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Auditory and Visual Word-Stem Completion: Separating Data-Driven and Conceptually Driven Processes

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Two experiments investigated the contributions of data-driven and conceptually driven processing on an implicit word-stem completion task. In Experiment 1, individual words were studied either visually or auditorily and were tested using either visual or auditory word-stems. Keeping modality the same from study to test led to more priming than did changing modality, but there was reliable cross-modal priming. In Experiment 2, subjects read sentences like *The boat travelled underwater* and inferred the subject noun (i.e. "submarine") or sentences like *The submarine travelled underwater* and categorized the subject noun (i.e. "boat"). At test, there was reliable priming for both actually read nouns and inferred nouns. In addition, a modality effect was evident for the actually read nouns but not for the inferred nouns. Taken together, these results imply that there is a basic conceptually driven contribution to priming plus an additional contribution of data-driven processing when surface form is the same at study and test.

A growing body of research points to an important dichotomy in the study of memory—that between *explicit* and *implicit* tests of memory. In tests of explicit memory, such as recognition and recall, subjects are asked to recollect overtly some previously presented material. Until quite recently this was the dominant procedure for the investigation of memory. However, work with amnesics initiated by Warrington and Weiskrantz (1970, 1974) has

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demonstrated that whereas amnesics show little evidence of memory when tested with explicit procedures, their memory is comparable to that of normals if testing is done implicitly. Warrington and Weiskrantz employed a word-fragment completion task in which subjects were asked to complete fragments such as *B_E_D* with the first word that came to mind. They found that prior presentation of the word to be completed (e.g. *BREAD*) greatly enhanced or "primed" performance on this completion task. Obviously, the material had been encoded and stored successfully by the amnesic subjects. The problem for them was in gaining the conscious access to it required by explicit tests of remembering.

This work with amnesics has recently gained renewed importance because of demonstrations that dichotomies in memory performance exist in normal subjects as well. For example, Tulving, Schacter, and Stark (1982) found that normal subjects showed no relation between performance on recognition and word-fragment completion tests of memory. Similar independence between performance on explicit and implicit tests had been demonstrated by Kolers (1976), who found beneficial effects from the prior reading of a passage of inverted text when subjects were retested one year later, despite the fact that they could not consciously differentiate between new and previously read sentences. This sort of saving without awareness also occurs when the materials to be learned are single words or pictures (e.g. MacLeod, 1988). In addition, using a perceptual identification test which requires subjects to read aloud tachistoscopically presented words, Jacoby has demonstrated that priming is susceptible to factors different from those that influence recognition memory (Jacoby, 1983; Jacoby & Dallas, 1981; Jacoby & Witherspoon, 1982). For example, recognition was strongly influenced by encoding strategy, whereas priming in perceptual identification was independent of whether the initial encoding of the words was graphemic, phonemic, or semantic.

Such differences have led some researchers (e.g. Squire, 1986; Tulving, 1985) to propose that there are distinct memory systems. In Schacter's (1987) terminology, "implicit memory" is revealed by tasks that do not require conscious recollection, whereas "explicit memory" is revealed by tasks that do require conscious remembering. However, an alternative explanation for the differential performance on the two types of tasks has been suggested by Jacoby (1983) and by Roediger and his colleagues (Roediger & Blaxton, 1987a, b; Roediger, Weldon, & Challis, in press; Weldon & Roediger, 1987). These researchers argue that most memory tests can be differentiated by the extent to which they require either data-driven ("bottom-up") processing, which is directed more at surface features of stimuli, or conceptually driven ("top-down") processing, which is directed at the deeper meaning of the stimuli. Furthermore, they suggest that the explicit/implicit dichotomy in memory results from the fact that explicit tests such as recognition and recall typically emphasize conceptually driven processes, whereas implicit tests

such as word-fragment completion, perceptual identification, or speed of reading inverted text typically emphasize data-driven processes.

Considerable research has shown that there is a strong interaction between encoding and retrieval tasks and that recollection improves if retrieval operations are similar to encoding operations (Fisher & Craik, 1977; Morris, Bransford, & Franks, 1977; Tulving & Thomson, 1973). Consequently, how well subjects perform on one or the other of the types of memory tasks may depend largely on the nature of the original type of encoding. To the extent that initial encoding manipulations stress conceptual encoding, tests of explicit memory may benefit; if data-driven processes are emphasized, tests of implicit memory may be favoured. In contrast to the notion of separate memory systems, therefore, the hypothesis put forward by Jacoby and by Roediger and his coworkers suggests that there is a single memory system and that level of performance is determined by degree of overlap of processes at presentation and at test. Richardson-Klavehn and Bjork (1988) present extensive coverage of relevant data in their recent review.

To test the processing view, Roediger and his colleagues (e.g. Roediger & Blaxton, 1987a) presented words either auditorily or visually and tested memory with either a visual word-fragment completion task or a recall task. They reasoned that if implicit memory tests such as word-fragment completion rely largely on data-driven processes, then they should be more sensitive to presentation modality than are conceptually driven recall tests. Their recall data replicated those of earlier researchers in demonstrating that recall is not strongly affected by presentation modality. In contrast, the implicit memory task of visual word-fragment completion was highly sensitive to modality of presentation, with performance following visual presentation superior to that following auditory presentation, although there was priming across modality. Similar patterns of performance emerged when mode of presentation was manipulated by varying typography or by using pictures and words as stimuli (Weldon & Roediger, 1987). Word-fragment completion performance was superior when the format of the stimulus was the same at presentation and at test. Because the auditory–visual distinction represents one of the purest manipulations within data-driven processes, however, it provides the strongest evidence for the case made by Roediger and his coworkers. Donnelly (1988) presents a careful review of the evidence relevant to the modality issue.

Our goal was to explore further the role of data-driven and conceptually driven processes in implicit memory by pursuing the study of modality effects. Two questions were addressed, one of design, the other of theory. Consider the question of design first. In almost all previous studies examining modality effects on word-fragment completion, the dependent measure was performance on a *visually* presented word-fragment. Hence, interpreta-

tion of the finding that subjects perform better on this task following visual word presentation than following auditory word presentation is somewhat ambiguous. Specifically, it may not be because the modalities are the same in the visual–visual condition that performance is superior. Rather, it may be that visual presentation is simply superior to auditory presentation for any number of reasons.

A properly balanced design to assess modality effects necessitates both a visual and an auditory word-fragment completion test, to our knowledge a test hitherto unexplored (cf. Donnelly, 1988). Consequently, in this study we developed an auditory version of the word-fragment completion task. More precisely, we used a word-stem completion task (Graf, Squire, & Mandler, 1984) in which either the first few letters of a word were presented visually, or its first few phonemes were presented auditorily. Extensive pilot work was done to ensure that the base level of word identification was similar in the two cases. In Experiment 1 we manipulated modality factorially at presentation and test, thereby permitting the magnitude of priming within and across modalities to be assessed in a balanced manner. We reasoned that the extent to which within-modality priming was greater than between-modality priming would provide some indication of the contribution of data-driven processes to the word-stem completion task. Conversely, between-modality priming probably reflects the operation of more abstract, conceptually driven processes.

The second issue addressed in this research was how the type of initial processing would influence later performance on the stem completion task. According to Roediger and his colleagues, memory performance depends on the overlap between data-driven and conceptually driven processes at presentation and test. In Experiment 2, we varied the extent to which an item was data-driven or conceptually driven by using as stimuli words that had been inferred as well as words that had actually been presented. Thus, subjects read or listened to sentences in one of two forms: *The boat travelled underwater* or *The submarine travelled underwater*. When presented with the first type of sentence, the subject was to infer the "specific" subject of the sentence (i.e. "submarine"). When presented with the second type of sentence, the subject was to indicate the category to which the noun belonged (i.e. "boat"). In either case, the subject was later given a stem completion test for the word *submarine*.

Following Roediger and his colleagues, and assuming that the actually presented sentence nouns would generate relatively more data-driven and less conceptually driven processing than the inferred nouns, we expected that the magnitude of priming would be greater for actually presented words than for inferred words. This hypothesis was based on the assumption that only presented items in this experiment would invoke data-driven processing of the sort that would be duplicated by a measure of implicit memory such as

the stem completion task. Because inferred words would appear to involve virtually no data-driven processing (the actual item is not presented), we expected that inferred words would show less priming on the stem completion task than would the actually presented words.

To summarize, we wished to assess the relative contribution of data-driven and conceptually driven processes in the word-stem completion task. This was done in two ways. In Experiment 1, we completed the 2×2 examination of modality effects on a word-stem completion measure of implicit memory. To do so, we constructed an auditory analogue of stem completion. The major goal was to investigate the extent to which the same-modality sequences would benefit stem completion more than the different-modality sequences. In Experiment 2, conceptual processing of the materials was manipulated by having some test words actually presented and others inferred at presentation (see Bassili & Smith, 1986). The issue of interest was the comparison of magnitude of priming for inferred versus actually presented words. According to the processing account, inferred words should prime less.

EXPERIMENT 1

Method

Subjects. Forty-eight undergraduate students at the Scarborough Campus of the University of Toronto served as subjects in this experiment. They were recruited from an introductory psychology course and received credit for their participation.

Procedure. Subjects participated in the experiment individually. Instructions and visual stimulus materials were presented over a video monitor; auditory stimuli were presented over a tape recorder. Progress through the experiment was self-paced; subjects controlled the flow of instructions by pressing relevant keys on a computer keyboard.

The experiment consisted of two parts: an initial study phase and a later test phase. For the study phase, subjects read a set of instructions that informed them that they would be presented with a list of words that they would be asked to recall later. Depending on the subject's presentation condition, two examples illustrating the words were then presented over either the video monitor or the tape recorder. There were 24 stimulus words that were divided randomly into three sets of eight. Words from each set were either presented to or withheld from subjects in a counterbalanced manner to establish primed and unprimed stem completion performance. Presentation was at the rate of one word every 8 sec, with visually presented words staying

on the screen for that duration and auditorily presented words occurring twice during that time.

In the test phase, subjects completed 48 stem completions, presented in either the auditory or the visual mode. Depending on the study set for a subject, eight of these stems were "old" in that they corresponded to previously studied words, eight were "new" in that they corresponded to stimulus words that had not been studied, and the rest were fillers. Prior to beginning the test phase, subjects were instructed in the following manner: "In a moment we will ask you to perform a recall test. In research on memory, however, it is often necessary to place a distraction task between the presentation of information and its recall. The distraction task we would like you to perform involves what are called stem completions." Then the task was explained to them with a few examples. Presenting the stem completion procedure under the guise of a distraction task may be important. Past research (see e.g. Graf et al., 1984, p. 174) has demonstrated that stem completions can turn into indices of explicit rather than implicit memory if subjects adopt a cued-recall strategy for their solution. Our instructions, therefore, were aimed at diverting the subjects' attention during the completion task away from the studied words. The fact that only a sixth of the stems in this task were derived from words that were actually presented to any given subject further minimized the likelihood of a cued-recall approach being adopted.

In the visual presentation condition, the word-stems were presented in a random order for 8 sec each on the video monitor. Subjects were instructed to respond aloud to the stems with the first completion that came to mind. These responses were recorded by the experimenter. In the auditory presentation condition, the word-stems were presented twice within a period of 8 sec by a professional speech pathologist, who took great care to truncate the words in a phonemically correct manner. The order of presentation as well as the method of recording subject responses were the same as in the visual presentation condition.

Results and Discussion

Percentage priming of word-stem completions, taken as the difference between performance on old and new test items, is shown in Table 1 for the four presentation-test conditions. Using the auditory analogue to the visual word-stem completion, we were able to achieve performance levels comparable to those found with its more familiar visual counterpart. More importantly, it may be observed in Table 1 that the auditory stem completion procedure yielded priming effects that were of similar magnitude to those yielded by the visual task.

TABLE 1
Percentage of Priming as a Function of Presentation and Test Modality in Experiment 1

	Presentation Modality	
Test Modality	*Auditory*	*Visual*
Auditory	36.5	26.0
Visual	19.7	36.5

For the visual word-stem completion test, the data corroborated those of Roediger and Blaxton (1987a, b). There was greater priming when study and test were in the same modality (V–V) than when they were in different modalities (A–V). The question of interest in this study was whether this same-modality superiority resulted from the contribution of a perceptual priming component, or whether there was simply some inherent advantage to visual presentation during study. The data provide a fairly clear answer. If visual presentation was inherently superior to auditory presentation, there should be a significant presentation main effect. This was not the case, as neither the main effect of test modality nor that of presentation modality was significant ($F < 1$). Instead, the data revealed a marginally significant interaction of test and presentation modality, $F(1, 44) = 3.93$, $MSe = 559.90$, $p < 0.06$, with both same-modality conditions showing greater priming than the two different-modality conditions.

In sum, these data suggest that there is indeed a modality effect on stem completion. The fact that there is greater priming under same-modality conditions (36.5%), in which there are both data-driven and conceptually driven processes, as compared to the priming in cross-modality conditions (22.9%) in which the data-driven component is minimized, suggests that data-driven processes play an important role during word-stem completion. This finding is in contrast to that typically found with explicit measures of memory: modality does not affect performance in such tasks as recall or recognition. These data therefore corroborate Roediger's contention that implicit memory tests are more responsive than explicit memory tests to data-driven processes. However, the very considerable priming that still appears in the two cross-modality conditions indicates that word-stem completion is responsive to non-perceptual processing as well. In Experiment 2, we explored this component further.

EXPERIMENT 2

Although Experiment 1 provided suggestive evidence of modality-specific data-driven processing, the results were not as strong as one might wish, and they also suggested a large conceptually driven processing component. In

Experiment 2, we sought to test the generality and robustness of the within-modality effect and to explore conceptual processing in a different way. Roediger, Weldon, and Challis (in press) suggest that reading a word without an appropriate semantic context involves primarily data-driven processing. Indeed, they go so far as to suggest that the difference between generate and read conditions be used as the benchmark for conceptual processing. In Experiment 2, the lists of words used in the first experiment were replaced with sentences, once again presented either auditorily or visually.

Subjects processed half of the sentences under each of two sets of instructions. To illustrate, a subject might see (or hear) the sentence "The *boat* travelled underwater", and be asked to think of the item indicated by the emphasized subject noun, in this case "submarine". Hence, the inference "submarine" was conceptually activated but never actually presented. This condition, therefore, involved minimal data-driven processing of "submarine". In contrast, that subject might see (or hear) the sentence "The *spoon* was used to eat the soup", and be asked to think of a category to which the subject noun of the sentence could be assigned (in this case, "utensil" or the like). Hence, in this condition the item "spoon" received *both* conceptual processing (categorization) and data-driven perceptual processing.

Comparison of priming on the word-stem completion task in the two conditions would provide a suggestive index of the relative contributions of the data-driven and conceptually driven processing components. In addition, the inclusion of both auditory and visual presentation and test conditions would permit us to determine whether the findings of Experiment 1 with isolated words would also be found when subjects processed words embedded in meaningful sentences, thereby allowing us both to examine the generalizability of the modality superiority effect and to determine whether its magnitude was dependent on the nature of the initial context of processing.

Method

Subjects. Ninety-six students at the Scarborough Campus of the University of Toronto served as subjects in this experiment. They were recruited from an introductory course in psychology and received course credit for their participation.

Procedure. A set of 24 sentences was prepared, each of which had as its subject noun a relatively general referent (e.g. "boat"), for which there existed a more specific subtype of that referent (e.g. "submarine"). The set of sentences, together with both their general and their specific subject nouns, is presented in Table 2.

TABLE 2
Stimulus Sentences Containing the General and Specific Subject Nouns for Experiment 2

The instrument/microscope was used to observe the virus.
The medicine/aspirin relieved the headache.
The powder/salt was shaken over the popcorn.
The animal/elephant drank the water with his trunk.
The expert/architect designed the house.
The implement/scissors served to cut hair.
The explorer/astronaut travelled to the moon in a rocket.
The container/coffin held a corpse.
The appliance/refrigerator was used to chill the salad.
The material/chalk was used to write on the blackboard.
The structure/church was attended every Sunday.
The support/ladder was used to climb to the roof.
The apparatus/projector served to show a film.
The paper/diploma signified graduation.
The utensil/spoon was used to eat the soup.
The creature/horse transported the cowboy.
The boat/submarine travelled underwater.
The workman/plumber repaired the clogged sink.
The rodent/porcupine threatened its enemies with its sharp quills.
The vehicle/tractor pulled the plow.
The weapon/knife was used in the stabbing.
The person/shepherd guarded the flock.
The clothing/raincoat protected against the downpour.
The insect/spider spun a web to catch its prey.

During the study session, a given subject was presented with 12 sentences with encoding task manipulated within subjects. All sentences appeared equally often in all experimental conditions. Prior to presentation of each sentence, subjects were instructed as to the task they were to perform on that sentence. If the command "GENERAL" appeared prior to a sentence, subjects were to think of an appropriate category label for the noun in the sentence. If the command "SPECIFIC" appeared, they were to think of the specific object to which the sentence was making reference. Counterbalancing across subjects ensured that a third of the subjects experienced the word "submarine" directly under "GENERAL" instructions, a third inferred the word "submarine" under "SPECIFIC" instructions without actually perceiving it, and the rest had no exposure to the word and provided baseline performance for the completion of its corresponding stem.

During test, all subjects were given the same 48-item word-stem completion test, composed of the stems of the 24 stimulus words and of 24 filler words. Six of the stems corresponded to nouns relevant to sentences studied under GENERAL instruction, six to nouns studied under SPECIFIC

instruction, and the remaining twelve corresponded to the subjects of sentences that had not been presented. Counterbalancing across subjects allowed us to calculate base rate performance such that (a) all calculations of priming were based on the *same* words and (b) the same words were compared under "actually presented" and "inferred" conditions.

Modality of presentation was varied between subjects, such that half the subjects received visual presentation and the other half auditory presentation. For visually presented sentences, the instruction to categorize or to infer appeared on the screen for 0.5 sec before the sentence and stayed on the screen for the 10-sec presentation duration. For auditory presentation, the instruction was stated on tape and was followed by two presentations of the sentence in the course of 10 sec. As in Experiment 1, the stem completion test items were presented for 8 sec in either the visual or the auditory mode, under instructions to complete the stem with the first suitable word to come to mind. Modality of test and presentation were manipulated across subjects, with 24 subjects in each of the four possible modality combinations. Following word-stem completion, subjects were given a free recall task, and were asked to recall as many of the categorized or inferred words as possible during a two-minute period.

Results

Percentage priming of both actually presented items and inferred items is shown in Table 3 separately for each of the four presentation and test modality combinations. A 2 (Auditory versus Visual presentation) × 2 (Auditory versus Visual test) × 2 (Presented versus Inferred nouns) ANOVA with repeated measures on the last factor revealed a significant presentation main effect, $F(1, 92) = 5.56$, $MSe = 437.24$, $p < 0.05$, indicating that priming of inferred items (15.3%) was not as great as that for actually presented items (22.4%). Because presented items benefited from data-driven processing in addition to conceptual processing, this increased priming would appear to reflect the added advantage resulting from data-driven processing.

TABLE 3
Percentage Priming of Word-Stems Corresponding to Words That Had Been Presented versus Inferred in Experiment 2

	Presented Words		*Inferred Words*	
	Presentation Modality		*Presentation Modality*	
Test Modality	*Auditory*	*Visual*	*Auditory*	*Visual*
Auditory	29.2	16.3	20.1	12.2
Visual	17.0	27.1	15.6	13.2

Results pertaining to the general and specific subject nouns are considered in separate analyses because this permits more straightforward comparisons between the present results and those of Experiment 1. Considering first the actually presented items, it can be seen that the data nicely replicated those of Experiment 1. There was greater priming when study and test items were in the same modality (28.2%) than when they were in different modalities (16.7%). This interaction was significant, $F(1, 92) = 6.15$, $MSe = 512.09$, $p < 0.02$, whereas the two main effects were not ($F < 1$). Further, the magnitude of the same-modality advantage was similar in the two experiments, 13.6% in Experiment 1 and 11.5% in Experiment 2.

Although it is difficult to compare across experiments, it is interesting to observe that the overall magnitude of priming was somewhat reduced in Experiment 2 (22.4%) relative to Experiment 1 (29.7%). In the first experiment, subjects were reading the words for a later memory test, whereas in this experiment they were thinking about the meaning of the word in the context of a sentence. Roediger has argued that perhaps the former task induces relatively greater activation of data-driven processing and the latter task relatively greater activation of conceptually driven processing. Assuming that the word-stem completion task is particularly responsive to data-driven processing, then the greater priming observed in Experiment 1 is not surprising. It is worth noting that MacLeod (1989) has demonstrated differential priming on an implicit word-fragment completion test that fits nicely with this difference over experiments. He found that isolated words in a list primed considerably more than did the same words in text, suggesting that this context effect is fairly general.

Turning now to word-stem completion performance for inferred items, several findings of interest emerged. A 2 (Presentation modality) × 2 (Test modality) ANOVA for inferred items equivalent to that for presented items revealed that neither of the main effects nor the interaction were significant. Although sentences were presented either auditorily or visually, the inferred items (by definition) were not themselves presented. Thus, the absence of any modality effect was to be expected. Further, failure to find any interactions with modality for inferred items lends support to the idea that it is replication of data-driven processing that is *specific* to the particular item that affects stem completion, rather than a more general reinstatement of a context effect induced by presenting the same modality again.

To test whether significant levels of priming occurred for inferred items, a 2 (Auditory versus Visual presentation) × 2 (Auditory versus Visual test) × 2 (Inferred versus Not presented nouns) ANOVA was performed comparing performance for inferred items with base rate performance. There was a large significant priming effect, $F(1, 92) = 31.76$, $MSe = 356.83$, $p < 0.001$, such that items that had been inferred during study were completed with greater accuracy than the corresponding new items. Hence, even in the absence of

any possibility for data-driven processing, prior conceptual processing was sufficient to benefit later word-stem completion performance. This finding corroborates the earlier findings of priming for inferred items reported by Bassili and Smith (1986). The ANOVA also revealed a significant main effect of test modality, $F(1,92) = 5.20$, $MSe = 390.92$, $p < 0.05$, indicating slightly better performance in auditory testing (33.9%) than in visual testing (27.4%).

It should be noted that the magnitude of priming for the inferred items (15.3%) was similar to the cross-modality priming of presented items (16.7%). A contrast comparing the two cross-modality cells for presented items with the four inference cells failed to produce any significant differences ($F < 1$). However, a contrast comparing the two same-modality cells of the presented conditions (AA and VV) with the remaining six conditions (AV and VA "presented" and the four "inferred" conditions) indicated significantly greater priming under same-modality conditions, $F(1, 92) = 12.60$, $MSe = 437.24$, $p < 0.001$. These data thus suggest that the contribution of the "conceptual" component is comparable in magnitude in the cross-modality and in the inferred conditions. Additional priming for actually presented same-modality items may thus result from the additional contribution of data-driven processes.

Finally, at the end of the experiment, subjects were given 2 min to recall the sentence subject nouns. On average, 35% of presented subject nouns were recalled, versus 38.5% of inferred subjects. A t-test for correlated samples comparing these two values was not significant [$t(95) = 1.09$, $p > 0.20$]. This finding demonstrates that our two task instructions (to categorize for presented items and to infer for non-presented items) equated well for potentially contaminating factors such as levels of processing.

GENERAL DISCUSSION

The encoding of a stimulus may entail both data-driven and conceptually driven processes. If the processing of that same stimulus is facilitated at a later time, it has been suggested that this priming is the result of the repetition of processes at study and at test (e.g. Jacoby, 1983; Roediger et al., in press). Hence, the priming may be the result of repetition of the data-driven component, the conceptually driven component, or both. These experiments attempted to assess the relative contributions of these two types of processing to priming in the word-stem completion task, a popularly used task for measuring implicit memory.

One indication that word-stem completion profits from the repetition of data-driven processing comes from experiments in which modality of presentation at study has been varied. Roediger and his coworkers found better visual word-stem completion performance if the study words were also in the visual mode than if they were presented auditorily. Although such data

would appear to provide evidence of a data-driven priming component, failure to include an auditory test condition makes interpretation of the results difficult. In Experiment 1, we rectified this omission by providing both auditory and visual stem-completion tasks. Regardless of modality of test, there was more priming when modality of study and test were the same than when they were different.

This finding is in marked contrast to what is typically found with such explicit memory tasks as recall and recognition. Such tasks are insensitive to modality and appear to be responsive only to conceptually activated encoding processes. Hence, our data corroborated earlier studies in pointing to the responsiveness of the implicit memory task of word-stem completion to data-driven processing (cf. Richardson-Klavehn & Bjork, 1988; Schacter, 1987).

Experiment 2 examined the contribution of conceptually activated processes more extensively. To encourage conceptual processing, the lists of isolated words used in the first experiment were replaced by sentences, and the task was changed from reading single words in preparation for a later memory test (Experiment 1) to categorizing of the presented subject noun or making an inference concerning the subject noun (Experiment 2). Because the categorization task led subjects to perceive the item whose stem they would later encounter, whereas the inference task required that this item be generated, this manipulation permitted the evaluation of the relative contribution of data-driven and conceptually driven processing to the priming task.

There was significantly greater priming for words that had actually been presented than for words that had been inferred, indicating the special contribution of data-driven processes to priming. Nonetheless, the significant priming of inferred items provided clear evidence for the contribution of conceptually driven processes as well.

In both experiments, modality of presentation was manipulated also, permitting further insight into the priming mechanism. First, the difference between same-modality and cross-modality priming was roughly comparable across the two experiments, despite the fact that the one-word presentation format of Experiment 1 encouraged data-driven processing, whereas the sentence presentation format of Experiment 2 encouraged conceptually driven processing. In other words, the modality-specific priming component appears to be independent from the non-perceptual component. Second, the magnitude of priming in the cross-modality conditions of Experiment 2 was similar to that found in the inference conditions. Whereas it is not possible to equate processes on the bases of similarity in the magnitude of their effects, this finding at least suggests the possibility that the cross-modality and the inference conditions of our experiments reflect the effect of the same conceptually driven processing operations.

The finding that priming of inferences was unaffected by modality manipulations serves to clarify the role of modality in priming. It is only the replication of data-driven processes specific to the particular item that benefits word-stem completion. Replication of general context, i.e. having study and test in the same modality, is insufficient to boost priming.

Although comparisons across experiments have to be done with caution, it is interesting to observe that the overall magnitude of priming of presented items was greater in Experiment 1 than it was in Experiment 2. This finding of greater priming in an implicit memory task following data-driven processes relative to that observed with conceptually driven processes is in agreement with other experimental data. For example, Jacoby and Dallas (1981) found more priming in a perceptual identification task for items that had previously been read than for items that had been generated. This is in contrast to the typical levels of processing effect found with tests of explicit memory. Similarly, Smith (in press) found that items that had been studied in the context of sentences were not primed to the same extent in a word-fragment completion test as were words that had been studied in isolation. MacLeod (1989) likewise found less priming in a word-fragment completion task for words that were processed in a more semantic, text-based context than for words studied in a list.

In conclusion, these experiments provide support for the hypothesis that tests of implicit memory are sensitive to prior processing, regardless of whether this processing was data-driven or conceptually driven. Further, our data are consistent with an intriguing possibility—that the contribution of these two components may be additive, such that greatest priming is revealed by words that benefit from both types of processing.

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