate School of the University of Minnesota. We thank Chris Azorson for important insights, Darcy Burgund, Stephan Hamann, Michael Masson, and James Nairne for comments on previous versions of this manuscript, and Denise Bencomo, Jason Fierstein, Erin Stoltz, and Michele Wright for assistance with data collection and analysis. An earlier report of this research was presented at the Annual Meeting of the Cognitive Neuroscience Society, San Francisco (1998).

Correspondence concerning this article may be sent to Chad J. Marsolek, Department of Psychology, University of Minnesota, 75 East River Road, Minneapolis, Minnesota 55455 (E-mail: chad.j.marsolek-1@umn.edu) <http://psych.umn.edu/psylabs/marsoleklab/index/>

References

- Badgaiyan, R. D., Schacter, D. L., & Alpert, N. M. (1999). Auditory priming within and across modalities: Evidence from positron emission tomography. *Journal of Cognitive Neuroscience, 11*, 337-348.
- Bassili, J. N., Smith, M. C., & MacLeod, C. M. (1989). Auditory and visual word-stem completion: Separating data driven and conceptually driven processes. *Quarterly Journal of Experimental Psychology, 41A*, 439-453.
- Becker, S., Moscovitch, M., Behrmann, M., & Joordens, S. (1997). Long-term semantic priming: A computational account and empirical evidence. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23*, 1059-1082.
- Blaxton, T. A., Bookheimer, S., Zeffiro, T. A., Figlozzi, C. M., Gaillard, W. D., & Theodore, W. H. (1996). Functional mapping of human memory using PET: Comparisons of perceptual and conceptual tasks. *Canadian Journal of Experimental Psychology, 50*, 42-56.
- Boles, D. B., & Clifford, J. E. (1989). An upper- and lower-case alphabetic similarity matrix, with derived generation similarity values. *Behavior Research Methods, Instruments, & Computers, 21*, 579-583.
- Bowers, J. S., Damian, M. F., & Havelka, J. (2002). Can distributed orthographic knowledge support word-specific long-term priming? Apparently so. *Journal of Memory & Language, 46*, 24-38.
- Bowers, J. S., & Marsolek, C. J. (Eds.). (2003). *Rethinking implicit memory*. Oxford: Oxford University Press.
- Buckner, R. L., & Koutstaal, W. (1998). Functional neuroimaging studies of encoding, priming, and explicit memory retrieval. *Proceedings of the National Academy of Sciences USA, 95*, 891-898.
- Burgund, E. D., & Marsolek, C. J. (1997). Letter-case specific priming in the right cerebral hemisphere with a form-specific perceptual identification task. *Brain and Cognition, 35*, 239-258.
- Burgund, E. D., Marsolek, C. J., & Luciana, M. (2003). Serotonin levels influence patterns of repetition priming. *Neuropsychology, 17*, 161-170.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.
- Cohen, N. J., & Eichenbaum, H. (1993). *Memory, amnesia, and the hippocampal system*. Cambridge, MA: MIT Press.
- Craik, F. I. M., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. *Journal of Experimental Psychology: General, 104*, 268-294.
- Curran, T., Schacter, D. L., & Bessenoff, G. (1996). Visual specificity effects in word stem completion: Beyond transfer appropriate processing? *Canadian Journal of Experimental Psychology, 50*, 22-33.
- Farah, M. J. (1994). Neuropsychological inference with an interactive brain: A critique of the locality assumption. *Behavioral and Brain Sciences, 17*, 43-104.
- Francis, W. N., & Kucera, H. (1982). *Frequency analysis of English usage: Lexicon and grammar*. Boston, MA: Houghton Mifflin.
- Gabrieli, J. D. E., Desmond, J. E., Demb, J. B., Wagner, A. D., Stone, M. V., Vaidya, C. J., et al. (1996). Functional magnetic resonance imaging of semantic memory processes in the frontal lobes. *Psychological Science, 7*, 278-283.
- Graf, P., & Ryan, L. (1990). Transfer-appropriate processing for implicit and explicit memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*, 978-992.
- Graf, P., Shimamura, A. P., & Squire, L. R. (1985). Priming across modalities and priming across category levels: Extending the domain of preserved function in amnesia. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11*, 385-395.
- Hamann, S. B., & Squire, L. R. (1996). Level-of-processing effects in word-completion priming: A neuropsychological study. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22*, 933-947.
- Hamann, S. B., & Squire, L. R. (1997). Intact priming for novel perceptual representations in amnesia. *Journal of Cognitive Neuroscience, 9*, 699-713.
- Hirshman, E., Trembath, D., & Mulligan, N. (1994). Theoretical implications of the mnemonic benefits of perceptual interference. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20*, 608-620.
- Hunt, R. R., & Toth, J. P. (1990). Perceptual identification, fragment completion, and free recall: Concepts and data.

- Journal of Experimental Psychology: Learning, Memory, and Cognition*, 16, 282-290.
- Jacoby, L. L., & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General*, 110, 306-340.
- Jacoby, L. L., & Hayman, C. A. G. (1987). Specific visual transfer in word identification. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 13, 456-463.
- Jacoby, L. L., Levy, B. A., & Steinbach, K. (1992). Episodic transfer and automaticity: Integration of data-driven and conceptually-driven processing in rereading. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18, 15-24.
- Jacoby, L. L., Toth, J. P., & Yonelinas, A. P. (1993). Separating conscious and unconscious influences on memory: Measuring recollection. *Journal of Experimental Psychology: General*, 122, 139-154.
- Keane, M. M., Gabrieli, J. D. E., Fennema, A. C., Growdon, J. H., & Corkin, S. (1991). Evidence for a dissociation between perceptual and conceptual priming in Alzheimer's disease. *Behavioral Neuroscience*, 105, 326-342.
- Kinoshita, S., & Wayland, S. V. (1993). Effects of surface features on word-fragment completion in amnesic subjects. *American Journal of Psychology*, 106, 67-80.
- Kirsner, K. (1973). An analysis of the visual component in recognition memory for verbal stimuli. *Memory & Cognition*, 1, 449-453.
- Loftus, G. R., & Masson, M. E. J. (1994). Using confidence intervals in within-subject designs. *Psychonomic Bulletin & Review*, 1, 476-490.
- Marsolek, C. J. (1995). Abstract visual-form representations in the left cerebral hemisphere. *Journal of Experimental Psychology: Human Perception and Performance*, 21, 375-386.
- Marsolek, C. J. (1999). Dissociable neural subsystems underlie abstract and specific object recognition. *Psychological Science*, 10, 111-118.
- Marsolek, C. J. (2003). What is priming and why? In J. S. Bowers & C. J. Marsolek (Eds.), *Rethinking implicit memory* (pp. 41-64). Oxford: Oxford University Press.
- Marsolek, C. J. (2004). Abstractionist versus exemplar-based theories of visual word priming: A subsystems resolution. *The Quarterly Journal of Experimental Psychology*, 57, 1233-1259.
- Marsolek, C. J., & Burgund E. D. (1997). Computational analyses and hemispheric asymmetries in visual-form recognition. In S. Christman (Ed.), *Cerebral asymmetries in sensory and perceptual processing* (pp. 125-158). Amsterdam: Elsevier.
- Marsolek, C. J., Kosslyn, S. M., & Squire L. R. (1992). Form-specific visual priming in the right cerebral hemisphere. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18, 492-508.
- Marsolek, C. J., Schacter, D. L., & Nicholas, C. D. (1996). Form-specific visual priming for new associations in the right cerebral hemisphere. *Memory & Cognition*, 24, 539-556.
- Marsolek, C. J., Squire, L. R., Kosslyn, S. M., & Lulenski, M. E. (1994). Form-specific explicit and implicit memory in the right cerebral hemisphere. *Neuropsychology*, 8, 588-597.
- Masson, M. E. J. (1986). Identification of typographically transformed words: Instance-based acquisition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 12, 479-488.
- Masson, M. E. J. (1995). A distributed memory model of semantic priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 21, 3-23.
- McClelland, J. L., McNaughton, B. L., & O'Reilly, R. C. (1995). Why there are complementary learning systems in the hippocampus and neocortex: Insights from the successes and failures of connectionist models of learning and memory. *Psychological Review*, 102, 419-457.
- Morris, C. D., Bransford, J. D., & Franks, J. J. (1977). Levels of processing versus transfer appropriate processing. *Journal of Verbal Learning and Verbal Behavior*, 16, 519-533.
- Nairne, J. (1988). The mnemonic value of perceptual identification. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 14, 248-255.
- Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia*, 9, 97-113.
- Plaut, D. C., & Shallice, T. (1993). Deep dyslexia: A case study of connectionist neuropsychology. *Cognitive Neuropsychology*, 10, 377-500.
- Richardson-Klavehn, A., & Gardiner, J. M. (1998). Depth-of-processing effects on priming in stem completion: Tests of the voluntary-contamination, conceptual-processing, and lexical-processing hypotheses. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 24, 593-609.
- Richardson-Klavehn, A., Gardiner, J. M., & Java, R. I. (1994). Involuntary conscious memory and the method of opposition. *Memory*, 2, 1-29.
- Roediger, H. L. III, & Blaxton, T. A. (1987). Retrieval modes produce dissociations in memory for surface information. In D. S. Gorfein & R. R. Hoffman (Eds.), *Memory and cognitive processes: The Ebbinghaus centennial conference* (pp. 349-379). Hillsdale, NJ: Erlbaum.
- Rueckl, J. G. (1990). Similarity effects in word and pseudo-word repetition priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 16, 374-391.
- Rueckl, J. G. (2003). A connectionist perspective on repeti-

- tion priming. In J. S. Bowers & C. J. Marsolek (Eds.), *Rethinking implicit memory* (pp. 67-104). Oxford: Oxford University Press.
- Rueckl, J. G., & Mathew, S. (1999). Implicit memory for phonological processes in visual stem completion. *Memory & Cognition*, 27, 1-11.
- Schacter, D. L. (1990). Perceptual representation systems and implicit memory: Toward a resolution of the multiple memory systems debate. *Annals of the New York Academy of Sciences*, 608, 543-571.
- Schacter, D. L. (1994). Priming and multiple memory systems: Perceptual mechanisms of implicit memory. In D. L. Schacter & E. Tulving (Eds.), *Memory systems 1994* (pp. 233-268). Cambridge, MA: MIT Press.
- Schacter, D. L., Badgaiyan, R. D., & Alpert, N. M. (1999). Visual word stem completion priming within and across modalities: A PET study. *NeuroReport*, 10, 2061-2065.
- Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of visual word recognition. *Psychological Review*, 96, 523-568.
- Squire, L. R. (1992). Memory and the hippocampus: A synthesis from findings with rats, monkeys, and humans. *Psychological Review*, 99, 195-231.
- Stark, C. E. L., & McClelland, J. L. (2000). Repetition priming of words, pseudowords, and nonwords. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 26, 945-972.
- Tardif, T., & Craik, F. I. (1989). Reading a week later: Perceptual and conceptual factors. *Journal of Memory & Language*, 28, 107-125.
- Vaidya, C. J., Gabrieli, J. D. E., Verfaellie, M., Fleischman, D., & Askari, N. (1998). Font-specific priming following global amnesia and occipital lobe damage. *Neuropsychology*, 12, 183-192.
- Van Essen, D. C., & DeYoe, E. A. (1995). Concurrent processing in the primate visual cortex. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 383-400). Cambridge, MA: MIT Press.
- Van Orden, G., Pennington, B., & Stone, G. (1990). Word identification in reading and the promise of subsymbolic linguistics. *Psychological Review*, 97, 488-522.
- Webster's Vest Pocket Dictionary*. (1989). Springfield, MA: Merriam-Webster.
- Woltz, D. J. (1990). Repetition of semantic comparisons: Temporary and persistent priming effects. *Journal of Experimental Psychology: Learning, Memory, and*

Sommaire

Le fait que l'amorçage par répétition puisse être propre à la forme dans certaines conditions est un important aspect du phénomène. La mesure de l'amorçage d'un mot propre à la forme est plus grande lorsque les mots sont présentés selon le même format (casse de la lettre et police) à l'encodage initial d'un mot (par ex., « bear ») et lors d'un test ultérieur (par ex., « bear ») que lorsque les mots sont présentés selon un format différent à l'encodage (par ex., « BEAR ») et lors du test (par ex., « bear »). En partie parce que de nombreuses études sur les effets de la profondeur de l'encodage de l'amorçage propre à la forme ont, jusqu'à présent, permis d'observer des résultats contradictoires en apparence, nous avons testé des théories de rechange pour expliquer de tels effets. Si la mémoire explicite involontaire facilite les effets de profondeur de l'encodage sur la mémoire propre à la forme, nous devrions alors voir à l'œuvre la mémoire propre à la forme lorsqu'une tâche d'encodage peu profonde (perceptuelle) est utilisée, mais celle-ci n'interviendrait pas lorsqu'on utilise une tâche d'encodage profonde (perceptuelle et conceptuelle). En revanche, si l'interactivité entre les processus visuels et post-visuels est nécessaire pour permettre les effets de profondeur de l'encodage sur la mémoire propre à la forme, nous supposons alors que la mémoire propre à la forme ne sera pas observée lorsqu'une tâche d'encodage peu profonde (perceptuelle) est utilisée, mais que celle-ci sera observée lorsqu'une tâche d'encodage profonde (perceptuelle et conceptuelle) est utilisée.

Les participants ont visionné des mots (par ex., « bear ») présentés au centre pendant l'encodage initial; par la suite,

ils ont complété des racines de mot (par ex., « BEA ») présentés dans le champ visuel gauche et le champ visuel droit masqués par un patron lors d'un test ultérieur. Dans l'expérience 1, la tâche d'encodage faisait appel au traitement perceptuel (encodage peu profond) et la mémoire propre à la casse de la lettre n'était pas observée. Cela diffère des résultats obtenus aux expériences précédentes, qui ne faisaient pas appel au masquage au moyen d'un patron. Cependant, au cours de l'expérience 2, la tâche d'encodage exigeait un traitement à la fois perceptuel et conceptuel (encodage profond) et la mémoire propre à la casse de la lettre était observée lors de la présentation des tests dans l'hémisphère droit direct, mais elle n'était pas observée lors de la présentation des tests dans l'hémisphère gauche direct. Cette observation se rapproche des résultats obtenus dans les études précédentes qui n'utilisaient pas le masquage au moyen d'un patron. Les présents résultats n'étaient pas influencés par la complétion de la racine du mot pour former les premiers mots qui surgissent à l'esprit ni par les mots récupérés explicitement à partir de l'encodage.

La profondeur de l'encodage peut influencer la mémoire propre à la forme grâce au traitement interactif de l'information visuelle et post-visuelle. Lorsque aucun masquage n'est utilisé et que la tâche d'encodage est peu profonde ou profonde, nous observons l'intervention de la mémoire propre à la forme (Marsolek, 2004). Nous avons pour hypothèse que l'absence de masquage se traduit par l'absence d'interférence perceptuelle lors du test et que, par conséquent, le traitement interactif visuel et post-visuel pen-

nant l'encodage est inutile pour surmonter l'interférence lors du test et pour activer les effets de la mémoire propre à la forme. De plus, nous observons la mémoire propre à la forme si un masque est utilisé et si la tâche d'encodage est profonde (expérience 2 de la présente étude). Nous supposons que le masque entraîne l'interférence perceptuelle lors du test et que, par conséquent, le traitement interactif visuel et post-visuel pendant l'encodage est nécessaire pour surmonter l'interférence lors du test et pour activer les effets de la mémoire propre à la forme. En revanche, nous

n'observons pas l'intervention de la mémoire propre à la forme lorsque le masquage est utilisé et que la tâche d'encodage est peu profonde (expérience 1 de la présente étude). Nous formulons comme hypothèse que le masquage entraîne l'interférence perceptuelle lors du test, de sorte que l'absence de traitement interactif visuel et post-visuel pendant l'encodage entraîne l'incapacité de surmonter l'interférence perceptuelle lors du test et, de là, empêche d'observer les effets de mémoire propre à la forme.