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Reactivating a Reactivation Theory of Implicit Memory

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Implicit and explicit memory tasks are interpreted within a traditional memory theory that distinguishes associations between different classes of memory units (sensory features, logogens, imagens, concepts, context tags). Associations from specific sensory features to logogens are strengthened by perceptual experiences, leading to specific perceptual priming. Associations among concepts are strengthened by use, leading to specific conceptual priming. Activating associations from concepts to logogens leads to semantic and associative priming. Item presentation also establishes a new association from it to a representation of the personal context, comprising an ''episodic memory.'' Such contextual associations play a major role in explicit memory tasks such as recall or recognition. A critical assumption of the theory is that presentation of a given item strengthens its sensory and contextual associations independently; this permits the theory to explain various dissociations of implicit and explicit memory measures. Furthermore, by assuming that brain-injured patients with global amnesia have a selective deficit in establishing novel associations to the context, the theory can explain their deficits in explicit memory along side their intact implicit memory.

INTRODUCTION

This special issue of the journal on implicit memory touches on central issues in cognitive psychology. Implicit tests of memory are those in which human subjects' memory for material experienced previously is revealed even though they are not instructed to recall intentionally nor are they required to consciously remember having recently studied the material. Implicit memory is shown by subjects responding more rapidly and accurately to repeated stimuli than to new material. This facilitation is called repetition priming.

Two broad types of priming have been distinguished. In *perceptual priming,* as shown for example in perceptual identification, a stimulus is shown in fragmented or degraded form and priming is revealed by enhanced identification of that target relative to unprimed stimuli. In *conceptual priming,* subjects initially produce an item as a conceptual associate of a cue word. Later that primed item is generated more readily as a category member or in answer to general knowledge questions.

Implicit memory tests are contrasted to explicit memory tests such as recall or recognition in which subjects are asked to retrieve a memory of an episode that happened at a specific time and place. Explicit memory is supposedly characterized by a conscious, intentional attempt to retrieve a specific event or episode. Since conscious awareness plays a major role in the distinction between implicit and explicit memory, it is appropriate to discuss the distinction in this journal devoted to the topic of consciousness. Moreover, the implicit–explicit memory distinction has stimulated and guided a considerable range of research and theorizing about memory over the past 20 years.

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Some mild terminological confusions exist in this field; some reviewers (e.g., Hintzman, 1990; Johnson & Hasher, 1987; Richardson-Klavehn & Bjork, 1988) recommend the terms *direct* and *indirect* to refer to tasks, since the parallel terms *explicit* and *implicit* are often confused with theories about the memory systems or psychological processes engaged by the tasks. However, that recommendation seems not to have caught on, and the field has simply added the direct/indirect terms as alternative names for the tasks. In this paper I will use the terms indiscriminately, equating ''direct = explicit'' memory task and ''indirect = implicit'' memory task. As always, the denotation of a given term can be determined by the context of its usage.

Three general types of theories of priming have been proposed: (1) the memory systems accounts (e.g., Schacter, 1990; Tulving & Schacter, 1990); (2) the processing account (e.g., Roediger, 1990); and (3) the component processing account (e.g., Moscovitch & Umilta, 1990, 1991). The memory systems approach supposes that performance on indirect tests (e.g., perceiving words or pictures) is mediated by memories in brain structures that differ from those involved in mediating performance on either conceptual priming tests or direct memory tests. The processing account divides memory tests into those emphasizing perceptual, ''data-driven'' processes versus semantic, ''conceptually driven'' processes; the theory predicts that priming will reflect the extent to which the indirect test uses the same psychological processes as were engaged by that stimulus during its earlier presentation. The component processing approach is an amalgam of the other two views and stresses the overlap of memory structures as well as component psychological processes between the study and indirect testing of an item. This hybrid approach also points to several finer distinctions (than just data-driven versus conceptually driven) among components involved in a memory test. It also attempts to relate different aspects of memory to different parts of the brain (e.g., Moscovitch, 1992). Consequently, it can account for a greater range of differential results (see, e.g., Vriezen, Moscovitch, & Bellos, 1995).

The present author has contributed very little to the burgeoning literature on implicit/explicit memory. However, as an intellectual exercise and a measure of theoretical progress, I propose to resurrect a theory of priming and amnesia that I proposed over 12 years ago and explore to what extent subsequent data can be explained in terms of that earlier theory. The theory was described in a speech delivered at the 1984 European Congress of Behavior Therapists in Brussels; it received a much delayed publication as a chapter in a conference volume (Bower, 1986). However, the theory proposed therein has not received much notice, so I take this opportunity to present the theory again.

The framework of the theory is that which was common in cognitive psychology in the mid 1970s, namely, Morton's (1969, 1979) logogen theory of word identification, Anderson and Bower's (1973) HAM associative network theory about lexical and conceptual structures, and their view of how event memories are recorded therein. While reading the literature to prepare the present paper, I discovered that similar views to those in my speech about priming and amnesia were published by Mandler, Graf, and Kraft (1986) and Diamond and Rozin (1984); so these ideas were in the zeitgeist of those times. Moreover, my view overlaps significantly with a recent account of implicit memory proposed by Reder (Reder & Gordon, in press; Reder, Nelson, & Stroffolino, in preparation). I believe those ideas have been cast

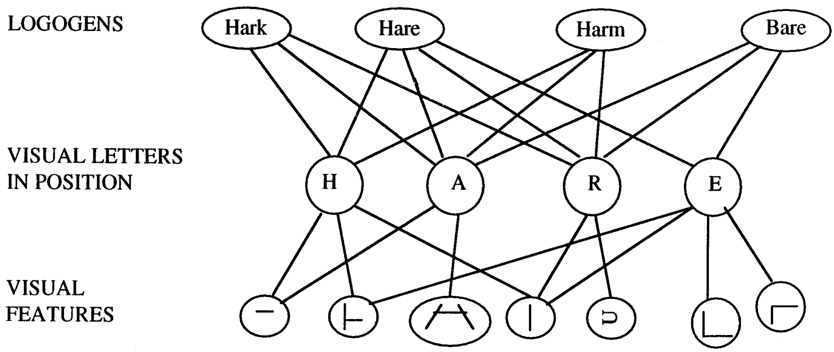

FIG. 1. Schematic representation of several memory units (''logogens'') in the neighborhood of the logogen for the word HARE. Associations from visual features to letters are shown, as are associations from visual letters-in-position to logogens. Units are depicted as circles, and associations by lines between circles. (Adapted from Bower, 1986).

aside prematurely for what I consider to be insufficient reasons, as I shall explain presently.

THE BASIC FRAMEWORK

The framework assumes that words have corresponding internal representations in memory as units to be called *logogens* or *lexical units.* A unit serves to collect together a variety of associations, thus serving as a switch juncture to pass activation from one unit to another in an associative network. Some of the relevant associations for a word include the visual letter patterns which comprise its appearance, the phonemes that comprise its sound, its conceptual meaning, possibly a perceptual description of the appearance of a canonical referent, its part of speech, and so on (see Anderson & Bower, 1973). To learn a word is to establish it as a perceptual unit in memory and to set up (through multiple experiences) many different associations to this lexical unit.

The upper part of Fig. 1 shows a fragment of the kinds of associations between visual letters-in-position and the lexical entry for the English word HARE, which I shall use in my illustrations below. I have shown positive associations only, i.e., letters-in-position which provide evidence for the corresponding lexical entry.[1] Each letter-in-position is associated to the many words which have that letter in that position.

This diagram could be greatly complicated in at least three ways. First, we could add inhibitory links (e.g., the E in the fourth position rules out HARM as the item) and add downward-pointing associations from higher to lower units (needed to produce the ''word superiority'' effect). As a second complication, it is highly probable that in many cases intermediate lexical units (small morphemes, syllables) need to be interposed in

[1] Several other proposals are plausible regarding the effective orthographic cues for visual word recognition. These include bigrams-in-position, vocalic-center groups, spelling patterns, pronunciation units, letter–shape cues, and so on. While such features could be added to the input level shown in Fig. 1 to provide a richer sensory representation of the stimulus, the basic logic of the theory would not be changed by their inclusion.

Fig. 1 between letters-in-position and the full word units in memory. For example, this is clearly the case for compound words such as *rowboat* and *gearbox*. But it is also likely that in English, many prefixes (*un-*, *in-*, *pre-*, *dis-*) and suffixes (*-able*, *-ed*, *-ness*, *-tion*) exist as intermediate morphemic units, since such smaller units can be primed independently. Thus, a target word like DISCOMFORT can be partially primed by earlier presentations of the words DISARM and COMFORT, just as the target word AWARE can be primed by earlier presentations of UNAWARE or AWARENESS (see Henderson, 1985; Stanners, Neiser, & Painton, 1979). These morphemic priming results should be kept in mind when we later examine amnesics' priming of pronounceable pseudo-words, such as DISFORT or MISARM.

A third complication of the model in Fig. 1 would add a parallel, automatic route of phonological encoding that intervenes between the visual orthography and the logogen units. Using overlearned grapheme–phoneme conversion rules (or feature associations), expert readers automatically and implicitly ‘‘sound out’’ visual graphemes, and these phonetic representations often have preexisting associations to the word logogens in memory. This phonetic route to logogen activation is parallel and in addition to the direct visual access to the logogen (Coltheart, Patterson, & Leaky, 1994; Grainger & Ferrand, 1994). Thus, for example, the phonetic route provides conflicting information which slows subjects' decisions that visually presented pseudo-homophones (e.g., TAIP, BRANE) are not words. We will return to this topic when discussing cross-modal priming.

The mechanism for word retrieval in the theory is very simple (e.g., see Morton, 1969; McClelland & Rumelhart, 1981). Presentation of an external visual pattern causes activation of the sensory features corresponding to the elements-in-position of that pattern. These feature nodes pass their activation along to the letter nodes, which in turn pass along their activation to the corresponding word nodes. A standard assumption is that the amount of activation passed from node i to node j increases with the momentary strength of activation of node i and the momentary strength of the association from i to j. Thus, if a_i is the activation of input node i and s_{ij} is the strength of association from node i to lexical unit j, then $A_j = \Sigma_i a_i s_{ij}$ is the activation accumulated at lexical unit j. It is standardly assumed that the model subject will perceive that lexical unit whose activation is both above an awareness threshold and highest among all those units activated by the stimulus. If none of the units is activated above threshold, then no word will be consciously perceived, although the subject may guess above chance on the basis of partial information about letters.

This minimal framework for word identification could be greatly complicated (see, e.g., Borowsky & Besner, 1993; Seidenberg & McClelland, 1989) without altering the general points of how the basic associative process will be used in the discussion below. The minimal model of Fig. 1 will suffice for our purposes.

THE FAST-STRENGTHENING ASSUMPTION

Our theory of priming makes one crucial assumption, as follows: Whenever a preexisting (‘‘old’’) association is successfully rearoused or reactivated by a perceptual or conceptual stimulus, that association is greatly strengthened, and this elevated strength of association will be maintained for a significant duration. The increment in strength decays over a long period of time, with the rate of decay being higher as competing and interfering associations to that stimulus are strengthened by their successful arousal.

I intend this strengthening assumption to apply to *any* preexisting association—those between two concepts and between concepts and words and pictures as well as those from sensory features to logogens. I also intend this strengthening assumption to apply to the establishment and strengthening of associations to memory units encoding novel perceptual compounds such as pseudo-words and novel geometric patterns (see, e.g., Salasoo, Shiffrin, & Feustel, 1985). For future reference, I will use the label ''Type-1'' to refer to all these associations: they include all old associations plus those encoding novel, integrated perceptual units. A second type of association (dubbed Type-2) will be introduced later.

For priming of visual word recognition, it is the visual letter-to-logogen associations that are most important. Thus, in terms of Fig. 1, visual presentation of the word HARE will greatly strengthen the four associations in Fig. 1 from the letters-in-position H, A, R, E to the word HARE so that the lexical unit for HARE will compete more effectively in the future with similar alternatives such as HARK, HARM, or BARE. It is this strengthening of the letters-in-position associations to the word node, of course, that is assumed to cause priming of that visual word. That is, upon repetition of the visual word HARE, it will be read more quickly because the word node will accumulate winning activation and pass threshold for perception more rapidly than before priming. Similar facilitation would occur for identifying the primed word HARE when it is flashed tachistoscopically or presented in a visually degraded, fuzzy manner.

An implication is that judgments that rely upon retrieval of the word node will be speeded by priming as well. An example of such a judgment is ''lexical decision,'' in which subjects decide whether a letter string such as HARE is an English word whereas HURE is not. As might be anticipated, decisions regarding nonwords that are orthographically similar to a word are especially slowed down by priming similar words. Thus, presentations of word competitors such as HARE, HIRE, and HURT will materially delay the model's time to reject a target string such as HURE as a word because so many actual words will be brought to mind by the associations of the common letters-in-positions. Such intrusive words are known to block and delay judgments about nonwords.

Perceptual identification and lexical decision are indirect or implicit-memory tasks that require the subject to make no reference to memory of past experiences. Neither does the model need to refer to past experiences in order to show priming. Rather, given stronger letter-to-logogen associations, the model just ''sees'' the primed word more quickly and may only be aware of that perceptual experience, and not aware that the item was presented earlier nor that its perceptual clarity is due to that earlier presentation. Later we will discuss the basis for awareness of memories of past episodes that underlies explicit or direct tests of memory.

WORD-FRAGMENT COMPLETION

The model in Fig. 1 also explains priming as measured by word-stem completion (HAR_ completed as HARE rather than others) and by word-fragment completion (e.g., H_R_ completed as HARE rather than HIRE or HURT). Earlier presentations of HARE will strengthen the corresponding letter-in-position associations to that word unit, so that it is more likely to win out in competition with other words evoked by that stem or fragment cue. With some fragments, the model's problem may be to come up with any (unique) word that fits the fragment rather than selecting the strongest among a set of possible candidate completions.

Let us assume that when the word is perceived, the amount of strengthening of the different letter-to-word associations (those from the four letters-in-position to HARE in Fig. 1) will vary independently. This implies that some letter-fragment cues will evoke the primed word whereas other fragments may fail. In many conditions, this assumption implies near-independence in priming measures of word access from different fragments of the same unit. Just this outcome has been observed with different fragments of the same word by Hayman and Tulving (1989; see also Tulving & Schacter, 1990).

The preexisting associations from letters to words in Fig. 1 are assumed to reflect the accumulated joint frequency of that letter-in-position (or letter bigrams) with that word. This relative joint frequency may be estimated by the Kucera–Francis (1967) count of frequency of different words in the language. Thus, the higher the frequency of a word in the language, the higher on the average will be the strength of the associations from its letter-in-position cues to the word node at the start of the experiment. Thus, perceptual identification will be easier for high-frequency words and for those that exemplify regular grapheme–phoneme rules. Moreover, on the standard assumption that strength of association is a concave-downward function of conjoint frequency, primed facilitation due to an experimental presentation would be predicted to be less for higher-frequency than for low-frequency words. This implication appears to be generally supported (e.g., Forster & Davies, 1984; Scarborough, Cortese, & Scarborough, 1977).

PRIMING INTERFERING WORDS

This theory implies that it should be possible to strongly prime competing words that will block successful completion of a fragment of a unique word. Such interference effects have been observed recently by Smith and Tindell (1995). For example, when subjects have only 5 s to complete a test fragment, fragments such as A_L__GY, T_NG__T, and C_U_TR_ are completed an average of 59% successfully (as ALLERGY, TANGENT, and COUNTRY) when unprimed, 75% successfully after their corresponding target words have been primed, but only 18% after a closely similar word has been primed (ANALOGY, TONIGHT, and CLUSTER, respectively). Thus, presentation of ANALOGY increases the strength of association of its letters-in-position to that word, so that the similar fragment A_L__GY, which matches the first and last letters and nearly matches the position of the L, will activate and bring to mind ANALOGY. Although ANALOGY does not fit the fragment (L is in the wrong position), it nonetheless serves to block and delay the search for a successful completion, thus allowing the brief test time to run out. The existence of interference from primed ''blockers'' (as Smith and Tindell call them) provides strong evidence for something like the framework's associative account of word identification.[2]

PREPROCESSING EFFECTS

Many investigators have examined whether visual priming survives alterations in the size, color, or type font of the orthographic characters (e.g., changing from typed to handwritten words). In general, such changes reduce priming somewhat. We may think of these alterations as involving a type of preprocessing of the sensory stimulus to normalize it into a canonical register or format. These transformations take time and may not fully capitalize upon the prior feature-to-letter-to-word associations that had been strengthened by the prior presentation. Kolers (1976) has shown that these kinds of orientation-normalizing operations can be learned and facilitated by practice in reading inverted texts. Understanding of these effects requires a more detailed model of visual-object identification (and memory) than we have developed here for our purposes.

MODALITY EFFECTS

The logogen framework assumes that spoken words eventually contact the same internal logogen unit as does the printed word except that the sensory route is via acoustic (speech) waveforms from which phonetic features have been extracted. Figure 2 depicts the general associative structures involved for the spoken word HARE. It is a homophone in that the sound activates two different word units, HARE and HAIR, a fact we shall use presently.

Figure 2 reflects the ''dual-route'' model in which silent word recognition involves both direct visual access and indirect phonetic access to the logogen unit. The Type-1 associations from the visual letters-in-position to the HARE logogen (marked a in Fig. 2) were illustrated before in Fig. 1; they provide the direct visual access to the word node. The darker arrows in Fig. 2 indicate the reader's automatic application of grapheme–phoneme conversion rules to the visual grapheme that produce the implicit phonemic representation. That phonemic representation in turn has preexisting Type-1 associations (labeled b and c in Fig. 2) to the two logogens. This is the indirect phonological route that is partially activated when visual words are processed and recognized. The activation of this indirect route (b, c) is far weaker than the activation of the direct route (a), but nonetheless its effects can be detected under sensitive experimental conditions (e.g., Coltheart et al., 1994; Grainger & Ferrand, 1994; Ziegler & Jacobs, 1995).

In terms of this model, auditory priming of spoken words may be explained in the same manner as was visual priming of visually presented words. The spoken word, ''[h] [â] [r],'' strengthens the preexisting Type-1 associations from the constituent

[2] Although Smith and Tindell (1995) found a dozen or more word pairs and fragments that caused substantial interference, other pairs for which interference would have been expected produced none. The exact description of the types of pairs and fragments that produce reliable interference undoubtedly depends on aspects of morpheme–phoneme knowledge beyond the letter-in-position coding used here and by Smith and Tindell.

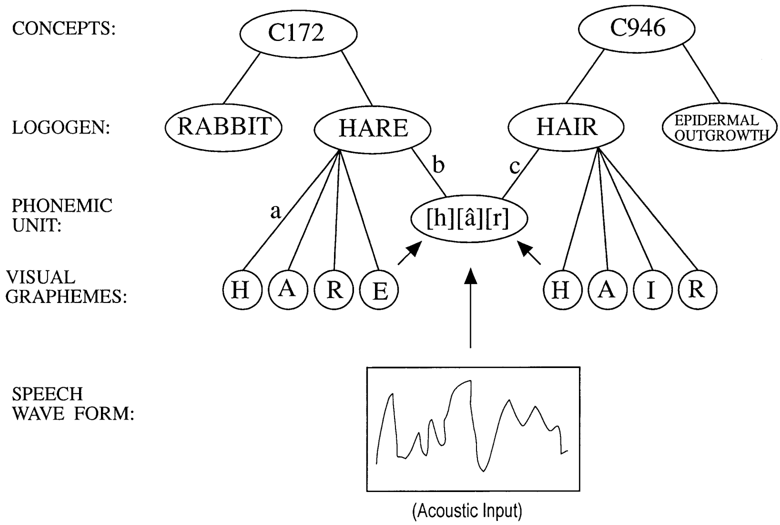

FIG. 2. Schematic representation of the logogens for HARE and HAIR. The visual graphemes activate their logogens by the direct-route, Type-1, associations (labeled a); automatic application of pronunciation rules creates a weak phonological representation which has preexisting Type-1 associations (labeled b and c) to the different logogens. The spoken word directly activates the phonemic representation. Type-1 associations also connect the name logogens to their concepts (No. C172 which also has the name *rabbit* and No. C946 which denotes the *hair* on one's head).

phonemes to the logogens—those labeled b and c in Fig. 2. These enhanced associations cause the same spoken word to activate its logogen(s) more rapidly on a later test, even over a noisy channel in which the acoustic signal is degraded and harder to identify. Depending upon how preprocessing of the acoustic signal is handled within the model, it should be able to produce varying degrees of reduction in priming as acoustic aspects of the spoken words are altered (e.g., changing from male to female voice or filtering out vocal frequencies).

Inclusion of the phonological encoding route in the model provides a basis for predicting short-term phonological priming. Thus, if the model has just pronounced the grapheme HARE, the specific rules (or associations) that produce the constituent phonemes from the grapheme will have been strengthened. Their strengthening will speed up for awhile the pronunciation of the other words that share those phonemes, such as PARE and FAIR (e.g., Butterworth, 1989; Dell, 1989).

RESIDUAL ACTIVATION OF THE LOGOGEN

A standard assumption in Morton's (1969, 1979) model is that once activated, a logogen has a persisting level of activation that decays over time. Thus, less activation from sensory input is required in order for the logogen to fire when the word is repeated a short time later.

This residual activation may be used to explain both *associative priming* (see below) and the intermediate level of *cross-modal priming* that is frequently observed for both healthy and amnesic patients (see Fig. 2). Thus, a visual prime will leave some residual activation on that logogen. In addition, the indirect phonological route will have been weakly activated by the visual word, elevating the b and c associations to a small degree. Thus, later input of the spoken word during a noisy test is more likely to pass the logogen's threshold of identification. Similar cross-modal priming would occur between a spoken prime and a visual test word or its fragments. The cross-modal arrangement produces less than intramodal priming because the intramodal route capitalizes upon the increased direct associations from the specific sensory features of the test stimulus to the logogen.

ASSOCIATIVE AND SEMANTIC PRIMING

Morton's (1969) original theory was developed to account for associative priming of perceptual identification of visual or auditory words. The basic idea was that meaningful contexts that imply a given concept and its word (from world knowledge in memory) will direct some prior activation onto that logogen. As a result, less sensory evidence will be required to activate that logogen above its threshold. This is a well-known phenomenon (e.g., Tulving & Gold, 1963). For example, the word LAMB flashed tachistoscopically can be ''seen'' more clearly in the context of having just heard ''Mary had a little ***'' than in a neutral or irrelevant context.

Standard forms of semantic priming have a similar explanation. To illustrate, in Fig. 2, I have introduced a single node for the concept which is indicated by either rabbit or hare and another node for the concept of the hair that grows on mammals.[3] The model assumes that presentation of a strong associate such as RABBIT will activate its logogen, which in turn will spread some of that activation to associated concepts and word nodes such as HARE and BUNNY (see, e.g., McNamara, 1992). The amount of activation spread will be greater the stronger the activation of the source node and the stronger the associative linkage (or the fewer the linkages) between the two nodes. The activation spread from the concept node to these logogens will lower the amount of sensory information they require in order to pass their identification threshold, thus facilitating for a brief time the perceptual identification of the word HARE, whether presented as a visual or auditory stimulus. This is the basis in this theory (and in Morton's) for short-term, associative and semantic priming of word identification (see Neeley, 1991).

The model in Fig. 2 supposes that semantic priming should be independent of target-word repetition priming since they reflect two separate effects. Den Heyer, Goring, and Dannenbring (1983) reported just such results. They presented related (*rabbit*–HARE), neutral (XXX–HARE), or unrelated (*cup*–HARE) prime–target pairs over three spaced trials, always requesting a lexical decision of the target words. Repetition of the target words speeded lexical decisions; the related semantic prime also speeded decisions, and by a constant amount over the three trials. These results are expected since repetition of the target strengthens its letter-to-logogen associa-

[3] Models of semantic memory, depicting relationships among concepts and showing how concepts are tied into the lexicon, are far more complex that what is summarized in the bare ''concept nodes'' shown in Fig. 2. For example, concept schemas are typically described by structured arrays of labeled ''slots'' filled by ranges of properties, and these concepts are located within both horizontal and vertical hierarchies of categorical relationships (see Rosch, 1978).

tions, whereas the semantic prime acts by briefly providing some head-start activation to the target logogen—a brief increment that dissipates by the time the prime and target are repeated later. By contrast, the strengthened letter-to-logogen associations are longer lasting, well beyond the interval between retests of an item. These considerations imply that the semantic prime and target repetition will be ‘‘additive factors’’ in facilitating lexical decisions.

AUTOMATIC VERSUS CONTROLLED SEMANTIC PRIMING

An important distinction in the literature on semantic priming is that between *automatic* and *controlled* processes (proposed by Posner & Snyder, 1975). Automatic processes are those that are fast and virtually nonconscious—they demand no attention, occur unintentionally, and are uninfluenced by subjects’ conscious strategies. On the other hand, controlled processes are those that are slower, require attention, and are influenced by subjects’ conscious intention and strategies. In semantic priming experiments, this distinction is operationalized by variations in the time between onset of the prime and onset of the target to which the subject responds (the ‘‘stimulus onset asynchrony’’ or SOA). Very brief SOA’s (100 to 350 ms) supposedly allow only automatic influences to operate; at longer SOA’s (1000 to 2500 ms), controlled processes such as conscious expectations can come into play.

A classic experiment by Neeley (1977) illustrates the automatic/controlled difference. Subjects in a lexical decision task were presented with one of four category names as primes followed shortly by either a nonword or a word belonging to one of the categories. For two of the categories, the target and prime were in the same category (e.g., BIRD–*robin*); for the other two categories, subjects were told to usually expect (5/6 of the time) the target word to come from the opposite category (e.g., BODY PART–*roof;* BUILDING PART–*arm*). Occasionally the prime was from an unexpected (but ‘‘natural’’) category, as in BODY PART–*leg.* Neeley found that at very short SOA’s (250 ms), priming occurred for strong preexisting, prime-to-target associations (e.g., BODY PART–*leg*), even when those pairs were unexpected in light of the experimenter’s instructions. On the other hand, the longer SOA’s (700 to 2000 ms), significant facilitation was found only for targets that fit the instructed relation (e.g., primed with BUILDING, expect a body-part target like *arm*), and inhibition was found for the unexpected targets (e.g., given BUILDING as a prime, *roof* or *robin* follow as targets).

The standard interpretation of these results is that at the very short SOA subjects had insufficient time for their instructed expectations to come into play; but longer SOA’s provided subjects enough time to mentally prepare several expected words of the target category, thus facilitating response to some one of them, while slowing response (relative to neutral controls) to a word from an unexpected category.

Such results are generally consistent with the present theory since the strength of association from the prime to the target for the familiar pairs (BIRD–*robin*) will be far greater and retrieved faster than the instructed temporary pairings for the experiment (expect a BODY PART target following the BUILDING prime). Presumably, it would take many hundreds of practice trials before the instructed pairings attain the high strength and speed of the familiar pairs. Since the weak instructed associates take more time to be activated by the prime, they show facilitation only at longer intervals.

In the standard paradigm with prime–target pairs, semantic priming is a very short-lived phenomenon; it is drastically reduced if not eliminated if one or two words are interpolated between the prime and the target. In the present theory, such fleeting effects imply that the activation passed from the semantic prime to the target logogen decays very rapidly with interpolated events. However, this quick decay may well be caused by the continual changes in semantic domains from trial to trial in the typical experiments. It is likely that if a longer persisting thematic context were to be established through a cluster of thematically related test items over a block of trials (e.g., words from the restaurant script), then the semantic relatedness effect would doubtless persist for longer. Such longer-term effects, of a thematic script priming lexical decisions of script-related words, have been observed by Sharkey and Mitchell (1985). However, the longer-term effects might be classified as controlled (''subject predicted'') rather than automatic.

A complex and mixed research literature has developed around several questions regarding semantic priming. One question is whether asymmetrical associations (e.g., *bar–drink* or *hot–potato*) will produce facilitation only if the prime and target are in the preferred temporal order. The outcomes vary considerably with the type of materials (e.g., word compounds, selected association norms), with SOA, and type of priming test; lexical decisions tend to be facilitated by either prime–target order, whereas reading speed is facilitated only by the preferred order. A further research literature is trying to decide whether semantic priming reflects strictly semantic relationships (e.g., common attributes) between the prime and target word or whether any manner of associative relationship will suffice. Considerable evidence suggests that for lexical decisions at short SOAs only semantic but not associative relationships produce priming[4] (Thompson-Schill, 1995). However, the results from other investigators (e.g., Fischler, 1977; Seidenberg, Waters, Sanders, & Langer, 1984; Shelton & Martin, 1992) are quite mixed, varying with procedural details and the measure of priming.

My theory is not sufficiently specified to make predictions about these complex interactions, and there is little consensus regarding general conclusions to be drawn from this literature. The resolution of some of the conflicting results may require a rethinking of what kinds of knowledge and experiences lead to the ''association norms'' (see Clark, 1970) which provide the experimental materials used in these paradigms.

HOMOPHONE RESOLUTION

The activation theory also explains biased retrieval of a particular spelling of the spoken homophone of HARE/HAIR. If the subject has recently been exposed to discussions about rabbits, then some of that activation would have spread (over Type-1 associations) more to HARE than to HAIR. Thus, the speech sound ''[h]/[e]/[r]'' would be more likely to retrieve the HARE lexical unit, so the subject would spell

[4] The present theory can explain such priming since activation can spread between semantically related words via their shared attributes, e.g., *horse* and *dog* share attributes of *animal, four-legged, has hair,* etc.

it that way (see Eich, 1984; Jacoby & Witherspoon, 1982). This temporary effect of semantic activation may compete against a long-standing, co-occurrence frequency bias (estimated by spelling norms) for people to interpret that sound as HAIR rather than HARE, i.e., the association marked c in Fig. 2 may have a baseline strength higher than that marked b.

INHIBITION AMONG COMPETING UNITS

Several theorists (e.g., Gernsbacher, 1991; McClelland & Rumelhart, 1985) have hypothesized that whenever alternative interpretations of a given stimulus exist (e.g., homophones, polysemous words) and a rapid ''winner-take-all'' decision is required for on-line processing, then an efficient processing network is one which has inhibitory connections among competing units. In this manner, the ''winner'' in a competition sends temporary inhibition to the losing alternatives, excluding them from interfering with the following discourse. If a similar assumption were to be adopted within our framework, it would imply that when different logogens compete for capture of a given homophone (HARE/HAIR), the eventual winner would inhibit the other one for awhile. That is, if the spoken homophone is presented in a context biasing one reading, it should produce brief interference with subjects' completing a visual fragment with the competing spelling; for example, hearing the homophone as HARE should interfere with completing a visual fragment like H_IR as HAIR.

Similarly, if inhibitory links exist among different meanings of a word, then presentations of that word in a context biasing one interpretation should produce temporary interference in completing fragments of words associated with its alternative meanings. Thus, mention of ''*river* BANK'' should retard later completion of fragments of words related to financial banks (e.g., MONEY, LOAN). Marcel (1980) has reported results of this kind within the visual modality (i.e., with suprathreshold visual primes and visual targets); however, if inhibitory links among competing concepts are assumed, then the negative priming outcome should arise cross-modally as well. While experiments investigating these issues may exist, I am not yet aware of them.

Although I mention inhibitory linkages among competing units as a possibility, I have not developed the full consequences of such a postulation. Therefore, I do not include inhibitory connections among memory units as a committed construct within the basic theory.

PRIMING BY EPISODIC ASSOCIATIONS

The second major type of associations to be distinguished are ''episodic associations'' between perceptually distinct units such as word–word paired associates. I will refer to these as ''Type-2'' associations since they involve the recording of a novel pairing of previously unassociated elements or events.

In healthy subjects (but not amnesics), study of novel word–word paired associates is known to produce a form of associative facilitation of the primed response. The critical test involves one of the items of the studied pair receiving an indirect memory test in the presence or absence of the other member of its pair. The indirect tests for priming may be given in either a fast automatic or a slow controlled manner.

An example of automatic priming based on episodic associations was reported by Paller and Mayes (1994), who used a sequential perceptual identification task. Following study of unrelated paired nouns in sentences, subjects were asked to identify the second of a pair of test words quick-flashed sequentially. The noun pairs in the test were either intact or rearranged from the studied sentences. The subjects showed strong repetition priming in better identifying individual old words compared to new words. Moreover, normal (but not amnesic) subjects showed significantly enhanced identification of second words when they followed their studied first words (compared to rearranged pairs). Thus, perceptual identification of an item was facilitated by preceding it with a word that had been associated to it in an earlier study trial.

An example of a controlled priming task is stem completion. Newly acquired word–word associations are known to enhance stem completion when the word associate is provided as a cue. For example, Graf and Schacter (1985) presented subjects with either related word pairs (*buttoned*–SHIRT; *delicate*–FRAGILE) or unrelated pairs (*kindly*–STICK; *dryer*–BLOCK) and instructed them either to relate the two words in a meaningful sentence or to decide whether the two words had the same number of vowels. Earlier presentation of the target words themselves (whether or not in pairs) may be thought of as reactivating and strengthening Type-1 associations, whereas elaborative study of the unrelated word pairs would lead to the setting up of Type-2 associations between them.

Subjects later attempted to complete the righthand word to a stem cue when it was accompanied by the same word as in the study pair (*buttoned*–SHI__; *kindly*–STI__) or by a different word (e.g., *delicate*–SHI__; *dryer*–STI__). The results showed that stem completion was aided by all three variables—reinstating the same context cue word as when the pair had been studied initially, prior relatedness of the pair, and elaborative processing of the novel pairs.

These results are as expected by the present theory. Reactivating related pairs or elaborative processing (versus vowel comparison) of the novel pairs during study will lead to strong associations. Thus, when the studied cue word is presented along side the fragment of its paired word (i.e., *delicate*–FRAG___ or *kindly*–STI__), activation will flow from the cue word to its concept in memory and thence to the logogen of the paired word, there to summate with input activation from the letter fragments. Thus, stem completion will be more likely for stronger or elaborated pairs when they are appropriately paired during the test trial.

A controversy in this literature is whether such associative stem completion is ‘‘process pure,’’ since subjects may use some explicit memory to do well on the task. We shall return to this task in our later discussion of amnesics’ performance.

PICTURE–WORD PRIMING

Priming in retrieving the names of canonical pictures of common objects has often been observed as has repetition priming when subjects categorize pictured objects. The object names are typically those which Rosch (1978) called ‘‘basic level’’ categories. The present framework easily extends to cover these effects. Again, the framework requires a sensory analysis of the input, perhaps using something like Kosslyn’s (1980) image-file theory or Biederman’s (1986, 1987) geon theory. To provide a

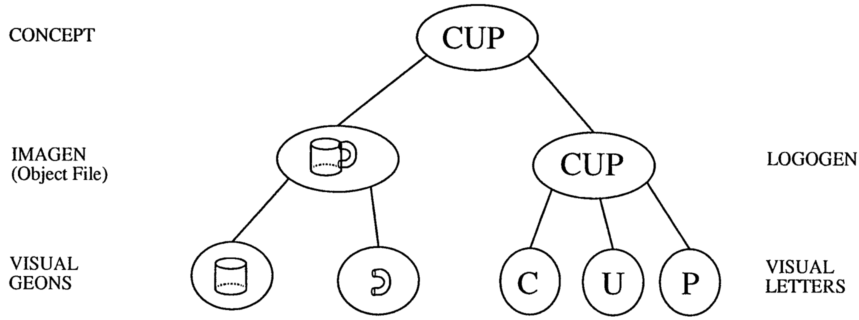

FIG. 3. Representation of two elementary geometric units (''geons'' of a cylinder and curved tube or handle) associated to the object file (''imagen'' unit) formed by their structured configuration. The imagen and the logogen for the word *cup* have converging associations to the concept node for cup.

specific illustration, I will adopt Biederman's theory which views simple visual objects as composed of configurations of primitive geometric elements (called ''geons''). Each configured-geon description of an object would then have associative links of Type-1 in long-term memory to a canonical object–picture file (a *lamp*, a *cup*, etc.), which Paivio (1978, 1986) calls an *imagen* in analogy to a logogen. The imagen in turn would be associated to the concept which in turn would be associated to the name of the concept (see Fig. 3). Thus, presentation of a picture of a common object would strengthen for a while the Type-1 associations of those geons-in-relations to the object file and concept. That strengthening implies that repetition of that same picture would more readily activate the canonical object and the concept. Therefore, one would observe facilitation in identifying the object in a tachistoscopic flash, in a fuzzy, unfocused slide projection, or from a fragmented outline, and the latency of naming the picture would be reduced, especially if it had been named upon its earlier presentation (strengthening the associations from the imagen to the logogen in Fig. 3). For the same reason, the latency of categorizing the object pictured (e.g., a *horse* as an *animal*) would be reduced. If an object has been categorized, thus reactivating and strengthening the Type-1 association between the object's concept and its superordinate category, that should prime and facilitate later categorizing the basic-level name of the object.

If activation spreads from the imagen via the concept to the word unit, then we may expect presentation of a picture to produce some modest amount of priming in identifying its name. The modest priming produced by viewing the picture should obtain whether the test stimulus is the visual word or the spoken word in noise. Also, different perspectives of an object or different instances of a category can be presented at the test phase, e.g., a different make of a *car* to be categorized. In general, these alterations will reduce the level of priming because they use different lower-level associations to the imagen than those strengthened by the specific object presented earlier (see Fig. 3).

Associative structures such as those in Fig. 3 imply further relations between word reading, picture naming, and categorization. In terms of associative distances, the diagram suggests that the concept may be retrieved from the picture, whereas the name of the pictured object is retrieved via the concept. This may explain the fact that people can semantically categorize a picture (say, of a *horse* as an *animal*) faster than they can name the object itself (e.g., Potter & Faulconer, 1975; Guenther, Klatzky, & Putnam, 1980). Similarly, people can read a word faster than they can categorize it or retrieve that name from a picture of the object. The associative distances depicted in Fig. 3 imply such relationships among retrieval times.

CONCEPTUAL PRIMING

In conceptual priming, the subject generates a conceptual associate to a stimulus word at a higher rate following earlier presentation of that associate as a prime. The experimental demonstrations almost always involve reactivation of old, Type-1 associations. The original observations of such priming for word associations were reported by Cramer (1966) and Cofer (1967). For example, following reading of words such as LEGS and STARS, primed subjects are more likely than controls to produce these as responses in later free association to stimuli (TABLE and SKY, respectively). This increase in frequency may be explained by supposing that presentation of the response word LEGS leaves some residual activation on that lexical unit and its corresponding concept. Consequently, when the stimulus concept TABLE spreads activation to the concept LEGS (via a Type-1, *has–as–parts* association), that spreading activation summates with the residual activation on the LEGS concept due to its earlier presentation; thus, LEGS becomes a likely response among those partially activated by the stimulus TABLE.

Similar reasoning explains the priming of nontypical exemplars of taxonomic categories. Prior associations (of Type-1) already exist linking common taxonomic categories to their exemplars. These category-to-exemplar associations vary in strength (e.g., the ‘‘dominance’’ measure of Battig & Montague, 1969). When presented with exemplars (either read or heard), the subject will activate the exemplar’s concept node, thus providing residual activation on that unit. Moreover, the subject is likely to spontaneously retrieve a category to which the item is associated (e.g., thinking ‘‘an *owl* is a *bird*’’), thus strengthening that Type-1, category-to-exemplar connection. Barsalou and Ross (1986) argue that this kind of spontaneous category arousal happens with exemplars of some categories (which they call ‘‘context-independent’’ categories) but not with others (‘‘concept-dependent’’ ones).

These ideas jointly imply priming in generation of exemplars of context-independent categories. That is, presentation of *owl* in a reading list will increase its likelihood of being generated freely later as an exemplar of the category *birds*. The priming effect should be stronger for low- than for high-dominance exemplars, since their presentation can produce the larger increase from the low-dominance baseline; i.e., low-dominance items have initially weak levels of node activation and weak Type-1 associations to the category. The priming should be strongest for study instructions that ask subjects to retrieve categorical information about items, and weakest for instructions that focus subjects on surface features of the word (e.g., count its vowels). The effect should also be greater for context-independent categories than for context-dependent ones.

Such priming is said to be ‘‘conceptual’’ because it operates via activation of concepts and their (Type-1) interassociations. Consequently, such priming should be nearly undiminished when the presentation-and-test-modalities are switched among visual word, or referent–picture, or spoken names. It is critical, however, that the concept aroused by the stimulus during initial presentation is compatible with that aroused by the category cue used for generation. Just this kind of failure can be arranged by using polysemous words (such as BAT, JAM, TABLE) whose meanings are biased in different ways by a contextual word. Thus, presentation of ''*traffic* JAM'' or ''*baseball* BAT'' should not increase (and may even decrease) the likelihood that JAM and BAT would be generated as exemplars to the stimulus categories of FOODS and ANIMALS, respectively. That is because ''*traffic* JAM'' will not reactivate the Type-1 association from FOODS to JAM.

SPECIFICITY OF CONCEPTUAL PRIMING

The present framework implies that conceptual priming should occur only with respect to the specific conceptual relationships (of Type-1) activated during the study phase. This implication has been confirmed in experiments by Vriezen et al. (1995). Their subjects initially classified words (e.g., *tree, pencil*) according to one of two different semantic criteria—either ''Is it man-made?'' or ''Is it larger than a breadbox?'' At later testing, a given word was processed according to either the same or the opposite question. The authors found significant facilitation of same-question judgments for a given word but no facilitation of different-question judgments. Despite the fact that both judgments would be loosely classified as ''conceptual,'' the present theory expects no priming across questions, because the altered test question does not access the kinds of facts (associations) that had been strengthened by the earlier question-answering episode.

This lack of cross-question transfer may be contrasted with predicted positive transfer across modalities of a word's presentation when the same conceptual question is asked. In a second experiment by Vriezen et al. (1995), subjects were presented at study with either a picture of a common object or its name and asked to classify it as man-made or not. At later testing, the item was presented again in either the same format (word or picture) or its opposite format, and the same question was asked again. In this case, significant cross-format priming occurred in answering the same question. Thompson-Schill (1995) has replicated and extended both parts of these findings by Vriezen et al. (1995).

These results are expected by our theory because in order to answer a conceptual question (e.g., about size), subjects must retrieve the concept and its queried association, regardless of whether the concept is retrieved during testing by a word or a picture of the referent. The concept-to-property association will have been strengthened during study and thus will facilitate answering the same question at test regardless of its modality.

In order to ask and answer a semantic question about a word or picture, the item must be presented by some means. That presentation, of course, will use and incidentally strengthen the specific letter-in-position associations to that logogen unit (or geon-to-imagen associations for pictures), even if the subject is answering a semantic question referring to the concept node. This strengthening caused by reading the visual word or naming the picture should be revealed later as priming in standard perceptual identification tasks or in word naming or picture naming tasks.

We may contrast this predicted priming effect, of a conceptual question onto a later perceptual task, with what is expected when the order of the questions is reversed. Thus, an earlier word naming task or lexical decision task should cause very little priming of a later conceptual judgment regarding that same word, especially for properties not automatically aroused by the word (e.g., ''Is it man-made?''). Although the word unit will be perceived slightly faster due to priming the Type-1 sensory associations, that facilitation is small relative to the longer time required to retrieve the information to answer the conceptual question.

Exactly these results on prime–test orders were obtained by Vriezen et al. (Experiments 3 and 4, 1995). Priming in lexical decision and in naming was obtained following an earlier ''man-made'' conceptual decision about the word, but no priming or very reduced priming was obtained for the reversed order, when man-made judgments occurred after earlier naming or an earlier lexical decision about the word. These results are expected by the current theory which supposes that the sensory associations of Type-1 are of necessity reactivated and primed in order to present the conceptual question, whereas the conceptual component need not be reactivated and strengthened by the surface, lexical task.

SUBLIMINAL PRIMING

We have presumed that in order for a presented word to become conscious, it must be activated above an awareness threshold by its orthographic or phonetic stimulus. However, one might entertain the possibility that subthreshold presentations of an item will cause the accumulation of activation on the corresponding logogen. In fact, Haber and Hershenson (1965) showed that repeated, brief (''subliminal'') exposures of the same word in succession led to the growth of a conscious percept on a later presentation. Furthermore, Marcel (1980, 1983) and others (e.g., Greenwald, Klinger, & Liu, 1989) have demonstrated semantic priming induced by subliminally presented words. Thus, a brief tachistoscopic flash of a word such as *child* that is masked will speed lexical decision to a related test word (*infant*) that just follows the subliminal prime (for critical reviews, see Bernstein, Bisonnette, Vyas, & Barclay, 1989; Dark, 1988; Holender, 1986).

Subliminal stimuli also are known to have indirect effects on performance. For example, Henley (1976) and Eich (1984) demonstrated the influence of concurrent subliminal words in one sensory channel upon interpretations of spoken homophones (the sound HARE/HAIR) in a second, attended channel. Mackay (1973) showed that concurrent, unattended words bias the interpretation of attended polysemous words (e.g., BANK related to river or financial institution). Bargh (1990, in press) and his associates have conducted many experiments showing cumulative subliminal priming of applicable personality-trait concepts that subjects later used to interpret social behaviors. They have also primed and increased the probability of social behaviors such as overt demonstrations of politeness, helpfulness, and lethargy. The powerful role of implicit priming of social cognitions has been highlighted in an important theoretical paper by Greenwald and Banaji (1995).

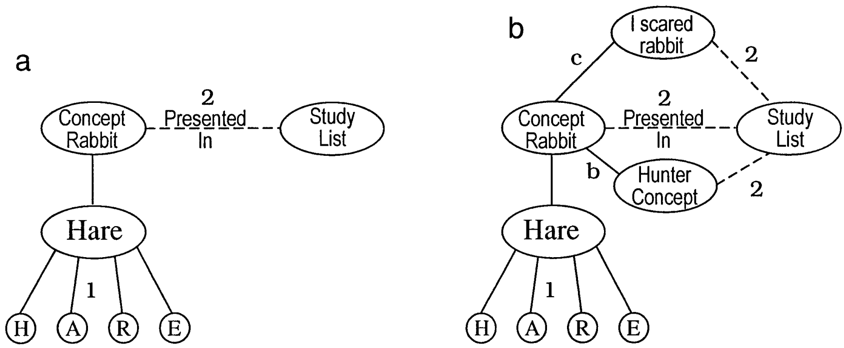

FIG. 4. (a) Schematic representation of the letters-in-position to the logogen HARE along with the new association (encoding the proposition) that the word/concept had been presented in a given study context. (b) Elaborated associations relating the presented word/concept HARE to other thoughts occurring during its study. New associations are indicated by dashed lines, and refreshed preexisting associations by solid lines. (Adapted from Bower, 1986).

Such results are generally expected by the theory. The associative networks in the theory operate the same way with subliminal as with supraliminal stimuli—accumulating activation, passing it among associated units, and having it decay away over time. The primary difference is just the magnitude of the activation involved—and, of course, the subjects' identification of the subtle stimuli. The controversy in this literature is spawned in part by a lack of consensus regarding the definition of ''subliminal''; the problem is that different performance indicators yield different estimates of whether people are aware of the alleged subliminal stimuli. As one example, subjects can judge with above-chance accuracy whether a brief subliminal prime that just precedes a test word is semantically related or unrelated to it; yet, they are at chance when asked to identify the subliminal prime itself (e.g., Bernstein et al., 1989; Bernstein & Welch, 1991; Dark, 1988). It is the interpretation of such discrepancies that fuels the debates over subliminal perception. The present theory has nothing useful to contribute to resolution of this issue.

EXPLICIT MEMORY

This network framework was long ago applied to explain results from explicit recognition memory and recall studies (see Anderson & Bower, 1972, 1973, 1974). The basic idea is that stimuli presented in a given context (say, words in a list subjects study in a laboratory) acquire an association to one's self in that context. In our current terminology, these are novel Type-2 associations since they associate two autobiographic events—one's being in a given context and witnessing the presentation of a stimulus there. These Type-2 associations vary in strength depending on parameters of the presentation and the person's learning strategies. These elements and associations are depicted in Fig. 4a.

A later, ''recognition memory test'' presents the studied items along with new distractors and asks subjects to judge whether or not each appeared in the earlier study context. The theory supposes that subjects use this occasion to activate the stimulus word, its lexical unit, and concept unit and then to check whether it is sufficiently associated to the list context. The test effectively asks whether memory provides sufficient evidence for the proposition that ''I witnessed that the word/concept HARE was presented in the specified study list.'' In the model, this proposition is verified by activating both the word node and the list node and measuring how much activation is passed along the Type-2 associations between them. If the summated activation is sufficiently large, it exceeds a criterion and the model reports that it has verified the test conjecture, i.e., that HARE did indeed appear on the study list. This retrieval process is the same as that which most activation theories use to verify the truth or falsity of conjectures (see, e.g., Anderson, 1976; Collins & Loftus, 1975).

This account views recognition memory as a special kind of ''source memory'' or ''context discrimination'' in which subjects are asked to remember the several contexts (if any) in which a stimulus occurred—rather like remembering which collections of friends (''items'') you had seen at each of several different parties (''list contexts''). Anderson and Bower (1974) showed that the more different contexts in which a verbal item occurred, the more interference (with lower d′) subjects suffered in judging whether it had occurred in any specific context. Such results are expected by interference among multiple Type-2 associations attached to a given item in memory.

An explicit recognition memory test asks subjects to try to use the test item to retrieve an association to a specified earlier context (e.g., ''the word list you studied yesterday''). By definition, such retrievals are backward-pointing, referring to memory for a past event. We use the concept of ''context'' to refer inclusively to a variety of subjective experiences and external stimulation prevailing at the time the event occurred. The room setting (appearance, odors, etc.) provides the external attributes of the context, whereas the subjective aspects include passing physiological states, moods, postural adjustments, and concurrent thoughts. A critical element of the context is the experiencing person—the self or ego—who is witnessing the event in question. These self-referenced associations provide the basis for personal episodic memories; retrieval of such associations are typically accompanied by subjects' memories of how they reacted to the stimulus earlier, or personal imagery of what they were noticing or feeling at the time and place when the test item was experienced earlier. In a sense, it is such awareness of remembering a past episode that is the signature of an explicit memory.

These contextual associations provide the basis for autobiographic memories, for the subjective sense of ''being there then.''[5] They are the means by which people's current mental state can put them in informational contact with a prior mental state. It is these connecting bridges to prior islands of personal experience that provide each of us with an impression that we exist as a coherent, continuously experiencing self—a recipient of sensory experiences and wishes and an agent of our plans and actions. Not only do contextual associations provide a basis for connecting ourselves to prior mental states, they also provide some basis for willfully controlling and manipulating those prior memories. With access to such memories, people can reason about or reinterpret prior experiences, elaborate upon them, draw conclusions, and edit or

[5] I am indebted to William P. Banks for sharpening the ideas in this section of the paper.

suppress them (see the ‘‘Opposition’’ test paradigm discussed below). The ability to form and/or retrieve these novel contextual associations is absent in global amnesics, which is why they have no explicit memory for past autobiographic experiences. We shall return to this issue later in our discussion of the amnesic deficit.

Bases for False Positive Judgments

When the context-retrieval model is applied to recognition memory experiments, new distractors (‘‘lures’’) are viewed as sometimes evoking false positive judgments for either of several reasons: (1) during study, one or more list items may have reminded the subject of the lure, so that the lure was subjectively experienced during, and becomes associated to, the study-list context or (2) at the time of testing, the lure may be confused with similar list items (or their reminded associates), so that subjects accept the lure as a list item. In addition, many inferential strategies are known to influence subjects’ criterion for accepting test items as studied ones. As one example, subjects’ estimates of the ratio of studied to lure items in the test set alters their criterion; as a second example, highly salient items that are not explicitly remembered will often be confidently judged to be lures, since subjects realize such items would have been explicitly remembered had they been presented in the study list (e.g., see Strack & Förster, 1995).

Considerable research and debate in the 1970s occurred around the issue of whether recognition of items in a list was affected by interitem associations (e.g., as reflected in intralist organization). The upshot of that debate was the eventual conclusion that recognition memory could indeed arise as well from the association of the test item to other cognitive elements that themselves are associated to the study context (e.g., Bower, Clark, Lesgold, & Winzenz, 1969; Mandler, 1967, 1980). Roediger and McDermott (1995) have recently demonstrated anew the powerful influence of interitem associations in recognition and recall memory. They were able to produce extremely high false-alarm rates to words that had not been studied but which were strongly related to words that had been studied. As noted before, such false alarms are likely whenever list words remind subjects of the lure word during study, thus associating the time-and-list context to that lure word.

These interitem associations are very likely to occur to knowledgeable subjects as they study a list of even nominally unrelated words. For example, suppose that subjects encounter the item HARE after having earlier studied the word HUNTER. Then they might spontaneously think of an elaboration such as ‘‘A hunter shot the hare.’’ In doing so, they reactivate and strengthen an interitem connection such as that labelled b in Fig. 4b. In like manner, upon seeing HARE in the study list, subjects might notice that it reminds them (via association c in Fig. 4b) of a recent time when they scared up a hare while on a nature hike. These elaborating thoughts will also form associations (labeled as Type-2 in Fig. 4b) that then serve as mediating elements between the word HARE and the list context. Anderson and Reder (1979), Bradshaw and Anderson (1982), and Bransford, Franks, Morris, and Stein (1979) have developed this notion of cognitive elaborations and how they can aid memory for the item. The use of such interitem associations for guiding recall of words plays a major role in theories of free recall such as Anderson’s FRAN model (1972), Anderson and

Bower's HAM theory (1973), and Raiijmaker and Shiffrin's SAM theory (1980). Considerable evidence has accumulated in support of this role (for a recent example, see Nelson, Bennett, Gee, Schreiber, & McKinney, 1993.)

As noted above, these interitem associations also play a role in recognition memory for items. In case the concept-to-list context direct association (labeled 2 in Fig. 4a) is not sufficiently strong, the covert associations elaborated around the concept's appearance in the study context (such as those labeled b, c in Fig. 4b) may add the weight of their evidence regarding the item's occurrence in the list context. In effect, the model can respond to the text word HARE as if it were saying, ''I do not remember that HARE occurred, but I recall thinking about a hunter shooting a hare, and I know HUNTER was on the list, so I think it's likely that HARE was also on the list.''

In passing, it should be noted that the associative structures in Fig. 4b set up to record the episode of the presentations of the word HARE in the study list are using parts of old memories as well as semantic memories (of words and concepts). Thus, to use Tulving's (1983) popular terminology, parts of ''semantic memory'' are being used to record an ''episodic memory,'' namely, that the person witnessed presentation of HARE in the study context. This treatment is required by the view that there is only one general memory system, but that particular memories differ according to their contents, strengths, ages, and association to their contexts of acquisition (see, e.g, Wickelgren, 1973, 1974). I will avoid here the debate over whether semantic memory and episodic memory are functionally distinct ''memory systems''—whatever that means. My view of the proposed distinction has always been somewhat cautious and well captured in critical articles by Anderson and Ross (1980), Hintzman (1990), Lewis and Anderson (1976), and McKoon, Ratcliff, and Dell (1986). As I shall show later, the results explained by alluding to the ''semantic versus episodic memory'' distinction in discussions of preserved versus impaired memory functions in brain-injured individuals (e.g., Tulving & Schacter, 1990) can be captured nearly as well by distinguishing between the reusing and strengthening of old Type-1 associations versus establishing brand new, Type-2 associations.

Independence Assumption

A major assumption in the theory is that upon presentation of a word in a study list, the amount of strengthening of the Type-2, concept-to-context association (2 in Fig. 4a) is a random variable that is statistically independent of the amount of strengthening of the sensory letter-to-word associations (those of Type-1, designated 1 in Fig. 4a) caused by that presentation. In other words, the learning reflected in sensory priming of the item is assumed to be independent of the learning of the context associations and/or interitem associations (those labeled 2 in Fig. 4b) that mediate explicit tests of recognition memory and free recall. According to this assumption, the probability that an item passes a direct memory test should be about the same whether it showed a large or small effect of priming in indirect tests such as perceptual identification or fragment completion, and vice versa.

This assumption is motivated by earlier work of Jacoby and Dallas (1981), who reported statistical independence between subjects' recognition memory for words presented earlier and the words' priming as assessed by perceptual identification.

Tulving, Schacter, and Stark (1982) also showed similar independence between recognition memory and fragment completion. Although considerable debate surrounds the theoretical and procedural ‘‘purity’’ of tests showing such independence (see Curran & Hintzman, 1995; Hintzman & Hartry, 1990; Richardson-Klavehn & Bjork, 1988, p. 497), we nonetheless adopt it as a simplifying assumption. In fact, a large portion of subsequent research by Jacoby and his associates has been based on this assumption of independent strengthening of the ‘‘priming component’’ of an item compared to its ‘‘explicit recognition memory component’’ (e.g., Jacoby, 1991; Jacoby, Lindsay, & Toth, 1992).

By assuming two distinct associations mediating priming versus recognition memory, the present framework is not forced to predict that any experimental manipulation that affects one of the associations must per force affect the other association in the same manner. Quite the contrary; manipulations that influence the Type-1, sensory associations (affecting sensory feature-to-logogen priming) are primarily modality-specific variations that affect ‘‘data-driven’’ processes involved in perception of the visual (or auditory) stimulus. In contrast, manipulations that influence the Type-2 associations (underlying novel concept-to-concept or concept-to-context memories) primarily involve meaningful (or semantic) elaboration of the item at the time it was presented for study.

It was the relative influence of these two sets of experimental variables that motivated many of the early demonstrations of implicit versus explicit memory. The experiments by Jacoby and Dallas (1981) are classic. Consider just one example: during study, words were either presented visually to be read or rather were only spoken (‘‘generated’’) by the subject as an associate to presented cue words. In a later tachistoscopic flash, the read words were better identified than were the generated words; but in recognition memory tests, the generated words were better remembered than the read words. Presumably, generation involved more conceptual elaboration (i.e., stronger Type-2 associations) than did reading, whereas reading the word reactivated and strengthened the visual letter-to-word associations (Type-1 associations) more than did speaking the word. And it is these primed visual associations that are exploited in the visual perceptual identification task.

Similar experiments have compared priming and recognition memory for pictures of common objects versus their names. As is well known, studying pictures of common objects produces higher free recall and recognition memory than does studying their corresponding names, even when the name is used as the test cue (Paivio’s, 1986, dual-coding theory provides several reasons for this result). In contrast, perceptual identification of the quick-flashed name is higher for items presented earlier as words than for those presented earlier as pictures.

Results such as these (which are dubbed ‘‘dissociations’’ or ‘‘double dissociations’’) are often presented as critical, even necessary, in support of postulations of different memory systems. The present framework sees them instead as understandable in terms of the relative contributions of two distinctly different sets of associations to the two performance tasks. Variables that influence the ‘‘data-driven,’’ perceptual associations (of Type-1) will affect judgments that depend upon their activation; variables that influence the ‘‘conceptual elaborative’’ associations (of

Type-2) of a concept to a list context will have larger effects upon explicit judgments of recognition memory or recall.

Some experimental variables affect both associative processes, whereas other variables affect one process but not the other. For example, presentation time per word during study enhances its recognition memory, but not its perceptual identification; this is because the longer study duration permits more elaboration of conceptual associates of the word but, beyond a minimal threshold, a longer duration of presentation does not enhance the perception of the word.

This analysis points to cases in which elaborative or conceptual processing during initial exposure to a word will increase performance on an indirect test of implicit priming, namely, exemplar generation from a category. Having subjects make category judgments during their initial exposure to exemplars will cause greater attention to, and strengthening of, the preexisting, Type-1 association between the category and the presented exemplar than will having subjects make a surface-oriented judgment (e.g., upper- vs. lowercase) about it. The stronger association established by the elaborative orienting task would then result in a higher frequency of that item being produced later as a category exemplar. From the memory-systems viewpoint (e.g., Tulving & Schacter, 1990) such a result appears paradoxical, since depth of processing would be enhancing performance on an implicit memory task; however, the result is quite consistent with the present viewpoint.

Subliminal Influences on Direct Memory Judgments

It appears that under certain circumstances, subliminal primes can be used to influence performance on various indirect tests, such as word-fragment completion, unscrambling of anagrams, and category generation (see Jacoby & Kelley, 1991). Beyond that, however, Jacoby and Whitehouse (1989) have also examined the influence of subliminal primes upon an *explicit* memory task, namely, Old–New recognition memory. They found that subliminal presentation of a new or old test item just before it was presented above threshold for judgment increased subjects' tendency to judge that item as Old (i.e., to increase both correct acceptance and false positives).

The authors suggested that the subliminal presentation enhanced the ''perceptual fluency'' attending the item's subsequent supraliminal presentation, and that that fluency persuaded subjects that the item was studied recently (was Old). Although they replicated and extended the results of Jacoby and Whitehouse (1989), Joordens and Merikle (1992) disputed their interpretation, finding that a similar recognition response bias was created by supraliminal primes, so the bias was not due specifically to the subliminal nature of the primes. Moreover, Bernstein, and Welch (1991) found that subjects could accurately judge (above chance) whether the alleged ''subliminal'' prime word was the same as the test word—thus placing the interpretation of the results in a different light.

A similar effect of perceptual fluency in biasing recognition judgments was reported by Whittlesea, Jacoby, and Girard (1990; see also Whittlesea, 1993). In their experiment each trial consisted of rapid serial presentation of seven words (at 67 ms each) quickly followed by a masked test word that was to be pronounced. Subjects then judged whether that test word was a repetition of one seen in the earlier list of seven. The test word was partially masked by visual noise (a field of dots) which, unbeknownst to subjects, caused more or less masking (dot density). The authors found that with less visual masking, subjects perceived the test word faster and were 4% more likely to accept it as a repeated item whether or not it was so. That is, improving perceptual clarity of the test word increased subjects' bias to accept as Old both repeated and nonrepeated words.

My theory can explain the speeded perception of the target word caused either by its earlier subliminal presentation (as in the study by Jacoby & Whitehouse, 1989) or its just-prior presentation in a study list (as in the study by Whittlesea et al., 1990). Importantly, these maneuvers did not influence memory-trace strength (d′) but only the response bias (''beta'') to accept a test item as Old. The results point to various strategic factors that underlie recognition judgments.

Perhaps the best explanation for such biases is the *misattribution* hypothesis of Jacoby and Kelley (1991), which supposes that people rely upon fluency of processing an item as a heuristic for judging whether they had experienced it previously. That is, under restricted circumstances (e.g., weak explicit memory, misinformation about sources of perceptual clarity), fluent perception may be misattributed to memory for the item rather than current sensory variables. The bias would be especially likely in the Whittlesea et al. (1990) study, which presented study words at a fast 67-ms rate; that rate may be insufficient to permit subjects to both identify the word and establish a context association to its representation. Consequently, subjects might have very little explicit memory to rely on for the recognition test. Under the circumstances, they may revert to the heuristic of basing some of their judgments on the items' variable ease of perception, especially since they have no better explanation for variations in the items' clarity. As Whittlesea et al. (1990) demonstrated in a later experiment, the biasing effect of perceptual clarity on recognition judgments completely disappeared when subjects were informed that they could attribute the varying clarity of the test items to parameters of the test presentation.

It appears unlikely that perceptual fluency will prove to be a strong, pervasive influence on recognition memory judgments. First, in most everyday situations, observers are well aware of the quality of sensory viewing/listening conditions, so they have little reason to attribute clear percepts to memory: ecological statistics are quite unfavorable for that attribution. Equating perceptual clarity with familiarity implies that people should often misattribute great originality to the ideas of any soft-spoken speaker—which is surely wrong. Second, one can think of many cases in which perceptual clarity would be enhanced but would not lead to increased recognition judgments. For example, people react perceptually very rapidly to their own name or those of familiar friends or photos of friends and possessions, but yet they would not thereby be likely to attribute that perceptual speed to the item's presentation in a recent study list. Third, the heuristic makes the wrong prediction about effects of several variables on recognition and perceptual clarity. For example, compared to low-frequency words, high-frequency words of the language are more easily identified in perceptual tasks; yet, word frequency has the opposite effect on recognition memory. Moreover, in recent research, Wagner, Gabrieli, and Verfaellie (1995) found several other variables that affected perceptual fluency and explicit recognition in opposite directions, thus presumably demonstrating that a common process could not underlie the two performances. Such considerations suggest that the perceptual fluency heuristic for recognition memory judgments may have limited generality and applicability.

The Opposition Tests

As noted above, Jacoby (1991) hypothesized that subjects' judgments in direct recognition memory tests involve both explicit context retrieval and implicit perceptual fluency of the item. In an attempt to separate the contributions of these supposed processes, Jacoby proposed the ''opposition'' procedure. It instructs subjects to perform under one of two different decision criteria, say, to a word fragment. The procedure may be illustrated by an experiment by Jacoby (1991). Subjects were presented with a list of words and then given a fragment completion test with either ''Inclusion'' instructions, to give any first completion that comes to mind, or ''Exclusion'' instructions, to give a completion but excluding any word that appeared on the study list.

We may use Fig. 4a to develop an account of subjects' behavior according to these two criteria. Having studied HARE and encountering a fragment like H_R_, Inclusion subjects may produce HARE because the strengthened letter-to-word associations (labeled 1 in Fig. 4b) suffice to activate the HARE logogen more strongly than competitors. Independently, the word HARE may be retrieved when subjects internally activate the ''list context'' as a covert cue (and subjects are typically encouraged to use this strategy). If subjects can retrieve the association of the list-context cue to the list word (such as those labeled 2 in Fig. 4a), that may remind them of HARE, and they can verify that it indeed fits into the test fragment. Let A represent the probability that the sensory associations (of Type-1) activate the primed word, and let R represent the probability that the list-context associations (of Type-2) enable reconstruction of the word. Then, assuming independence of the two processes, the net probability of the subject producing the primed word on an Inclusion test is $I = A + (1 - A)\,R = R + (1 - R)A$.

Turning to the Exclusion task, the studied word will be given if the sensory associations activate that word (with probability A) but the subject fails to retrieve the Type-2 association that this word appeared on the excluded study list and should thus be edited out (with probability $1 - R$). Thus, this joint event has probability $E = A(1 - R)$. From these two equations, one can derive the estimates of $R = I - E$ and $A = E/(1 - R)$.

These two equations are those of Jacoby (1991), who has shown their applicability across a wide range of tasks. In particular, experimental manipulations that should influence elaborative associations to the context of the material's presentation (e.g., divided attention, conceptual processing, aging) were shown to affect estimates of R but not A when these equations were fit to data. On the other hand, experimental variables that are expected to influence the sensory component (e.g., modality shifts) were shown to affect estimates of A but not R. Jacoby has argued that the fit of these equations to a variety of results supports the assumption of independent processes (for a contrary view, see Curran & Hintzman, 1995). The point of discussing Jacoby's approach is to note that my theory's presumption of independent strengthening of associations of Types-1 and -2 (in Fig. 4a) maps closely onto his distinction and his equations for estimating ''implicit'' versus ''explicit'' memory components in the Opposition tests.

Learning Novel Nonwords

The current framework provides for the learning of novel nonwords; they are simply new patterns composed out of novel sequences of familiar units. Nonwords come in many varieties, including novel compounds of old words, compounds of old morphemes or syllables, or simply novel sequences of consonants. The former nonwords allow application of whole-pattern pronunciation rules, whereas the latter usually do not.

The current framework learns novel patterns by simply recording into memory a description of the units-in-position for that pattern—at whatever level the units are perceived (letters, syllables, words). Presentation of the sensory elements together as a unitary perceptual gestalt causes a memory unit (representing their configuration) to be established in long-term memory (see Asch, 1969; Asch, Ceraso, & Heimer, 1960). The individual elements-in-position establish Type-1 associations to this configural unit (similar to a logogen). Repetitions of this novel pattern cause rearousal and strengthening of these (Type-1) sensory elements-to-unit associations; each presentation also establishes (in healthy brains) an episodic memory, recording (by a Type-2 association) the context in which that pattern had been encountered. With repetition, the former nonword takes on the properties of a unitized memory code much as does a familiar word. The multiple contexts in which the pattern has been encountered will interfere with and become confused with one another and effectively will become unretrievable. Thus, a new decontextualized unit will be created in long-term memory by stripping away (or superimposing a composite of) the specific contexts of the episodes in which the unit was experienced. The process is similar to the extraction of common elements from similar experiences by Hintzman's (1986) MINERVA model or McClelland and Rumelhart's (1985) connectionist model. More elaborate models of how people codify nonword letter strings are presented by Feustel, Shiffrin, and Salasoo (1983) and by Salasoo et al. (1985).

As a nonword string becomes more integrated over successive repetitions, it will also show progressively stronger priming effects as revealed, say, in perceptual identification (see Feustel et al., 1983; Salasoo et al., 1985). Thus, with repetition, the nonword would be seen more quickly, at shorter exposure durations, or under poorer conditions of degraded stimulation. This enhancement would simply reflect increasingly strong letter-in-position associations (of Type-1) to that string's logogen unit in memory.

Learning Novel Objects

The analysis just provided for the learning of novel letter strings applies as well to the learning of pictured novel objects such as those used in research by Schacter, Cooper, and Delaney (1990; also Cooper, Schacter, Ballesteros, & Moore, 1992; for a review, see Cooper & Schacter, 1992). They presented college students with pictures of novel three-dimensional geometric objects composed of blocks and polygons and asked them to judge whether the object depicted was ''pointing'' more to the left or to the right. Later they judged whether a presented display depicted an object that was physically possible or impossible. The investigators found a repetition priming effect for the possible figures: the possible/impossible judgment was quicker for repeated possible objects than for nonrepeated (control) objects. Gabrieli, Milberg, Keane, and Corkin (1990) found similar repetition priming for implicit performance on connected line-segment figures drawn between five dots in a 3×3 dot matrix.

The current theory supposes that novel visual objects (or dot patterns) are recorded in memory as perceptual structural descriptions (see e.g., Palmer, 1975). For example, one of the possible objects used by Schacter, Cooper, and Delaney (1990) would be described in terms of the configuration of the basic geons involved, the orientation of their concavities, the geons' points of contact, and so on (see Fig. 3 above). The more often the person views the novel object, the stronger would be the Type-1 associations from the individual parts to its perceptual unit in memory. This unit in memory then provides for rapid identification of the object upon its later presentation. That is the basis for priming with novel objects or parts of novel scenes. In healthy brains, presentation of this perceptual unit (imagen) will also establish a Type-2 association to the context, noting the place and time when this object was seen. This provides the basis (if needed) for explicit recognition memory judgments regarding the novel figure.

Retention of Implicit and Explicit Memories

Several commentators (e.g., Jacoby & Dallas, 1981; Schacter, 1989; Tulving, 1983) have emphasized that implicit memories are often retained for far longer than explicit memories. A typical basis for this claim (e.g., Sloman, Hayman, Ohta, Law, & Tulving, 1988) are experiments showing a greater decline over a given retention interval for a direct memory measure (e.g., recognition memory) than for an indirect memory measure (e.g., fragment completion). However, extreme persistence in indirect tests of memory does not generally hold (see e.g., the review by Richardson-Klavehn & Bjork, 1988, p. 522). For example, repetition priming of word-stem completion typically declines to baseline within about 2 h, whereas recognition memory often remains above baseline for normal subjects beyond that delay. But even granting that implicit memories are more persistent, that fact alone need not create special difficulty for the present theory, since the two forms of memory performance are based on distinctly different associations.

A more serious concern is that comparisons of forgetting rates of performance across different tasks is fraught with interpretive problems due to different measurement scales for the tasks. To reach a conclusion of different forgetting rates, a significant interaction must arise when comparable measures are analyzed for the direct and indirect tasks. But in most cases the measures used (e.g., exposure duration needed for perceptual identification vs. recognition accuracy) are not directly comparable. Even when measurement scales are directly comparable, only a few data patterns (e.g., cross-over interactions) can be taken as strong evidence for reliable differences in forgetting rates, and these are rarely found in this research literature. (For discussion of the problem, see Loftus, 1978.)

A further complication is that different measures of both implicit and explicit memory show considerable variability in forgetting rates across studies. This variability regarding explicit memory measures has been known for some time, at least since 1922, when Luh (1922) reported vastly different retention curves for recall, recognition, reconstruction, and relearning of serial lists. Memory researchers have typically viewed with skepticism comparisons of forgetting rates gleaned from such measures (e.g., Crowder, 1976, p. 371)—again, because of noncomparability of measurement scales plus our knowledge of how to manipulate the difficulty of practically every memory test.

In a similar vein, alternative measures of implicit memory (e.g., perceptual threshold, lexical decision, reading speed, fragment completion) appear to yield radically different forgetting rates when examined in a qualitative manner. It would seem that specific performance models for each task will be needed to understand these differences.

Moreover, it is not obvious that relevant factors have been equated across different indirect tests. For example, at one time it was widely believed that implicit memory as assessed by word-fragment completion (where there is a unique completion) yielded much slower forgetting than when assessed by word-stem completion (with 10 or more possible completions). The current model could explain such a difference in terms of a greater likelihood of interference and recovery of the many competing completions to the stem cue letters compared to no competitors for the unique fragment cue (see our earlier discussion of interference in fragment completion).

However, Roediger, Weldon, Stadler, and Riegler (1992) conjectured that earlier studies had confounded the word frequency of the items used with the different types of tests: in particular, items used to test fragment-completion tended to be longer and less frequent words in the language than items used in the stem-completion tests. And frequency of a target word is known to influence its completion probability. When the two kinds of tests were carried out with the same set of words, thus controlling frequency, Roediger et al. (1992) found no difference in the degree of priming (i.e., primed minus unprimed completions of the target word) and no difference in the rate of forgetting of priming as assessed by the two different tasks. Such findings suggest caution in inferences regarding comparative forgetting rates for other implicit memory tasks.

I raise this issue of differential forgetting rates in order to dismiss it, because it is often cited (e.g., Schacter, 1989) as a strong criticism against activation theories of priming, of which the current theory is a special variety. It is claimed that activation of preexisting memory units could not underlie repetition priming because such activation would have decayed too rapidly to produce facilitation at long intervals of several days. But the present theory has two sources of activation-produced priming: the residual activation of a logogen that has been aroused by an earlier presentation and the strengthening of the Type-1 associations, either those between concepts or those from the letters-in-position cues to the logogen unit. Based on the time decay of semantic priming, I would guess that the former activation decays more rapidly than do the sensory associations to the logogens. It is the persistence of these latter, strengthened associations that underlies longer-lasting repetition priming.

A second criticism often lodged against the activation theory of priming is that it is said to require a preexisting unit in memory that can be reactivated by the prime.

Thus, it is alleged that such theories cannot explain repetition priming observed for pseudo-words, novel word compounds, nonwords, novel diagrams, and novel visual objects. But as explained above, the present theory has no special difficulty in this respect. A novel pseudo-word or word compound is simply recorded as a new memory unit (like an impoverished logogen without semantic associations). The newly established Type-1 associations from the letters-in-position to that configured memory unit then provide the basis for enhanced performance on later indirect tests. Similar remarks apply regarding the learning of novel configurations of geons that provide structural descriptions (*imagens*) for novel objects; the constituent, geon-to-imagen Type-1 associations provide the basis for facilitated performance when these novel patterns are repeated.

If these counterarguments are plausible, then the standard arguments against the general activation theory of repetition priming have lost their force. In particular, the current version of the activation and elaboration theories of yesteryear can still be maintained.

Transfer-Appropriate Processing

It is fitting that we compare the current approach to the processing framework proposed by Roediger (1990). This has been an influential alternative to the prevailing ‘‘memory systems’’ view of implicit memory. Roediger proposes analyzing performance on indirect memory tests in terms of the principle of transfer-appropriate processing, TAP (as originated by Morris, Bransford, & Franks, 1977). The basic idea is that response to a target stimulus will be facilitated to the extent that the subjects' processing of it on the test trial overlaps (shares components) with the processing of it (or its associate) upon its original presentation. For example, identifying and reading a visual word primes later perceptual identification of the quick-flashed word because of shared components of the two tasks.

The TAP principle is similar to Tulving's (1983) principle of encoding specificity. In a general sense, these principles of memory retrieval and utilization are undoubtedly correct. They are modern restatements of the ‘‘common elements’’ view of transfer of learned behaviors (e.g, Singley & Anderson, 1989; Thorndike, 1906). The present theory implicitly acknowledges the crucial importance of shared components between study and testing. But any two psychological tasks have many similarities and differences. An important issue is to identify the many shared and nonshared psychological components between the prime and target tasks and to predict their relative weights in determining transfer performance.

The TAP principle does not itself provide a detailed analysis of particular indirect memory tasks; rather, it provides a tool for assisting that task analysis. Roediger (1990) proposed that a useful division of indirect memory tasks was into ‘‘data-driven’’ perceptual ones versus ‘‘conceptually driven’’ generation tasks. He further proposed that two tasks within a given class would prime one another but two tasks from different classes would not prime one another. The research available at the time showed the utility of this general distinction. However, while this distinction often suffices, research has advanced to the point of requiring finer distinctions to be made among different tasks within each variety. As on example, it is unclear where associative or semantic priming falls within this classification. As a second example, classifying a pictured object and reading its name would both seem to be data-driven processes; yet transfer (priming) between the two tasks is very weak.

More problematic are the large differences between tasks that are aggregated under the rubric of ‘‘conceptually driven.’’ These differ greatly in their potential for priming one another. Consider, for example, the question of whether categorizing the shape of the referent of a word will prime (transfer to) categorizing its functional use. Since in each case the person is processing information about the referent of the target word, the general TAP principle might expect substantial priming. But in fact there is very little, and that little comes about simply due to quicker perception of the target word (Thompson-Shill, 1995). As a second example, consider transfer between categorizing the shape of the referent of a word and its color. Since both judgments involve retrieving the visual appearance of the referent, the TAP principle might now confidently predict strong priming between answering the two types of questions about an object. But in fact there is very little. Several other failures to transfer between semantic questions were noted earlier in our review of the results of Vriezen et al. (1995). The Vriezen et al. experiments also found asymmetric priming between two tasks: answering a conceptual question about a visual word primed its perceptual identification as well as a lexical decision about it (a ‘‘data-driven’’ task), but lexical decisions or reading a word did not prime answering a conceptual question about it. Such cases point to a need to refine the TAP principle. Indeed, Roediger, Srinivas, and Weldon (1989) and Roediger and McDermott (1993) have acknowledged the need to refine the earlier distinctions within the TAP framework.

The required refinements would identify the shared components of two tasks that are critical for transfer. The present theory identifies these as particular associations that are activated (and strengthened) during initial study and are reactivated by the target during testing. To be sure, some of these associations are ‘‘data-driven’’ (sensory-to-logogen) and some are ‘‘conceptually driven’’ (category-to-exemplar), to use Roediger’s (1990) terminology. But the current approach has the ability to make finer distinctions than does the TAP principle—for example, to notice that property information involves different associations to a concept than does function information and that shape and color attached to a concept are also different associations. In fact, these distinctions were routinely made in the earliest semantic network models (Anderson, 1983; Minsky, 1968; Quillian, 1966).

AN HYPOTHESIS REGARDING GLOBAL AMNESIA

A portion of the significance attached to the distinction between direct and indirect memory tests stems from differential performance on such tests when normal people are compared to patients who have suffered various kinds of brain injury or traumas. Global amnesic patients comprise a varied lot, including those with anatomic lesions caused by chronic alcohol abuse (Korsakoff’s syndrome), bilateral resection of the medial temporal lobe and hippocampus (e.g, case H.M.), bilateral stroke, cerebral anoxia, and *Herpes simplex* encephalitis. Temporary anterograde amnesia is also often seen following electroconvulsive shock therapy (Graf, Squire, & Mandler, 1984) and high dosages of certain drugs such as alcohol and scopolamine (e.g., Hashtroudi, Parker, Delisi, Wyatt, & Mutter, 1984).

Numerous studies have shown reasonably preserved memory in memory-disordered patients as indexed by indirect tests of memory together with impaired memory as indexed by direct tests. Thus, amnesics are impaired in free recall, cued recall, and recognition memory for learning words or pictures, but they show intact repetition priming on perceptual identification, lexical decision, enhanced reading speed, word-fragment or word-stem completion, picture-fragment completion, semantic priming, and category-exemplar generation. As an example, Graf et al. (1984) found normal word-stem completion in amnesic patients, but greatly impaired recall when these subjects were explicitly asked to retrieve only the study-list words from the stem cues. Similarly, Graf, Shimamura, and Squire (1985) found that amnesics showed preserved priming on an indirect test of exemplar generation of category members, but were impaired in free recall for the presented words.

The hypothesis to be offered to account for such data is very simple: these memory disorders result from a severe loss in the person's ability to establish and strengthen *novel, new* associations of Type-2. These include associations between perceptually distinct units (e.g., word–word paired associates) as well as between an item and the context of its presentation. In other words, the brain injury of amnesics has severely impaired their ability to establish and strengthen the elaborative, Type-2 associations (see Fig. 4), especially associations to context; on the other hand, the injury has left relatively intact their ability to temporarily strengthen already existing associations, including prior concept-to-concept associations as well as sensory-to-logogen associations (e.g., those labeled Type-1 in Fig. 4).

Thus, in global amnesia, old knowledge is relatively preserved (though below normal, as shown by Squire, Haist, & Shimamura, 1989), and it can be reactivated and reflected in priming on indirect tests; however, new ''episodic memories'' regarding perceptually distinct, unrelated contents and their contexts of occurrence are difficult to establish. More specifically, we hypothesize that the amnesic's deficit is a restricted inability to form new associations of two or more perceptually distinct contents, such as unrelated words, pictures, and contexts. New associations of an item to the context of its occurrence prove especially difficult for amnesics to establish. Of course, it is the retrieval of an earlier context that is the cardinal feature of an episodic memory. It is also the basis for establishing personal autobiographic memories, for patients' building bridges connecting mental states of their recent past to their current mental state.

The hypothesis regarding memory disorders caused by brain damage can be extended as well to explain memory performance of people suffering temporary anterograde amnesia due to electroconvulsive shock or to high dosages of drugs such as scopolamine or alcohol. Similarly, comparisons of young versus elderly people often reveal greater age-related declines in direct memory tests than in indirect tests. In many respects, the dissociations observed with direct and indirect tests with these conditions are similar to those reported for patients with global amnesia—and would be explained in the same manner. That is, these physiological conditions cause a selective deficit in establishing new, elaborative (Type-2) associations, while leaving intact the ability to strengthen preexisting associations of Type-1.

The hypothesis that amnesics have difficulty establishing Type-2 but not Type-1 associations captures a significant portion of the literature, as we shall show. That generalization captures the fact that amnesics lose access to recent autobiographic episodes—they have no sense of having ''been there then'' for recent episodes. On the other hand, the theory explains how amnesics are able to show conceptual priming for category-exemplar generation as well as repetition priming for novel, integrated, perceptual configurations (e.g., nonwords or novel objects).

Illustrating the Amnesia Hypothesis

To illustrate how this hypothesis explains amnesics' data, consider an experiment by Graf et al. (1984), which asked amnesic and normal subjects to study a list of words, then presented them with three-letter stems; some subjects were asked to complete the stems with any word, whereas other subjects were asked to complete them only with a word from the studied list. Firstly, the theory supposes that presentation of the word in the study list strengthens preexisting letter-to-word associations of Type-1 in both amnesics and normals. Thus, when asked to provide any completion to the stem, both groups of subjects are predicted to show a priming advantage for the study-list word based on these equally strengthened, Type-1 associations.

Second, by assumption, the study presentation will have also established a novel Type-2 association of the word to the study-list context for normal subjects, but not for amnesics. So, when asked to give only stem completions that were on the study list, amnesics have few if any associations (of Type-2) to the list context. This lowers their performance for two reasons: first, amnesics can not use the list context along with the stem to cue their recall of the list word; second, they are unable to monitor and edit out (suppress) competing words that the stem cue evokes, whereas normal subjects can use their Type-2 association to suppress wrong completions and to continue searching for the list item. By the same token, if amnesics were to be tested with Jacoby's Inclusion/Exclusion instructions, they would suffer the consequences of having no Type-2 associations, namely, an inability to control (either to augment or to edit and suppress) ideas suggested by implicit, nonconscious memory processes.

An experiment by Verfaellie and Treadwell (1993) is relevant to these predictions. They tested amnesic (Korsakoff) patients and nonamnesic (alcoholic) controls using Jacoby's opposition procedures. Subjects first studied a word list presented visually, half to be read, half as easy anagrams to solve. (Aanagram solution is known to enhance explicit memory—an ''elaboration'' effect). Next, a second word list was presented auditorily. Subjects then performed under either Inclusion instructions (say ''Old'' to words from either list) or Exclusion instructions (say ''Old'' only to words from the second, auditory list).

The results supported the reactivation theory's predictions. For amnesics whether operating under Inclusion or Exclusion instructions, there was no difference whatsoever in Old recognition responses to first-list (visual) compared to second-list (auditory) words. That is, absent list-1 contextual associations, amnesics lacked the information needed to exclude list-1 words from recognition regardless of exclusion instructions. In contrast, control subjects responded Old to many fewer of the list-1 words under Exclusion than Inclusion instructions. Also, under Inclusion instructions controls remembered more of the anagram (elaborated) words than the read words, whereas amnesics showed no such benefit from solving anagrams. Thus, as predicted, amnesics showed no memory advantage due to elaboration and no influence of Inclusion versus Exclusion instructions during testing.

Similar accounts can be provided for a substantial fraction of the literature that demonstrates how amnesics are greatly impaired on explicit, direct tests of memory, but are relatively intact on many indirect tests. In the current theory, performance on the direct memory tests largely reflect the formation of novel associations of items to a study-list context (which process is impaired in amnesics), whereas performance on the indirect tests reflect reactivation and strengthening of preexisting Type-1, associative linkages either from a stimulus to a preexisting logogen or imagen or from concept-to-concept, established prior to the brain injury.

The theory expects that amnesics will show intact semantic and conceptual priming because those performances typically depend upon reactivating and strengthening old Type-1 conceptual associations that predated the patient's brain injury. Thus, amnesics are expected to show faster perceptual identification of a semantic associate target of a presented prime (e.g., seeing the flashed test word CHAIR when cued with TABLE). Amnesics are also expected to generate category exemplars at a greater frequency after having been primed with them. The existence of such priming effects with global amnesics is well documented (see Richardson-Klavehn & Bjork, 1988).

Numerous experiments have also shown repetition priming in amnesics using fragment completion of standard pictures of common objects, such as cups, cars, and telephones. The present theory expects amnesics to show such priming since image files for these common objects were probably already in the person's long-term perceptual memory before he or she suffered the brain injury that caused the global amnesia. Therefore, presentation of the object pictures to amnesics in the experimental context will reactivate and strengthen those preexisting geon-to-imagen associations (see Fig. 3), thus facilitating their reuse in perceiving and responding to the object during a later presentation.

Amnesics and Associative Priming

A question in this literature is whether amnesics can utilize interitem associations to boost explicit recall and to boost performance on indirect tests of implicit memory. Our hypothesis implies that amnesics can make some use of strong preexisting associations (of Type-1), since presentation of such word–word pairs will simply reactivate and temporarily strengthen these premorbid associations. Indeed, Schacter (1985) reported priming for amnesics of such explicitly cued production of the second word by the first word of two-word idioms (e.g., *sour grapes; small potatoes*). Our hypothesis suggests that although amnesics might be able to produce *grapes* as a likely primed completion to the cue *sour,* they probably would not be able to discriminate if asked whether they had earlier studied *sour grapes* or *sour dough.* They would have no context association (of Type-2) resulting from that earlier study episode to support such a discrimination.

On the other hand, the theory clearly predicts that amnesics should be unable to establish all new associations (of Type-2) between perceptually distinct units, such as in unrelated word–word paired associates or different concepts related in novel factual assertions. For example, following study of a list of arbitrarily paired words, a test of associative priming might measure whether one of the items would be perceived (or its stem completed) more readily in the presence of the other member of its studied pair. An earlier report of such priming by episodic associations in amnesics was published by Graf and Schacter (1985), but, upon later reanalysis of their data, they seem to have retracted that conclusion (Schacter & Graf, 1986).

That negative conclusion, of no associative priming in amnesics, seems to be the prevailing view. As one example, Shimamura and Squire (1989) found that amnesics showed no associative priming for studied, unrelated word pairs, whereas healthy controls showed robust associative priming due to Type-2 learning of these novel associations. Having studied elaborative sentences (e.g., ''A BELL was hanging over the baby's CRADLE''), subjects were tested to complete the stem of a second word when it was accompanied either by the first word of its sentence (BELL–CRA__) or by a new word (APPLE–CRA__). Although studied words were successfully completed more often than unstudied words by both controls and amnesics (due to strengthening of Type-1 associations), only control subjects showed a pair-specific advantage, i.e., facilitation for same-pair completions (due to controls' Type-2 associations). The authors concluded, ''Thus, although amnesic patients do exhibit entirely normal priming of pre-existing memory representations, they do not appear to exhibit priming of new associations in this paradigm.'' (Shimamura & Squire, 1989, p. 721)

As noted earlier, Paller and Mayes (1994) found a similar pattern of results for associative priming in a sequential perceptual identification task. Following study of unrelated paired nouns in sentences, subjects were asked to identify single test words quick-flashed sequentially in pairs. The noun pairs in the test were either intact or rearranged from the studied sentences. As expected, both amnesics and healthy controls showed repetition priming in identifying individual old words better than new words (due to Type-1 priming). On the other hand, although normal controls showed a robust facilitation in identifying second words followed by their studied first words (compared to rearranged pairs), the amnesic subjects showed no such facilitation due to intact pairs. Paller and Mayes (1994) therefore arrived at the same conclusion as did Shimamura and Squire (1989): amnesics show little to no associative priming following study of novel, unrelated word pairs.

Amnesics Learn Novel Objects

We turn now to the type of novel materials that amnesics apparently can store sufficiently to demonstrate repetition priming. Research by Schacter, Cooper, Tharan, and Rubens (1991) has shown that memory-impaired patients show significant repetition priming for pictures of novel, perceptually integrated objects. Similarly, Gabrieli et al. (1990) found intact perceptual priming of connected line-segment figures with amnesics. Such results demonstrate people's special ability for storing unified perceptual objects and for setting up Type-1 associations from their geon parts to the configural memory unit, which ability is preserved in amnesic patients. Amnesics preserved learning of novel visual patterns suggests that the primary sensory areas involved in such learning (e.g., occipital lobe, striate and prestriate cortex) may store sensory patterns independently of facilitatory input from those brain areas (e.g., medial temporal and hippocampal areas) that are usually damaged in global amnesic patients. Indeed, Gabrieli, Fleischman, Keane, Reminger, and Morrill (1995) found a patient with damage to his right occipital area who showed no visual perceptual priming but performed normally on recognition memory for the words seen. That is another example of a dissociation between Type-1 and Type-2 associations. The exact boundary conditions of perceptual organization of parts needed to produce such priming are yet to be explored (see, e.g., Asch, 1969).

Amnesics Learn Novel Pseudo-Words and Integrated Letter Strings

Amnesics' ability to store integrated perceptual displays applies as well to the storage of new pseudo-words and letter strings. Reports over a decade ago by Diamond and Rozin (1984) and Cermak, Talbot, Chandler, and Wolbarst (1985) had suggested that amnesics would show no priming after studying novel pseudo-words. However, more recent research has changed that conclusion. The earlier research has been faulted as suggesting to subjects that they could utilize whatever explicit memories they could retrieve to solve the indirect task (which benefited the normal controls, of course). As efforts have been made in later experiments to minimize normal controls' use of explicit recollections to solve the indirect task, the newer research has indicated that normal controls and amnesics show equal degrees of priming in perceptual identification of pseudo-words. Such results were found for the amnesic, H.M., who showed normal perceptual priming with pronounceable pseudo-words in an experiment by Keane, Gabrieli, Mapstone, Johnson, and Corkin (1995). Moreover, similar priming of perceptual identification for pseudo-words was even demonstrated for Alzheimer's patients, who suffer far greater memory disorders than do typical amnesics (Keane, Gabrieli, Growden, & Corkin, 1994).

Even more impressive is a finding by Keane, Gabrieli, Noland, and McNealy (1995), who found normal perceptual priming (tachistoscopic identification) of orthographically illegal (unpronounceable) strings of three to five consonants. Each string was studied several times, providing the amnesics with multiple learning opportunities, before it was tested.

Similar conclusions were drawn from research by Musen and Squire (1993). They presented normal and amnesic subjects with novel compounds composed of one-syllable words such as *gumpark* and *jamdirt*. A list of such compounds were read during 10 study trials and then read again during a final test trial either as the studied pairs or as rearranged pairs (*gumdirt, jampark*). Compared to reading new words in compounds, the old words in compounds were read faster by both normals and amnesics. This happens, in principle, because the Type-1 associations to the logogens for the constituent words had been primed. Moreover, a reading advantage for old studied pairs over rearranged pairs was observed for both normals and amnesics and was of equal magnitude. So, with sufficient repetition, novel word compounds were learned by amnesics to a level sufficient to be revealed in an indirect test such as reading speed.

An interesting question is whether the 10 spaced, practice trials of pronouncing a given compound effectively converts a verbal association into a miniaturized perceptual-motor skill; in other words, practice may transform a declarative memory into a procedural one, as Anderson's (1982) skill-learning theory would predict. That view of the result would be consonant with the general finding that amnesics show intact learning of perceptual-motor skills—a topic to which we now turn.

Perceptual-Motor Skills

So far this paper has ignored research on perceptual-motor skills, but has concentrated instead on implicit and explicit memory for verbal and pictorial materials, with later sections comparing normal controls with amnesic patients. I realize that some of the earliest, most startling data on memory dissociations included the finding that H.M., who was severely amnesic and unable to learn verbal material, showed normal learning of perceptual-motor skills such as pursuit-rotor tracking and inverted-mirror tracing (Cohen, 1984; Corkin, 1965, 1968). Later amnesics also showed benefits from repeated practice on solving specific jigsaw puzzles and on inverted word reading (see the reviews by Squire, 1982; Squire & Cohen, 1984). Despite showing improved performance on these tasks over several days of practice, amnesics could not explicitly recall ever having worked on the tasks before—a striking disconnection between their acquired skill and their ability to recall practicing it. These cases provided the basic, and dramatic, observations underlying numerous postulations distinguishing ‘‘procedural’’ from ‘‘declarative’’ memories.

The present theory expects that amnesics, being unable to record Type-2 contextual associations, will not explicitly remember having experienced the skill-learning task before. Beyond that, however, the theory does not specifically address the learning of psychomotor or intellectual skills. I would note that the present framework is consistent with the ACT theory of Anderson (1983) which views the learning of procedural skills as involving quite different memory units (viz., condition–action *productions*) and learning principles than those involved in acquiring descriptions of episodes (so-called ‘‘declarative’’ memories). Conceivably, the differing natures and contents of the two acquisition mechanisms could cause the two sorts of knowledge to be dissociated in amnesic patients. I offer no specific hypotheses along these lines.

My theory also does not address amnesics’ learning of emotional associations (Johnson, Kim, & Risse, 1985) nor classical conditioning of their eyeblink responses (Wieskrantz & Warrington, 1979). In those cases learning may well be mediated by other parts of the brain (e.g., amygdala, sensory–motor cortex, basal ganglia, cerebellum) distinct from the verbal associative areas of the brain that appear to be damaged in global amnesia and which are required to establish contextual-verbal memories describing the earlier acquisition contexts of these skills.

Functional Amnesia

The present theory assigns considerable importance to the role of contextual associations in the elaboration and control of explicit, personal memories. Moreover, it views the experiencing self or ego as a central component of that autobiographical context. We may apply these ideas in attempting to understand the patterns of memory transfer found in certain forms of functional amnesia, namely, posthypnotic amnesia and the dissociative disorder of multiple personality. It is now reasonably well established that in these cases implicit, nonconscious forms of memory transfer quite well from one state to another, whereas explicit memory of the same material is frequently absent. For example, material learned under hypnosis that is covered by a suggestion for posthypnotic amnesia will hardly be evidenced posthypnotically in explicit measures of recall, but will appear robustly with indirect tests such as perceptual identification or stem completion (see Bower, 1990; Kihlstrom & Hoyt, 1990).

Such dissociations could arise if the suggestion for posthypnotic amnesia temporarily blocks access to the Type-2, contextual associations formed under hypnosis, but is unable to undo or block the implicit effects due to strengthening the Type-1 sensory associations activated by presentation of the material during hypnosis. The fact that explicit memory returns upon later removal of the amnesia suggestion indicates that the subject had indeed formed these Type-2 associations and could access them under favorable conditions. However, while the amnesia suggestion prevailed, it somehow blocked the person from making experiential contact with that ‘‘alter ego’’ central to the context encoding those earlier memories. How it does so is a complete mystery to me.

A similar pattern of results arise when considering memory transfer between two different ‘‘personalities’’ of patients with multiple-personality disorder. A report by Nissen, Ross, Willingham, Mackenzie, and Schacter (1994) is most informative in this respect (see also Ludwig, Brandsma, Wilbur, Bernfeldt, & Jameson, 1972). Nissen et al. found that material studied by their patient while in one personality state would transfer strongly to another personality when indirect tests were used (e.g., perceptual identification). On the other hand, memory transfer was seldom observed with explicit, direct measures of memory. For example, complex stories or ambiguous paragraphs that could be interpreted somewhat differently by the different personalities showed no explicit memory transfer and were treated as entirely novel by the second personality. Again, it was as though the Type-2 associations linking the material to the experiential context of one personality were not accessible to the experiential context prevailing during the alternate personalities. (For discussion of the contribution of emotional contexts to the differing ‘‘personalities,’’ see Bower, 1994.)

Similar ideas may apply to the restricted amnesias seen in patients who have suffered a traumatic event (e.g., a vicious rape, attack, accident, combat) that induced a temporary ‘‘dissociative state’’ in them during the episode. For example, a rape victim may dissociate during the episode and later repress (‘‘black out’’) the actual rape scene from conscious recollection; yet, she will still show excessive fear to specific situations resembling the traumatic scene or specific stimuli encountered there (see, e.g., the report by Christianson & Nilsson, 1989). In my theory these differing bits of knowledge would be recorded by Type-2 versus Type-1 associations.

These remarks regarding the functional amnesias are speculative, preliminary, and presented merely to note their parallel to the organic amnesias. I offer them to suggest that the Type-1 versus Type-2 distinction may prove to be a useful tool for understanding some of the dissociative phenomena observed in these functional disorders.

FINAL COMMENTS

The proposed theory of priming in indirect memory tests, and its relations to direct memory tests, is fundamentally simple and old fashioned. It exploits the conceptual apparatus of associative networks that was current in the early 1970s. Moreover, the theory makes use of a hypothesis regarding global amnesia that was stated earlier not only in my 1984 speech (Bower, 1986) but also by Rozin (1976; Diamond &

Rozin, 1984) and Mandler (1980). Indeed, Mandler et al. (1986; also Graf & Mandler, 1984) identified rather much the same types of knowledge and their learning principles as identified in the current approach. An advantage of the present approach is the detail provided regarding how words (as orthographic or phonetic feature bundles) are learned, identified, and related to their corresponding concepts. The present theory is compatible with both the processing framework of Roediger (1990), the memory-strength ideas of Reder et al. (in preparation), and the ‘‘component processing’’ theory of priming advocated by Moscovitch and Umilta (1990, 1991).

This approach also restates a particular view of direct memory measures such as recognition memory, cued recall, and free recall, a viewpoint that has proved useful in explaining memory for autobiographical events, for sentences and texts far more complicated than the single-word paradigms popular in studies of priming (e.g., Anderson, 1976, 1983; Bower & Cirilo, 1985). The approach distinguishes between reactivating old memories versus establishing new ones (including personal contextual associations), but it has no special need to distinguish semantic from episodic ‘‘memory systems.’’ Amnesia is hypothesized to impair the acquisition on one class of associations (of Type-2) but not the reactivation and temporary strengthening of premorbid associations (of Type-1).

Our discussion has deemphasized the issue of subjects’ awareness of past episodes for guiding their current performance. All that is required in the theory is that the test stimulus activate above threshold and retrieve the association (really, the proposition) that a token of it was encountered in a specified, earlier context. For our purposes here, it is sufficient to equate the subjects’ awareness with the percepts and memory units whose activation levels exceed a threshold amount in working memory (see, e.g., Baars, 1988).

The distinction between implicit and explicit memories, which hinges upon subjects’ ‘‘memory awareness,’’ is rendered in the model as Type-1 versus Type-2 contextual associations. Retrieval of the latter associations provides the basis for subjects’ memory awareness, the subjective sense of remembering ‘‘being there then’’ during a past experience. These explicit memories of personal experiences provide a sense of unity, coherence, and continuity to our conscious mental life. The ability to form and retrieve contextual associations also supply us with the means for *controlling* the expression of our memories—for combining and reasoning about our past experiences, for monitoring, editing, suppressing, and reshaping the contents of our memory reports. Lacking contextual associations to recent experiences, amnesics have lost conscious control of their memories and in the process have lost the subjective sense of having ‘‘been there, done that’’ for their postinjury experiences.

What is remarkable is how much of the data on direct and indirect memory tests with normals and global amnesics is generally explained by a few simple ideas added to the old framework of associative networks. Of course, critics may object that the approach lacks parsimony, alleging that it merely postulates in an *ad hoc* manner a different type of association to explain whatever new feature of data is turned up. They might denigrate this exercise as just another demonstration of the flexibility (metaphorically, another ‘‘epicycle’’ in a Ptolemaic theory of the cognitive universe) that contributes to the survival of an outdated theoretical paradigm. However, a thoroughgoing associative theory has only ‘‘mere associations’’ as the medium and currency within which to represent the varying bits of knowledge that our human subjects so obviously display in experiments. Furthermore, I would argue that the associations have not been postulated in an *ad hoc* manner. Traditionally, the existence of the presumed associations has never been in doubt: letters and sounds are associated to words, words to concepts, concepts to one another, and events to the context to their occurrence (see, e.g., Anderson & Bower, 1973).

The value of the present theoretical exercise will be determined in part by whether the parsimony and elegance of the account exceeds that of other alternatives. In that regard investigators will doubtless place their bets differently depending on their commitments and reinforcement histories.

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