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Martin A. Conway
Susan E. Gathercole
&
Cesare Cornoldi

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An Associative Theory of Implicit and Explicit Memory

Gordon H. Bower
Stanford University, CA, USA

A central focus of memory research for the past 15 years has been implicit memory—its varieties of forms and their inter-correlations, its properties and functional relationships to experimental variables, and especially the relation of implicit to explicit memory. The amount of information collected around these topics has been immense, even staggering, and the research literature has grown far beyond the limits of our capacities to read it all, to catalogue and comprehend it all.

In such situations of information overload, a useful strategy for reducing cognitive strain is to examine simple theories of the psychological processes involved, and see to what extent the major generalisations within the field can be captured by a simple theory. We understand at the outset that the phenomena are probably far too complex to be fully explained by a simple theory; nonetheless, a theory that explains, say, 80% of the major generalisations can still serve a useful function as a mnemonic device, to catalogue and organise the major findings for teaching purposes, and to identify situations in which the processes operating are more complex than the mechanisms postulated in the simple theory.

Although I have personally contributed very little to the literature on implicit memory, I would like to propose such a simple theory. I will proceed by bringing out of the closet a hoary old dinosaur of a theory of implicit memory. This is one I proposed over 12 years ago in a little noticed speech I gave at an obscure conference of European Behavior Therapists meeting in Brussels (Bower, 1984). I presented the theory again with more illustrations in a recent paper in the journal *Consciousness and Cognition* (Bower, 1996) that may serve as a reference for the present article. I have since discovered that my ideas about priming set forth in that 1984 paper were very similar to those of Mandler (1980) and of Graf and Mandler (1984; see also Mandler, Graf, & Kraft, 1986). They used the term "intra-unit integration" (or "organisation") to characterise what in my theory are bundles of associations amongst sensory elements comprising a word or memory unit.

THE BASIC FRAMEWORK

The framework of the theory is that which was common to cognitive psychology in the 1970s, namely, John 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. To characterise the arousal of ideas within the model, I use the idea of spreading activation from Anderson's (1976) ACT model, also found in McClelland and Rumelhart's (1981) connectionist models.

The framework assumes that words have corresponding internal representations in memory as units called *logogens* or *lexical* units. Each unit serves to collect together a variety of associations, and provides a switching juncture to pass activation from one unit to another in the associative network. A word logogen would have associations to visual letter patterns which comprise its appearance, the phonemes that comprise its sound, its part of speech, its various conceptual meanings, possibly a perceptual description of the appearance of a canonical referent, and procedures for identifying the object, action, or property. In learning a word, we set up in memory a perceptual unit for it along with many different associations arising from multiple experiences with the contexts of its use.

Figure 2.1 shows some of the associations between visual letters-in-position and the lexical entry for the English word HARE, which I will use for my illustrations. Only positive associations are shown; each letter-in-position also has associations to the many other logogens which also have that letter in that position. This associative diagram could be complicated in several ways: we could augment the letter-in-position cues with more graphemic features such as bigram or spelling patterns or intermediate morpheme cues such as frequent prefixes (un-, dis-), suffixes (-ion or -ness), or syllables (see Dorfman, 1994); we could add inhibitory links between levels, so that the final letter E would rule out HARM; and we could add inhibitory links among logogens at a given level that engage in a "winner-take-all" battle to identify the external stimulus. Finally, the graphemic input probably needs to be augmented by a parallel automatic route of phonological encoding that intervenes between the visual orthography and the logogen units. Strong evidence indicates that mature readers have highly practised productions that convert graphemes into covert phonemes and these productions fire automatically to create phonological influences on reading—for example, slowing decisions that pseudo-homophones like BRANE are not words or that the grapheme BARE does not designate an animal (e.g. McCann & Besner, 1987; Seidenberg, Petersen, MacDonald, & Plaut, 1996).

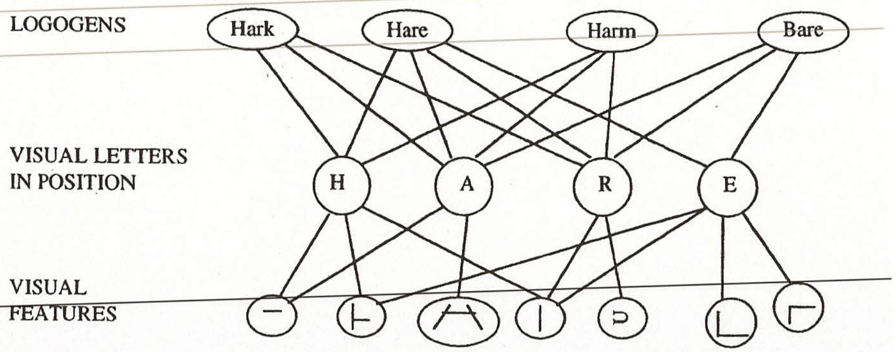


FIG. 2.1. Schematic representation of several memory units ("logogens") in the neighbourhood of the logogen for the word HARE. Associations from visual features to letters are shown, as are associations from visual letters-in-position to logogens. Units are depicted as circles, and associations by lines between circles. (Figure 1, p.29 from "Reactivating a reactivation theory of implicit memory" by G.H. Bower, 1996, *Consciousness and Cognition, 5,* 27–72. Copyright by Academic Press Inc. Reprinted by permission.)

My point here is that the framework in Fig. 2.1 is minimal but could be greatly complicated to make a more adequate model of word identification. However, these amendments would not alter the general points made later regarding implicit and explicit memory.

In these connectionist theories, the mechanism for word retrieval is spreading activation. Presentation of a visual word causes activation of the sensory features corresponding to its letters-in-position. These feature nodes pass along their activation to the word nodes. The activation transmitted along a given input line is the product of the activation of the sensory element times the strength of its association to the logogen; the activation accumulated at a given logogen is the sum of the activations of its incoming associations. It is 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 logogens is activated above threshold, then no word will be consciously perceived, although the model subject may be able to guess the target above chance based on partial information about letters-in-position.

THE FAST STRENGTHENING ASSUMPTION

To explain priming, this theory makes one assumption: whenever a pre-existing or old association is successfully re-aroused 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 elevated strength will decay over time, fading more rapidly the more often that sensory element participates in the arousal of competing and interfering logogens. This strengthening assumption is presumed to apply to any pre-existing association—not only those from sensory features to logogens but also those between logogens and their concepts, those between two concepts, and those between pictures and other nonverbal stimuli and their names. It is also intended to apply to the establishment and strengthening of associations to memory units that encode novel perceptual, unitary configurations ("gestalts") such as pseudo-words and novel geometric patterns. For convenience, let us call this entire collection "Type-I" associations: it includes not only all old associations but also those encoding novel, integrated perceptual patterns. Later I will introduce a second type of association to characterise episodic memories.

These strengthened sensory feature-to-logogen associations are my rendition of the process of "intra-item integration" identified in Mandler's (1980) two-factor theory of recognition memory and in Graf and Mandler's (1984) theory of repetition priming. My theory differs from Mandler's earlier one in that he supposed that such intra-item integration was sufficient for recognition memory, whereas in my theory recognition memory of well-integrated units often requires something more than this.

Priming Visual Word Recognition

For priming of visual word recognition, the visual letter-to-logogen associations play a critical role. Earlier visual presentation of HARE will strengthen the four associations in Fig. 2.1 from the letters-in-position H, A, R, E to the logogen for the word HARE. Consequently, that logogen will compete more effectively in the future with similar alternatives such as HARK, HARM, or BARE. Thus, these strengthened associations from sensory features to the logogen underlie repetition priming. A second presentation of the word HARE will be read more quickly because the word node will accumulate winning activation and pass threshold for perception more rapidly than before priming. Thus, the word would be more likely to be seen in a brief tachistoscopic flash or when presented in a degraded, fuzzy fashion.

We can also expect that decisions that rely on retrieving the word node would be speeded as well. This includes lexical decisions in which subjects decide that a letter string such as HARE is an English word whereas HURE is not. The model also expects that decisions regarding nonwords will be especially slowed by priming words similar to them. Thus, presentations of HARE, HIRE, and HURT will substantially slow down later rejection of HURE as a word, because it reminds the model of so many highly available words.

Such models explain word-frequency effects in lexical decision and perceptual identification. The pre-existing associations from letters to logogens in Fig. 2.1 will reflect the accumulated joint frequency in the language of that sensory feature with that word. Thus, perceptual identification will be easier for high-frequency words and for those that follow regular grapheme–phoneme rules. Moreover, due to limits on strength, facilitation due to priming should be less for high-frequency than for low-frequency words—and that accords with the facts of the matter. In addition, Logan (1990) and Kirsner and Speelman (1993) reported a power-law speed-up in lexical decisions with practice on repeated words, although there was some later question to what extent the speed-up was associated with specific recurring stimuli as opposed to a general effect of practising the lexical decision task (Kirsner & Speelman, 1996).

Perceptual identification, reading speed, and lexical decision are indirect tasks that do not require subjects to refer to past experiences. Nor does the model need to refer to past experiences to exhibit priming. Rather, due to strengthened letter-to-word associations, the model simply "perceives" the primed word more quickly. It may only be aware of that perceptual experience and not aware that the item had been presented earlier nor that its perceptual clarity is due to that earlier presentation. Later I will discuss how awareness enters into the model's account of explicit memories.

Other Indirect Measures

Besides indirect measures such as perceptual identification, reading speed, and lexical decision, the model may also be applied to several other indirect memory tasks. An example is word-stem or word-fragment completion. Presentation of the grapheme HARE will strengthen the visual letter-in-position associations in Fig. 2.1 to that logogen, so that it will be more likely to win out in competition with other words evoked by an appropriate stem (HA_ _) or fragment cue (H_R_).

A second example is the letter insertion and letter deletion measures of priming introduced by Reingold (1995). In the insertion task, subjects are shown a test string of letters plus two extra letters, and must decide which of the two could be inserted into the test string to make a word. Thus, given the test string CRAH and the extra letters R and S, the subject should insert S to spell CRASH. Reingold found that compared to unprimed controls, subjects primed with CRASH were speeded in finding that solution. This would be expected by the theory in Fig. 2.1 because earlier presentation of CRASH would strengthen the letter-in-position associations that are also evoked by the test string CRAH, thus readily bringing CRASH to mind as a candidate target for insertion. Reingold also found that if the test string was a familiar word, such as CASH into which R or S was to be inserted, subjects took longer to solve the problem. The model expects this, because the test string strongly activates its own logogen that will then compete with and retard finding the solution.

In Reingold's deletion task, two letters in a test string are underlined (e.g. C H A S H) and subjects decide which underlined letter should be deleted to make a word. Here, priming with the solution word (CASH) speeds performance. Reingold found again that a test string that made a familiar word (C R A S H) caused delay in subjects' solution times. This would have the same competing-response explanation as given before.

Priming Interfering Words

As the last remark indicates, priming of competing responses is a natural implication of this associative account. One simply strengthens an alternative response to cues similar to those used in the indirect memory test.

An example of interference in perceptual identification was provided by Ratcliff, McKoon, and Verwoerd (1989). In one condition of their experiments, a brief flash of a target word (e.g. DIED) would be followed by a forced choice against a similar alternative (DIED or LIED). Prior presentation of the target word (or the distractor) in a study list increased choice of the target (or the distractor) on the later test trial, thus either facilitating (or interfering with) identification of the target word.

Strong interference was also reported by Reingold (1995) for the letter-deletion task after priming a competing response. For example, after being asked during study to delete the E or D in PEDARL (to get PEARL), subjects are considerably slowed when later asked to delete A or R in PEDARL (to get PEDAL). Presumably, the study episode strengthened the letter-in-position associations to PEARL, and that response was evoked by the altered test stimulus, thus interfering with finding the solution to the test string.

Interference has also been reported by Smith and Tindell (1997) who primed competitors to completing test word fragments. Fragments like A_L_ _ GY, T_NG_ _T, and C_U_TR_ when unprimed were completed an average of 59% successfully within five seconds (as ALLERGY, TANGENT, COUNTRY), and when primed were completed 75% successfully. In contrast, the fragment was completed successfully only 18% of the time after a similar word had been primed (ANALOGY, TONIGHT, CLUSTER). Because presentation of a competitor such as ANALOGY strengthens those letters-in-position to that word, the similar fragment A_L_ _GY will activate that competitor. Because it almost but not quite fits the fragment, ANALOGY serves to block and delay the search for a successful completion, thus allowing the brief test time to be exceeded.

As a further illustration, Wolters (1996) in a talk given at the Padua conference described several experiments demonstrating strong interference effects from priming competitors in a word-stem completion task.

Modality Effects

Priming also occurs in other sensory modalities. The logogen framework assumes that a spoken word eventually contacts the same logogen unit as does the visual word except that the sensory elements and input associations are acoustic and phonetic rather than orthographic. Figure 2.2 shows the relevant elements, including not only the phonemic elements directly activated by the acoustic wave form but also the parallel route by which visual words cause expert readers to automatically activate the covert sound of the word, at least to a mild degree. The phonemic features have a collection of sensory associations to the word logogens that are used in spoken word identification. For experienced language users, these will be old associations of Type 1. These associations can be strengthened by hearing the word in a study list, so that it will be identified more readily in a later hearing test given against a noisy background. This describes auditory

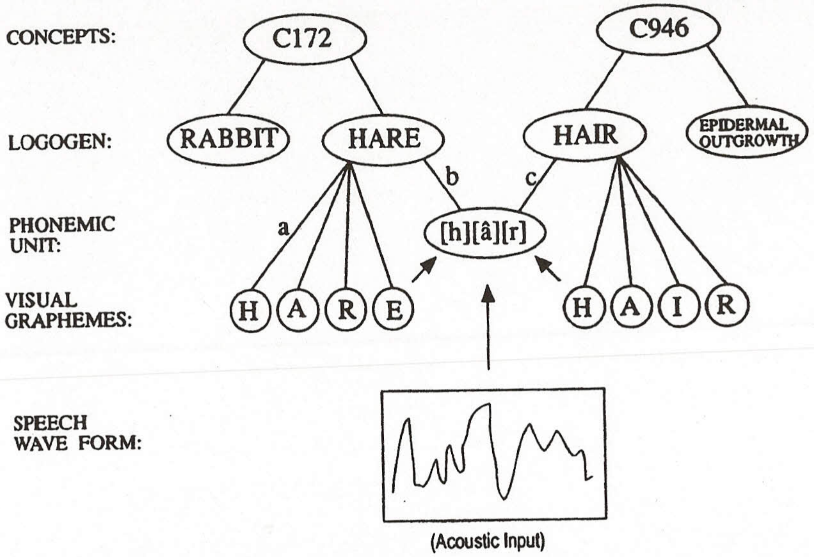


FIG. 2.2. Schematic representation of the logogens for HARE and HAIR. The visual graphemes activate their logogens by the direct-route, Type-1, associations (labelled a); automatic application of pronunciation rules creates a weak phonological representation which has pre-existing Type-1 associations (labelled 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). (Figure 2, p.34, from "Reactivating a reactivation theory of implicit memory" by G.H. Bower, 1996, *Consciousness and Cognition*, 5, 27–72. Copyright by Academic Press Inc. Reprinted by permission.)

priming. These phonetic associations also provide a basis for some phonological priming of similar-sounding words (see later).

Residual Activation of the Logogen

Morton's (1969, 1979) logogen model assumed that once a logogen has been activated, its level of activation persists for a while before decaying to baseline. An alternative formulation is that its threshold is temporarily lowered. In any event, less sensory information will be needed for the logogen to pass its threshold and fire when the word is repeated a short time later.

This residual activation provides an explanation of several observations including the intermediate amounts of *cross-modal priming* that are typically observed. Thus, a visual word prime will leave some residue of activation on that logogen, and in addition may activate and strengthen the indirect phonological route, strengthening the association labelled b in Fig. 2.2. Consequently, the later spoken word HARE in a noisy channel would now be more likely to pass the logogen's threshold of identification.

The theory also expects that cross-modal priming due to residual activation will transfer to a modest degree from a spoken prime to a visually presented target. Cross-modal priming due to residual activation is expected to be much less than same-mode priming because the same-mode route capitalises in addition on reusing the strengthened associations from the specific sensory features to the target logogen.

Enhancing Cross-modal Transfer of Priming

Evidence indicates that cross-modal priming can be augmented by instructing subjects to image the stimulus in the alternate modality. As one example, Roediger and Blaxton (1987) enhanced auditory priming of a visual word-fragment completion task by instructing their subjects to image the printed visual appearance of the spoken words. (Such conversions may be simulated in theory by production rules that the instructions set up in an executive controller that guides the operation of working memory.) The conversion thus causes a spoken word to recapitulate a weakened version of the event of perceiving the visual word and strengthening its letter-to-logogen associations.

Augmentation of cross-modal priming from vision to audition has also been reported. Stuart and Jones (1996) asked subjects to vividly imagine the sound (pronunciation) of a visually presented word. Subjects who imagined the sound of the word later showed more accurate identification when it was spoken softly in a background of white noise. On the other hand, Stuart and Jones found, as the theory expects, that imagining the sound of the referent of a word (e.g. the ticking of a CLOCK, the lowing of a COW) did not prime identification of the sound of the word itself spoken in noise.

Semantic Priming

Residual activation due to associations can also be used to explain semantic and associative priming. Thus, presentation of the word DOCTOR will speed lexical decisions for related words such as NURSE or HOSPITAL. Furthermore, if a text has been discussing rabbits, then residual activation on that concept node will cause the person to more readily perceive the word HARE in a degraded or quick flash, or judge that it is a word. Residual activation will also explain homophone resolution. Thus, the model person would resolve the spoken ambiguous sound HARE/HAIR in terms of the HARE logogen recently activated by mention of rabbits. These expectations accord with well-established facts in this area.

Phonological Priming

Residual activation can also explain the availability of studied words on a later rhyming test. For example, after studying a list containing BUY and BLUE, subjects are more likely later to give those as the first rhymes that come to mind to the test words TRY and THREW (Mandler et al., 1986). A similar kind of phonological priming based on similar-sounding words arises with stem completion. After reading aloud a series of related words such as ARROW, NARROW, and HARROW in a study list, subjects are more likely later to complete a visual word stem SPA_ with a word that sounds like the primers, viz., SPARROW. The result can also arise with dissimilar orthographies, as when overt reading of DARE and HEIR prime later stem completion of CHA_ as CHAIR (Mandler et al., 1986). This outcome is predicted by the model because the common phonemes (e.g. "_air") mildly activate the logogens for words that share those phonemes, thus causing the logogen for CHAIR to be activated above baseline. Thence, the visual stem CHA_ is completed as CHAIR rather than CHANCE or CHAIN.

Priming by Episodic Associations

In healthy subjects (but not amnesic patients) study of novel word–word paired associates will set up a new association between those two concepts. Thus, activation of one member of the pair will spread activation to the other member in an amount and speed depending on the strength of the association. This associative spread provides the basis for priming of a learned response associated to a cue. The critical observation is to show facilitation when one of the items of the studied pair receives an indirect memory test in the presence versus the absence of the other member of its pair.

An example of associative priming was reported by Paller and Mayes (1994). After studying word pairs, their subjects were tested in a sequential perceptual identification task: two words were quickflashed one at a time in succession and subjects tried to identify the second word. They were better able to do so if the second word had been previously associated to the first word shown in the pair of test flashes.

A second example of associative priming arises with stem completion. Graf and Schacter (1985) found that subjects completed word stems with the studied response word at a higher rate when the stem was accompanied by the other member of a studied paired associate. The model's explanation for this is illustrated in Fig. 2.3 which shows the memory trace set up due to studying the pair DRYER–BLOCK. At the test, DRYER is presented beside the stem BLO_ with instructions to complete it with the first word that comes to mind. The model supposes that the cue word (DRYER) sends activation over to the logogen of the associated unit (BLOCK), there to summate with the activation coming into that BLOCK logogen from the strengthened, Type-1 associations from the sensory fragments BLO_. Thus, the model is more likely to complete the stem with the studied item when it is accompanied by the other member of its studied pair. Moreover, and as predicted, the stem-completion rate is greater the stronger is the elaborative encoding of the association from the cue to the response word.

As will be discussed later, Fig. 2.3 is incomplete in that it does not show an association of the studied pair (DRYER–BLOCK) to the experimental context in which it was presented. As explained later, such context associations can be retrieved and used to modulate (or suppress) the expression of a given association—for example, for the subject to obey instructions to exclude the studied response word (BLOCK) as a completion to the stem cue (BLO_ _). The presumption that contextual associations can modulate the expression of other, primed associations relates to the question of whether episodic associative priming involves differing degrees of implicit versus explicit memory depending on the nature of the test procedure (e.g. whether or not fast reactions are required). We will revisit this issue later in our discussion of Jacoby's (1991) "Process Dissociation" procedure for estimating automatic versus recollective contributions to performance in various memory tasks.

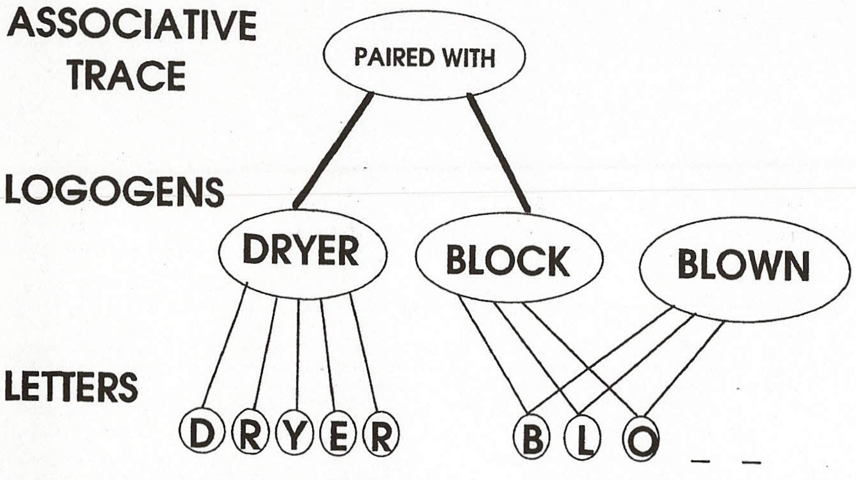


FIG. 2.3. Diagram of associative priming in stem completion. Study of the pair DRYER–BLOCK establishes an association (trace of the pairing) in memory connecting the two. Subjects are asked to complete the stem BLO_ in the presence of the paired cue (DRYER) or an unassociated cue.

Picture–Word Priming

Priming is also observed in facilitation of naming or categorising pictures of common objects like *cups* and *horses.* To deal with such data, the present framework must hypothesise some means by which visual objects are recognised. Several approaches are plausible, but for illustration I will use Biederman's (1986, 1987) geon theory which views visual objects as composed of configurations of primitive geometric elements (called "geons"). Each configured-geon description of an object would have Type-1 associations in long-term memory to a canonical object-picture file which Paivio (1978, 1986) has called an *imagen* in analogy to a logogen for words. The imagen would be associated to a concept, which would be associated to one or more names for the concept. Figure 2.4 shows the basic ideas. The lines here denote pre-existing Type-1 associations.

Picture priming follows directly from this associative diagram along with the assumption that associations are strengthened by their use. Presentation of an object-picture will strengthen the Type-1 associations of the geons-in-relations to the corresponding imagen and concept. Thus, on repetition, the picture will be seen more quickly in a tachistoscopic flash, or when unfocused or covered with visual noise, or when shown as a fragmented outline (Biederman & Cooper, 1991). The speed of naming a repeated picture will also be increased, especially if it had been named when it was presented earlier. Similarly, if categorising the object pictured (categorising a *horse* as a *animal*) strengthens Type-1 associations from the object concept to its superordinate category, that should facilitate later categorisation of the same picture.

If activation spreads from the imagen via the concept node to the word unit, then presentation of the picture will produce some modest, cross-modal priming of its name, and that should occur whether the word is presented visually or spoken in noise. This cross-modal priming can be augmented by instructing subjects to imagine what the name of the pictured object looks like, i.e. image the visual grapheme PENCIL when shown a picture of a pencil. Roediger, Weldon, Stadler, and Riegler (1992) found that such graphemic encoding enhanced priming as measured by visual word-fragment completion. Presumably, im-

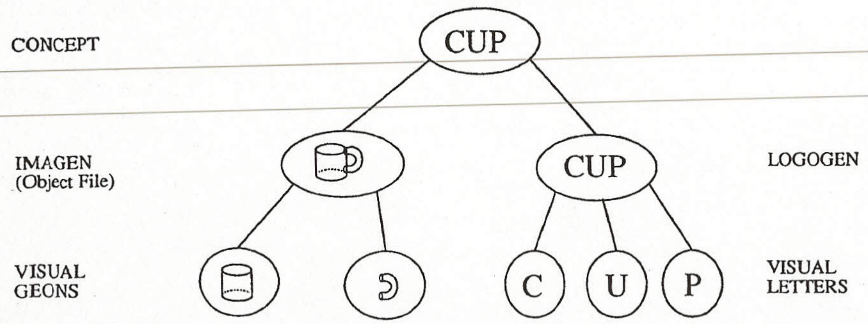


FIG. 2.4. Representation of two elementary geometric units ("geons" of a cylinder and curved tube that serves as a handle) associated to the object file ("imagen" unit) formed by their structured configuration. The imagen and the logogen for the word *cup* have converging associations to the concept node for cup. (Figure 3, p.40, from "Reactivating a reactivation theory of implicit memory" by G.H. Bower, 1996, *Consciousness and Cognition*, *5*, 27–72. Copyright by Academic Press Inc. Reprinted by permission.)

agining the canonical referent to a name should also enhance later perceptual identification of a picture of that canonical referent.

Our associative analysis also implies that presentation of a pictured object will create interference in perceptually identifying a degraded version of a very similar-appearing object. Ratcliff and McKoon (1996) reported such interference in priming of similar-appearing pictures (e.g. a hot-air balloon and a lightbulb; a loaf of bread and a mailbox).

A complete theory will also need some way to represent our knowledge of common sounds that we can identify, such as the sound of footsteps, a motor car, a bird song, Beethoven's Fifth Symphony, and so on. While I have no specific proposals in this respect, the obvious approach is to represent such stimuli in the abstract as a temporal sequence of segmented sound patterns from which acoustic features are extracted which are then associated with the category of the sound. These would be Type-1 sensory associations, so they could be activated and strengthened by an earlier priming experience in an experimental study list. Consequently, on re-hearing the same sound, subjects would be able to identify it accurately faster and with greater certainty. This kind of priming in identification of naturalistic sounds has been reported by Chiu and Schacter (1995).

Learning Novel Patterns

Any learning theory must also deal with the learning and subsequent priming of novel patterns such as nonwords and novel objects. Within associative network theories, a novel pattern is learned by recording into memory a description of its units-in-position and their inter-relationships (e.g. sequence of familiar letters or syllables; or a configuration of geon units). When the pattern is presented as a unitary perceptual gestalt, it causes a memory unit (similar to a logogen or imagen) to be established and its sensory features to be linked into that unit. For example, visual presentation of the letter string TUN will set up sensory associations from the letters-in-position, T then U then N, to a logogen encoding that pattern. Repetition of this pattern will re-arouse and strengthen these associations, and these provide the basis for priming in later identification of this novel letter sequence. As a nonword becomes better learned with repetition, it will be more easily identified at shorter exposure times or under more degraded stimulation (for a more detailed model, see Salasoo, Shiffrin, & Feustal, 1985).

Conceptual Priming

Conceptual priming refers to the fact that having the subject generate or think about a conceptual associate to a stimulus facilitates that response to a second presentation of that stimulus. The experimental demonstrations almost always involve reactivation and strengthening of old, Type-1 associations. An example is shown in Fig. 2.5 for exemplars associated to the category of BIRDS. We suppose that when subjects are presented with exemplars such as OWL and EAGLE, they activate their associations to the corresponding taxonomic category, thus strengthening these associations. Such automatic activation will be stronger for instance-to-category associations that Barsalou and Ross (1986) have described as "context-independent". But even for weak associates, asking subjects during study to engage explicitly in semantic categorisation of the exemplars (a "depth of processing" manipulation) should especially strengthen these associations.

As a consequence, reading these exemplars in a study list will increase their probability of being generated later when the model is asked to retrieve instances of the category. The enhancement in production frequency should be especially large for nontypical exemplars which normally have a low baseline of generation. The enhancement arises for two reasons: first, presentation of the exemplar during study leaves some residual activation on that logogen, causing it to stand out among other exemplars; and second, activation of the exemplar-to-category association during study strengthens the very association that is utilised in the later category generation test.

Such exemplar priming is conceptual because it varies according to activation of the concepts (of BIRD and OWL). Three consequences follow: first, conceptual priming should transfer across presentation-and-test modalities of the stimuli, among auditory or visual word or referent picture modes of presentation. Second, the outcome depends on the studied stimulus evoking the same concept as is evoked during testing. For example, a picture of a baseball *bat* would not be expected to enhance the later probability of generating BAT as an exemplar to the test category of SMALL ANIMALS.

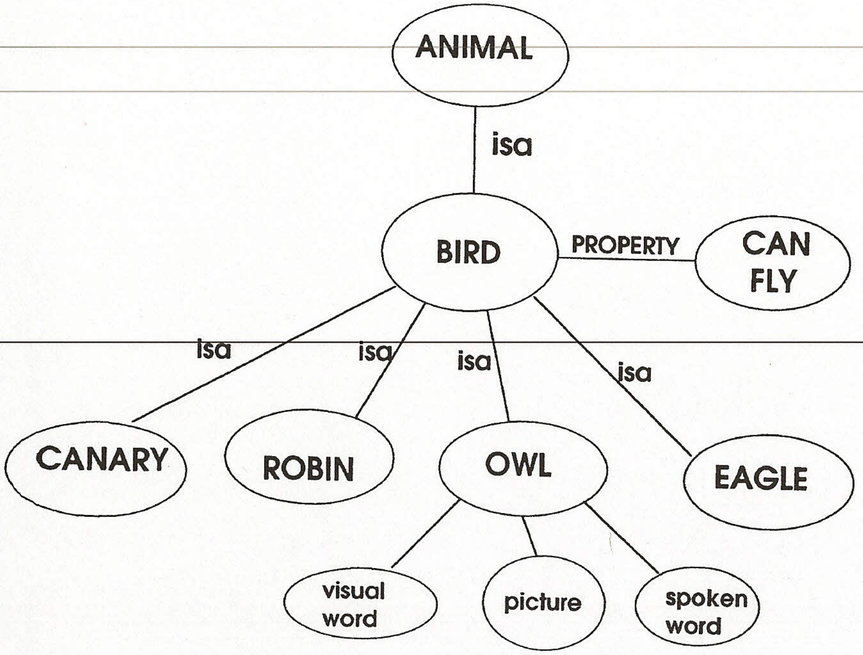


FIG. 2.5. Pre-existing associations from a category (BIRD) to exemplar concepts (*canary*, *robin*, etc.). Thinking of an exemplar as an instance of the BIRD category will increase the later probability of generating it as an exemplar of the category. The OWL concept can be accessed from either the visual word, the spoken word, or a picture of an owl. Superordinate and property information attached to the BIRD concept is also depicted.

A third consequence is that the conceptual priming should show encoding specificity—that is, it should be specific to the particular associations aroused during initial encoding of a word. This implication was confirmed in experiments by Vriezen, Moscovitch, and Bellos (1995). Their subjects classified the referents of nouns according to one of two criteria—either "Is it man-made?" or "Is it larger than a bread box?". At later testing, a given noun was classified according to either the same or the opposite question. Significant facilitation occurred for same-question judgements but very little for different-question judgements.

This result is expected by the model. Figure 2.6 shows the relevant associations attached to the concept, say, of a TREE. This theory expects facilitation when answering the same question because that reuses the strengthened conceptual association; on the other hand, only slight priming will arise if the questions are changed, because different facts (or associations out of TREE) must be accessed to answer the different questions. That is, retrieving the

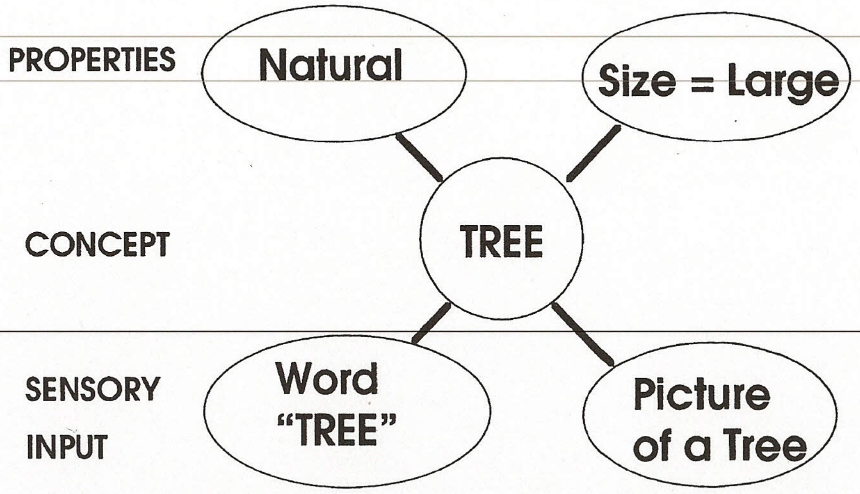


FIG. 2.6. Conceptual associations to the concept of TREE which can be accessed and strengthened via its name or a picture of a referent. The properties shown are of the size and naturalness of trees.

fact that a TREE is natural (rather than man-made) will not strengthen the association to its size that is needed to answer whether it is larger than a bread box.

This lack of cross-question transfer may be contrasted with strong transfer between verbal versus pictorial routes of accessing the TREE concept when asking the same semantic question. Thus, if during study the subject answers that a picture of a TREE represents an object larger than a bread box, that will strengthen the same conceptual association needed to answer that same question for the word TREE whether it is presented later in either spoken or written form. Although repetition of the same question in the same form will slightly reduce the time to access the logogen, the reduction in time is quite small relative to the much larger time required to retrieve and answer the conceptual question.

EXPLICIT MEMORY

The associative network theory was long ago used to explain results from explicit memory tests such as cued recall, free recall, source memory, and recognition memory (Anderson & Bower, 1972, 1973, 1974). In our theory of human associative memory (HAM: Anderson & Bower, 1973), Anderson and I proposed that one purpose of memory is to record the history of a subject's experiences. And the most elementary autobiographic record is one asserting that I (the subject) witnessed a particular event at a specific time and place. We rendered this as the recording into memory of a bundle of structured associations describing a Fact observed in a given temporal-spatial Context, as in the prototypical assertion "Last night in the park a hippy kissed a debutante".

The way the theory applies to recognition memory, then, differs slightly depending on whether the experimenter's to-be-remembered "items" are already familiar units such as single words or pictures of common objects, or whether they are novel combinations of several familiar units, such as unrelated pairs of words or letters, novel names like Simon Wiesenthal, or novel assertions such as "A hippy kissed a debutante". The model encodes a novel combination by setting up an associative structure that describes it, such as labelled links to the first and second part of a name, or to the three letters of a novel trigram, or to the agent-action-object concepts comprising an assertion. That associative cluster is also linked into the context in which this pattern was presented, such as that I read the name Simon Wiesenthal in one of Larry Jacoby's papers.

Later, when asked to intentionally recognise a specific constellation or pattern of elements, such as a test proposition, we presumed that the model-subject searches for a match of the test probe to a structure in memory having just those elements or concepts in just those relationships. So, the model in one sense can "recognise" that the name Simon Wiesenthal is "familiar"; moreover, if the association to context can be retrieved, the model can "recognise" in addition that it was Larry Jacoby who introduced me to that name. Experimental conditions that create the former association while blocking retrieval of the latter contextual one (e.g. divided attention during testing) will lead to many "false fame" judgements of the sort observed by Jacoby and Kelley (1991).

The theoretical analysis is considerably simplified for the standard item recognition-memory experiments in which subjects are presented with single familiar words or object pictures, and are later asked to indicate whether each of a series of test items had been presented in the study list (are "Old") or not (are "New" lures). The question for the subject in this case is not whether the test item is "familiar" in the standard meaning of that term, as all items are so; rather, the question is whether it had been presented in the study list. I will be dealing with this simple case for the remainder of this paper.

The basic idea is shown in Fig. 2.7a, namely, presentation of a familiar or well-integrated item in a given context sets up an association between the item and the experimental context. I call these Type-2 associations because they are encoding a new association between two arbitrary autobiographic events—one's being in a particular place and time, and witnessing some stimulus event there along with one's reaction to it. The strength of this episodic association will vary with the usual learning parameters, including semantic elaboration.

A later "recognition memory" test presents the studied items along with some new distractors and asks subjects to judge whether or not each appeared in the earlier study context. The model simulates this process by accessing the strength of association between the test item's concept and the earlier experiential context.

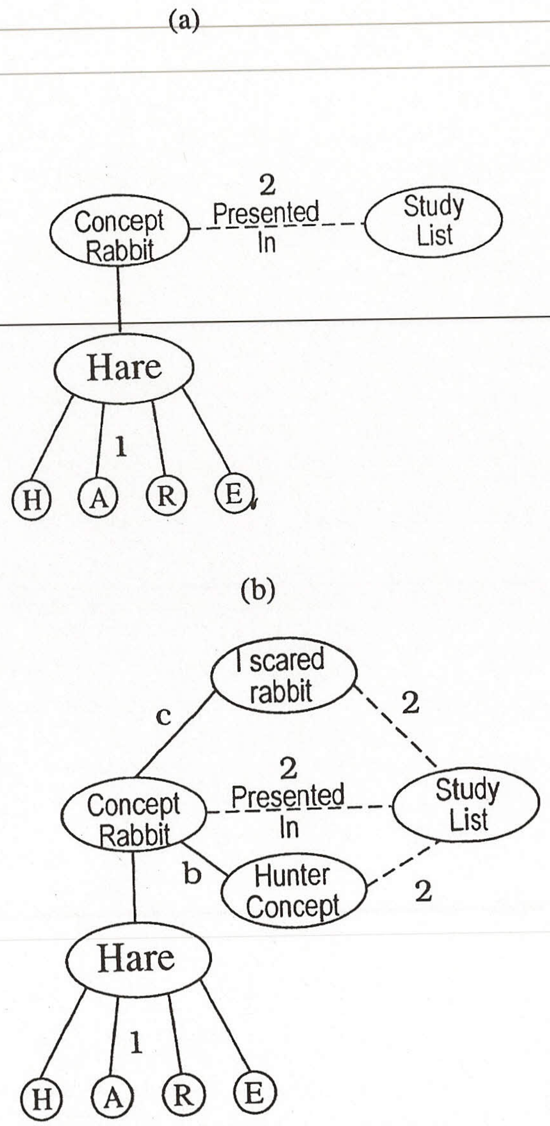


FIG. 2.7. (a) Schematic representation of the associations from the letters-in-position to the logogen HARE and its concept, along with the new association (labelled 2) encoding the proposition that the word/concept had been presented in a given study context. (b) Elaborated associations relating the presented word/concept HARE to other thoughts occurring during its study. New associations are indicated by dashed lines, and refreshed pre-existing associations by solid lines. (Figure 4, p.44, from "Reactivating a reactivation theory of implicit memory" by G.H. Bower, 1996, *Consciousness and Cognition*, 5, 27–72. Copyright by Academic Press Inc. Reprinted by permission.)

If the strength of this association is sufficiently large, then a positive recognition response is given. With minimal assumptions, this line of theorising leads to the standard "signal detection" theory of recognition memory.

The connection of the studied word to the study-list context may be strengthened through semantic elaboration and inter-item associations. Thus, on studying HARE in the list, the subject might relate it to the word HUNTER which occurred earlier in the list, and it may also trigger a specific memory of a time he scared a rabbit while on a hike (see Fig 2.7b). These elaborations provide redundant routes for connecting the concept to the study context, so that they provide back-up support when the direct association is very weak. These redundant connections help to explain why explicit memory improves with semantic processing of items during study (see Anderson & Reder, 1979).

Explicit recognition-memory tests point backwards in time, asking subjects to retrieve a memory of a past event. I use the concept of "context" to refer inclusively to a variety of external stimuli as well as subjective experiences accompanying earlier presentation of the item. A critical element of the context, of course, is the experiencing person—the self or ego—the internal sense or feel of oneself as a witness to an event, albeit in this case a trivial event (i.e. seeing HARE in a study list). These contextual associations provide the basis for autobiographic memories, for the subjective sense of "being there then". They provide the substrate for the "autonoetic consciousness" described by Tulving (1985a). They are the means by which people's current mental state can be put into informational contact with their prior mental states, providing them with a sense of personal continuity and coherence.

The Independence Assumption

A major assumption of the theory is that on presentation of a word in a study list, the amount of strengthening of the Type-2, concept-to-context association (labelled 2 in Fig. 2.7a) is a random variable that is statistically independent of the amount of strengthening of the sensory letter-to-word associations (those of Type 1, labelled 1 in Fig. 2.7a) caused by that presentation. That is, implicit learning reflected in sensory priming of the item is assumed to be independent of the learning of the Type-2 context associations or inter-item associations that underlie explicit memory tests. This assumption is controversial, but it is motivated by the research showing independence between the subjects' explicit recognition memory for studied words and their priming in perceptual identification (e.g. Jacoby & Dallas, 1981) or in fragment completion (Tulving, Schacter, & Stark, 1982).

An important consequence of this independence assumption is that the theory is not forced to predict that experimental variables that influence indirect measures of memory will necessarily influence direct measures in the same manner. Rather, we know that some variables that primarily involve "data-driven", perceptual processes will influence the Type-1, sensory associations but not the Type-2 contextual associations. On the other hand, other variables such as semantic elaboration, generation, and mnemonic strategies will enhance the Type-2 contextual associations, but not the Type-1, sensory associations.

It is not uncommon for different procedures to affect the two types of associations in different directions. As one example, words that are read during study are identified more easily later when quickflashed, whereas words that are generated to an associated cue during study are remembered more on a recognition memory test (Jacoby & Dallas, 1981). Such interactions are called "dissociations" and are often taken as evidence for different memory systems. The present theory sees them instead as revealing the relative contributions of the two types of associations to the different types of memory tests.

It would be a mistake, however, to strictly align Type 1 and 2 associations with exclusive control of performance on indirect and direct tests, respectively. As a counter-example, consider the fact that reading a category exemplar will increase its perceptual identification more but its category generation less than will generating it to a strong category cue during study (BIRD–E_). This is because actually generating the exemplar during study causes more strengthening of the category-to-exemplar association (used again in the later generation task) than does merely reading the word (see Wagner, Gabrieli, & Verfaellie, 1997). So, that is an example in which a conceptual orienting task influences performance on a memory task often classified as "indirect".

Opposition Procedures

Jacoby (1991) and Mandler (1980; also Atkinson & Juola, 1974) have argued that subjects' judgements in recognition memory tests reflect both an explicit "recollective" component and an implicit "familiarity" or "fluency" component. To separate these two factors, Jacoby proposed "opposition" procedures which instruct subjects to perform under one of two different decision criteria. The "Inclusion" criterion instructs subjects to perform some task in such a manner that the hypothetical "recollection and familiarity" processes will summate in facilitating performance. The "Exclusion" criterion asks subjects to perform in such a manner that the two alleged processes are placed into opposition. The manner in which this is done, and the theoretical analysis, varies somewhat with the task.

Let us first consider the task of word-fragment completion. After study of a list of words, subjects are shown word fragments and asked to give either the first completion that comes to mind ("Inclusion") or to give only completions that exclude any word that appeared on the study list ("Exclusion"). Notice that the Exclusion test places the alleged automatic or familiarity component of memory into opposition to the recollective component. Notice also that in order to mimic the task performance induced by such instructions, a complete cognitive theory needs to postulate executive control routines that operate over and make use of declarative memories. In Anderson's (1983) ACT theory, these control routines are represented as sets of "if–then" rules or productions that (a) encode the instructed goals and action plans, and (b) are loaded into working memory to control the cognitive machinery. For example, Exclusion instruction would be encoded by productions that set as a condition for expressing an associated response (to a cue) that the response must be associated with one designated context (source) but not with the forbidden source.

The present theory provides an account of fragment-completion produced under these Inclusion and Exclusion instructions (see Fig. 2.8). Recall that visual presentation of a word in the study list will both increase the Type-1 sensory associations to its logogen, and possibly (and independently) establish a Type-2 association to the context. So, when given the word fragment along with Inclusion instructions, the model may access the studied logogen either directly from the sensory associations or perhaps by retrieving it from the list context, and confirming that it fits the fragment. (Indeed, Inclusion subjects are often encouraged to use this recollection strategy; even if not so encouraged, they soon discover its utility during the test series.) If A denotes the probability of accessing the target word from the fragment's sensory features, and R denotes the probability of retrieving it from the list cue, then the likelihood that the subject produces the primed word on an Inclusion test will be $I = A + (1–A) R = R + (1–R) A$.

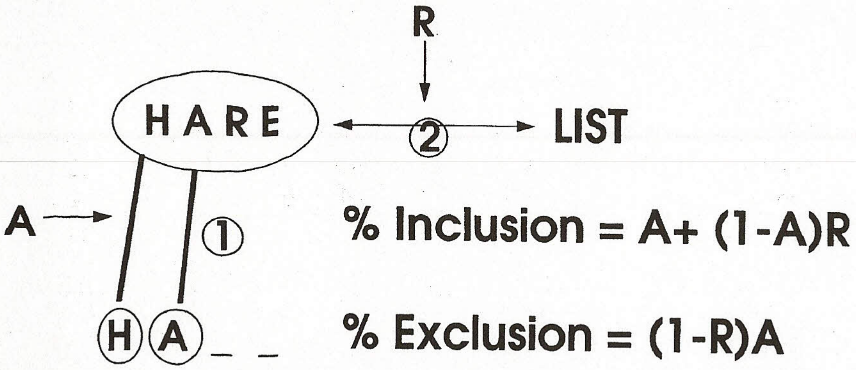


FIG. 2.8. A portion of the associative structure (from Fig. 2.7a) needed to characterise the opposition tests in fragment completion of HA__. With probability A the sensory ("automatic" Type-1) associations from the fragments retrieve the logogen, and with probability R the logogen can be retrieved ("Recollected" by Type-2 associations) from the study-list cue, and then fit onto the fragment.

Turning to the Exclusion task, subjects will give the primed item as a completion only if its logogen is triggered by its strengthened sensory associations but no contextual association is retrieved and used to exclude this completion. The joint likelihood of these events is $E = (1–R) A$. From these two equations, one can estimate $R = I–E$ and $A = E/1–R$.

These two equations are those of Jacoby (1991) who has shown their applicability over a range of tasks. Of special importance is his finding that experimental variables that should influence the formation or use of Type-2 associations (such as semantic elaboration, divided attention, ageing) primarily influence estimates of R, the recollective component. In contrast, he finds that variables that should affect the formation or use of Type-1 sensory associations (e.g. modality shifts) are primarily reflected in estimates of the familiarity component, A, rather than the recollective part. Thus, in certain cases the present theory maps neatly onto Jacoby's equations for the opposition procedure. For other cases, the analyses diverge, as we shall show shortly.

Context Associations as Modulators

Our analysis of the Exclusion task shows how retrieval of contextual associates can be used by the subject to suppress or exclude another association. However, such suppression will succeed only if sufficient time is allowed during the test for the subject to bring the contextual associate to mind before the to-be-suppressed associate intrudes and is expressed. Let us consider two cases from the literature, one in which subjects are pressured to respond quickly, the other without time pressure.

Experiments by Reingold and Goshen-Gottstein (1996) may be used to illustrate the situation without time pressure to respond. They examined episodic associative priming using stem completion of the response word in the presence (vs. absence) of the stimulus word following paired associate learning, rather like the DRYER–BLO(CK) materials illustrated earlier in Fig. 2.3. They found that when subjects were instructed to exclude any response word from the studied list as a completion, associative priming was greatly reduced. The present theory explains such findings by assuming that an association to the study context was set up for each pair (say, linked to the "paired with" top node in Fig. 2.3). Under slow, self-paced testing conditions, retrieval of this context tag from either the cue-word or the stem will suffice to enable the learner to exclude the studied completion.

The findings in this case (for the slow, stem-completion task) may be contrasted to those in tasks that emphasise processing speed such as reading speed and lexical decisions for paired words. In these cases, subjects show consistent pair-specific facilitation (compared to scrambled pairs) for both reading speed (Poldrack & Cohen, in press) and for lexical decision (Goshen-Gottstein & Moscovitch, 1995). Theoretically, these performances require no references to past contexts to modulate performance; rather, the subjects' explicit goal is speeded processing. Therefore, the small boost in activation of the response word created by the presented stimulus term (of the prior episodic association) helps to achieve that speed goal.

Experiments by Hay and Jacoby (1996) that were reported at the conference by Jacoby (this volume) illustrate results due to speeded time pressure. In the "incongruent" condition of their experiment, a weakly established associate from a desired list context was pitted against a strongly established associate from a to-be-excluded list context. For example, the association KNEE–BONE might receive three times as many study trials as the association KNEE–BEND in an initial list, making the former much stronger. In their incongruent condition, the weaker pair would then be presented briefly in a second list context, followed by a speeded test with the common cue term (KNEE–B_N_) and instructions to produce only the to-be-remembered response from the second list and exclude that from the first list. Subjects were tested with a "response deadline" procedure, requiring them to respond immediately to the stimulus word on hearing a tone, which arrived either one or three seconds after the visual stimulus was presented. Hay and Jacoby found that subjects intruded the strong associate more often the shorter the deadline and the greater was its initially established strength relative to that of the weaker associate.

This outcome is consistent with the present theory which supposes that subjects need time to retrieve the weak second-list context tag that is required to suppress the stronger response to the stimulus KNEE-B_N_. Thus, when a fast response is demanded, the strong associate that fits the situation may be "blurted out" before the weak associate (attached to the second study context) can be retrieved to inhibit the strong associate. In this manner, the theory may explain cases of strong habits overriding more considered, "socially acceptable" responses.

The Diagnostic Context Model

Although the present theory implies Jacoby's equations for the stem completion task, it diverges from his analysis of "recognition" in two-list tasks. Let us consider the difference in more detail. In the typical experiment, subjects study two distinguishable lists of items, say, one presented visually and the other auditorily; the items may be temporally blocked by their two types or may be mixed together during presentation. Subjects then have a "recognition" test with Old and New items. That test occurs under either Inclusion instructions, to say "Yes" to items from either list, or Exclusion instructions, to say "Yes" only to items from one of the lists, and "No" otherwise. Jacoby suggests that false acceptance of the to-be-excluded old items indexes the automatic or familiarity component of recognition.

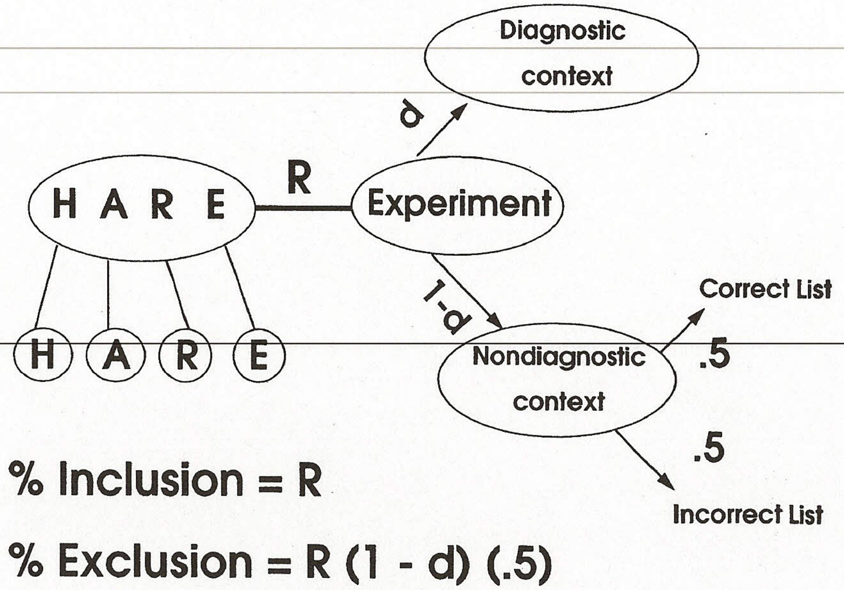


FIG. 2.9. The model elaborated for learning of diagnostic contexts. With probability R the presented item becomes associated to the general experimental context, and with further probability d that context proves to be diagnostic of the item's specific list-membership. (Adapted by permission from "Measuring the bases of recognition memory: An investigation of the process dissociation framework" by N.W. Mulligan & E. Hirshman, 1997, *Journal of Experimental Psychology Learning, Memory, and Cognition*, *23*, 280–304. Copyright by the American Psychological Association.)

I believe that this task is better viewed as involving source discrimination (see Fig. 2.9). As an item is studied, subjects form an association to the experimental context, let us say with probability R. Moreover, for given list conditions, that contextual information may be diagnostic of the item's exact list, let us say with probability d. Whether a given contextual association is diagnostic depends on the list conditions. For example, associating a word with the female voice of its speaker would be diagnostic if that speaker were unique to a given list, but would not be diagnostic if she presented both lists. As a second example, thinking of a semantic associate to a presented word could be diagnostic if the two list contexts differed in type of orienting task, but not if both asked for semantic processing.

When asked to judge whether items had been presented in the target list, Inclusion subjects will do so if the item has an association to any aspect of the general experimental context, which happens with probability R. On the other hand, Exclusion subjects will make an error of commission if the item is associated to the general context but not to a diagnostic feature of it, so they guess the wrong list. The probability of these joint events (shown in the lower branch of Fig. 2.9) is R (1–d) (.5). These are the equations of the "Diagnostic Context" model for such two-list discrimination tasks as proposed by Mulligan and Hirshman (1997). An important implication of the model is that Exclusion subjects will make more errors of commission the greater is R, their nondiagnostic memory for items in the to-be-excluded list, and more errors the more similar are the two sources to be discriminated. R can be increased by requiring semantic rather than phonetic processing of the individual words in the to-be-excluded list. Also, 1–d can be increased by making the two sources (lists) more similar or the two orienting tasks more similar, which should cause more errors of commission by Exclusion subjects. On the other hand, this increased interlist similarity should not affect R, which controls the Old/New recognition rate of Inclusion subjects.

Mulligan and Hirshman (1997) found both these effects. The problems these commission errors create for Jacoby's analysis of the two-list task are clear. His "process dissociation" equation for Exclusion errors is (1–R)A. Yet, Mulligan and Hirshman found that semantic encoding, which Jacoby usually conceives as a factor increasing recollection (R), increased rather than decreased Exclusion errors. They also found that interlist similarity (reflected in 1–d) increased Exclusion errors, although one is hard-pressed to see how that variable would increase an item's perceptual fluency (Jacoby's A factor). Even if we were to grant that interlist similarity somehow increased perceptual fluency (A), we could not explain why it did not elevate the Old recognition rate for Inclusion subjects, as that is supposed to reflect perceptual fluency.

The Diagnostic Context model can also be used to explain some results that Jacoby presented at the conference (Jacoby & Hay, this volume). In that experiment, subjects studied a given word one, two, or three times throughout a first list, then were presented with a second study list. Subjects were then instructed to recognise (say "Yes") only to items from the second list (and exclude those from the first list). Half the subjects were tested with a very short deadline interval (750 milliseconds) and half with an appreciably longer interval (to respond between 1250 and 2000 milliseconds). The results showed that with the fast deadline, subjects were more likely to make an error of commission (say "Yes" to a list-1 item) the more often it had been studied in list 1. In theory this arises because the deadline provided insufficient time to retrieve the distinctive ("list 1 or 2") context tag required to exclude the increasingly stronger, faster first-list response. In contrast, with the slower deadline, subjects showed the reverse trend, being better able to exclude the first-list response the more often they had studied it. This could arise in theory because more study trials provide more opportunities for subjects to associate a distinctive list-1 context tag to those response terms, and the longer deadline provides subjects sufficient time to retrieve this distinctive context, enabling them to exclude the first-list response to the test pattern. Thus, depending on the time pressure to respond to the test stimulus, the theory expects multiple study trials of a to-be-excluded item to either increase or decrease its intrusion in the exclusion procedure.

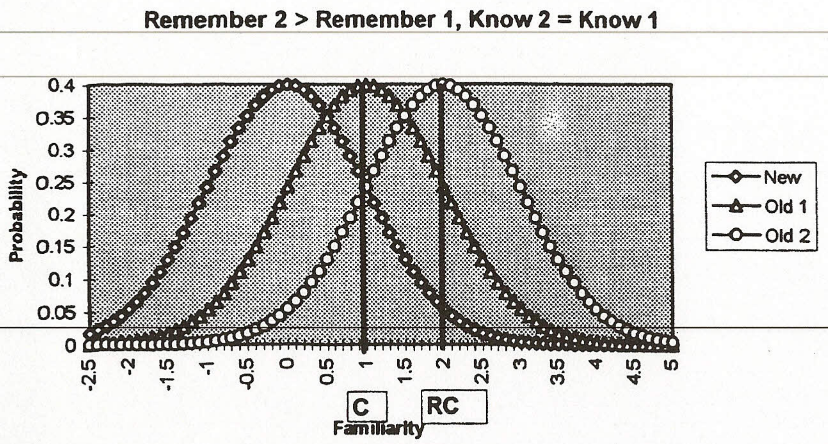
I conclude along with Mulligan and Hirshman (1997) that their Diagnostic Context model is more appropriate than Jacoby's "process dissociation" analysis of this two-list task. The diagnostic-context formulation is also consistent with other data that question the familiarity view of recognition memory, such as the way multiple tests of the same distractor slow down later recognition that it is not an Old target item (see e.g. Atkinson & Juola, 1974).

Remember and Know Judgements in Recognition

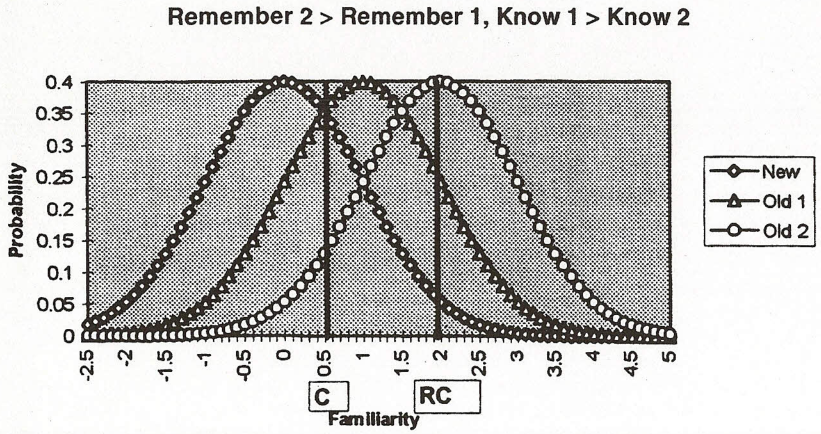
The theory in Figs. 2.8 and 2.9 asserts that recognition memory judgements arise from association between the concept corresponding to the test item and aspects of the context. The associated context may be sufficiently discriminating to enable the subject to remember when and where the item was presented, by what means, and how he or she reacted to it. In other cases, the context retrieved by the test stimulus may be far more diffuse and vague, simply suggesting that the item seems "familiar" in the experiment. We may think of this process in terms of the test item retrieving from memory more or less evidence for the hypothesis that the item had been presented in the experiment. Anderson and Bower (1972) showed how to effect this translation from an item's number of contextual associations to a more or less continuous variation in amount of evidence for its recognition. This continuous output from memory provides the basis for applying statistical decision theory to recognition memory. Test items that retrieve appreciable evidence of having been presented on the target list will be classified as Old, whereas other test items that retrieve less than a criterion amount of evidence for list membership will be classified as New.

Tulving (1985a) and Gardiner and Java (1993) have proposed a qualitative distinction between two kinds of recognition judgements: "Remember" judgements, which are accompanied by recollection of some specific details of the context, and "Know" judgements, which correspond to subjects' vaguer feelings of familiarity about a test stimulus without retrieval of more specific information about the encoding episode. Gardiner and Java have argued that these two types of recognition judgements exhibit different functional relationships to experimental variables. For example, intentional learning and various kinds of elaborative encoding increase "Remember" judgements but not "Know" judgements (Gardiner & Parkin, 1990).

By adopting a proposal from Hirshman and Masters (1997) and Donaldson (1996), the present approach can perhaps accommodate the findings of Gardiner and his associates. Let us begin by supposing that when the contextual evidence retrieved is clear and specific—that is, when the amount of evidence exceeds a high criterion—the subjects will have the subjective experience that leads to a



Remember 2 > Remember 1, Know 2 = Know 1



Remember 2 > Remember 1, Know 1 > Know 2

FIG. 2.10. A model for the Know–Remember paradigm. The Old 2 distribution of Familiarity (amount of evidence) has a higher average strength than the Old 1 distribution, and both exceed that of the nonpresented New ("distractor") items. The lower criterion (C) is used for Old/New recognition judgements, and the upper criterion (RC) for Recollection judgements. Items with strengths between the lower and upper criteria are judged as "Know" items. Top panel: Remember 2 exceed Remember 1 judgements, whereas Know 2 equal Know 1 judgements. Bottom panel: Remember 2 exceed Remember 1 judgements, whereas Know 1 exceed Know 2 judgements. (From "Modeling the conscious correlates of recognition memory: Reflections on the Remember–Know paradigm" by E. Hirshman & S. Master, 1997, *Memory and Cognition*, *25*, 345–351. Copyright by the Psychonomic Society.)

"Remember" judgement. When the evidence is less, is vague and diffuse, the subjective experience will be more like a feeling of familiarity, leading subjects to render a "Know" judgement. We may think of such cases as exceeding a lower criterion for saying "Old," but not exceeding an upper criterion sufficient for making a "Remember" judgement (see Fig. 2.10).

One implication of this analysis is that estimates of Old–New memory discrimination (such as d') based on the upper ("Remember") criterion should be the same as those based on the lower ("Know" plus "Remember") criterion. This prediction, first noted by Donaldson (1996), was tested by his reviewing reported results from 80 conditions of 28 different experiments in the literature which permitted these estimates. Donaldson found that the Old–New discriminability estimates (d's) were approximately the same whether based on the Remember judgements alone or the sum of the Remember and Know judgements. That outcome provides strong support for the criterion-based interpretation of Remember versus Know recognition judgements.

The theory expects that increases in degree of learning will lead to higher levels of evidence ("familiarity" in Fig. 2.10) for an item's list membership. Example distributions of familiarity for New ("distractor") items and for weak ("Old1") and strong ("Old2") learning conditions are shown in Fig. 2.10, from a paper by Hirshman and Masters (1997). The strong versus weak memory distributions might correspond to semantic-versus-phonetic processing during encoding, generate-versus-read study conditions, intentional-versus-incidental learning, divided-versus-undivided attention during encoding, more-versus-less rehearsals, and more-versus-less retention (for a review, see Gardiner & Java, 1991).

Curiously, in each of these conditions, the proportion of Know judgements remained approximately constant. Such an outcome is consistent with the distributions shown in the top half of Fig. 2.10: Old2 items exceed the upper criterion (RC) more often than Old1 items, but the proportion of the two Old distributions falling within the Know region (between the upper and lower criteria) remains approximately constant. Clearly, the theory does not require unusual criteria in order to accommodate such results.

This theory can accommodate a number of other findings. The lower panel of Fig. 2.10 illustrates the case where better learning leads to more Remember but fewer Know judgements than does a poorer learning condition. Results of this kind have been frequently reported. For example, Rajaram (1993, Experiment 1) found that study items processed semantically by subjects later yielded more Remember recognition judgements but fewer Know judgements than were given to items processed phonetically. A similar pattern of more Remember but fewer Know recognition judgements was found in a second experiment by Rajaram (1993) when comparing recognition by subjects who studied pictures versus those who studied words at encoding. A third example (reported by Gardiner & Java, 1990) is that study of words produced more Remember than Know judgements, whereas study of nonwords produced more Know than Remember judgements. Such results are consonant with the distributions in the lower panel of Fig. 2.10 in which semantic compared to phonetic processing (or picture vs. word encoding, or words vs. nonwords) produces stronger contextual associations (such as Old2 compared to Old1 distributions in Fig. 2.10), and the criterion for Old recognition is lowered slightly.

An advantage of the criterion-based theory is that by altering the setting of the criteria, the model has a way to explain the influence of nonmemory or decision factors on recognition memory judgements. For example, Strack and Förster (1995) showed that informing subjects in advance that a higher percentage of the test items were Old caused them to lower their criterion for Old recognition, increasing both their false alarm rate and the proportion of Know judgements without affecting the proportion of Remember judgements. There was also a decrease in the average confidence (of being Old) assigned to the Know judgements. Such results would be expected by setting the lower criterion (C in Fig. 2.10) at a lower level the higher the proportion of Old to New items in the test series. This is also a more optimal decision criterion given knowledge of the composition of the test list. Presumably, similar criterion shifts could be induced by differential monetary pay-offs and penalties for Remember, Know, and New judgements given to Old versus New test items.

The serious disadvantage of the two-threshold model is its flexibility; it often has as many parameters as there are degrees of freedom in the scant data to be fit, so it is difficult to reject the model. I realise too that Gardiner (1988) and his colleagues have mounted a spirited defence of the utility of the Remember–Know distinction, arguing that it captures more than just high versus low confidence in memory judgements. Nonetheless, the ease with which Donaldson (1996) and Hirshman and Masters (1997) have explained a range of results with the two-threshold model suggests that more discriminating tests of the alternative hypotheses may be needed in investigations of Remember–Know judgements.

AN HYPOTHESIS REGARDING GLOBAL AMNESIA

Much of the interest in indirect versus direct memory tests arises from the fact that brain-injured patients with global amnesia are greatly impaired on direct memory tests but not much impaired on indirect tests. Global amnesia patients suffer from damage to several different areas of the brain, either diencephalic mid-brain structures or bilateral medial-temporal (hippocampal) structures. Global amnesia is typically diagnosed from the person's impairment on explicit memory tasks—a lowered ability to recall or recognise recently presented events and information. Yet patients may be only moderately impaired, if at all, on indirect memory tasks, in semantic-memory judgements, and in retrieving long-term memories of autobiographic events from before their brain injury. A controversy in this literature concerns the extent of amnesics' impairment in recognition-memory tests (e.g. Hirst et al., 1986), but the consensus view is that it is significant.

The hypothesis suggested by this reactivation theory is a very old one, proposed earlier by Rozin (1976) and Graf, Squire, and Mandler (1984), among others. It proposes that global amnesia results from a reduction in the person's ability to establish and consolidate into long-term memory novel, new associations of Type-2. These include associations between perceptually distinct items (e.g. word–word paired associates) and between an item and the context of its presentation. Although the brain injury of amnesics has weakened their ability to consolidate Type-2 associations, it has left intact the amnesics' ability to reactivate, retrieve, and momentarily strengthen old Type-1 associations. That is the basis in this theory for amnesics being able to show relatively intact semantic memory, perceptual priming, stem-completion priming, and conceptual priming (e.g. category exemplar generation). Although amnesics will show good priming in these cases, their lesser ability to form novel contextual associations means that they will often be unable consciously to remember having witnessed the priming episode itself. The hypothesis also explains the fact that amnesics are relatively unimpaired in retrieval of autobiographic episodes stored in long-term memory from before their brain injury.

One consequence of amnesics' deficit in contextual learning is their inability to utilise updating information from memory in order to control current responding. Such updating and editing problems arise whenever subjects must learn to replace an old learned response with a second, new response demanded by the same situation. The classic illustration of such problems is the A–B, A–C interference paradigm of paired-associate learning in which subjects must learn to give a new response, C, to an old stimulus, A. Indeed, one of the earlier observations of the amnesic syndrome was that patients were unusually susceptible to response competition (causing negative transfer and interference) in the A–B, A–C paradigm. In classic experiments by Warrington and Weiskrantz (1974, 1978), amnesics studied two related lists of words, where recall of each word was cued by its first three letters, as in STA(MP) and TAB(LE). Once a given stem-to-word association had been primed, however, amnesics then suffered inordinate interference in trying to learn to give a different response to those same stem cues, as in completing STA_ as STA(ND) and TAB_ as TAB(BY). The first-learned, A–B association continued to be intruded to compete with the new, to-be-remembered, A–C association. Rather similar results for amnesics were reported for priming of related word–word associations, such as STAMP–MAIL, then STAMP–LETTER (Mayes, Pickering, & Fairbairn, 1987; Winocur & Weiskrantz, 1976).

Exactly such results are expected by the hypothesis that amnesics can prime old associations but have difficulty consolidating new contextual associations. So, although they can prime and express pre-existing stem-to-word associations STA(MP) and word-word associations (STAMP–MAIL), they are unable to utilise contextual information (e.g. earlier versus later list) to modulate, control, and suppress the expression of the different primed associations.

The theory predicts that amnesics will be impaired in learning novel pairings of distinct materials such as word–word paired associates; consequently, amnesics will show impaired associative priming. Thus, having studied word pairs such as BELL-CRADLE, amnesics should show lesser pair-specific facilitation in completing the stem when given the intact test compound BELL–CRA_ _ _ than when given a test with a different left-hand word (e.g. CALL–CRA_). Shimamura and Squire (1989) found this result, as have others.

Some Limitations on the Amnesia Hypothesis

In contrast to the theory's expectations, however, the outcome in such associative priming experiments appears to depend on the exact manner in which the configuration of sensory elements is presented and the degree to which the test for priming reinstates that sensory configuration. Apparently, if the words are presented as a unified perceptual gestalt and the test involves either perceptual identification (Gabrieli, Keane, Zarella, & Poldrack, 1997), reading speed, or lexical decision (Goshen-Gottstein & Moscovitch, 1995) for the pair of words presented in the same configuration as before, then almost normal pair-specific facilitation is observed in amnesic patients. In his review of this literature, Squire (1992) reported that amnesics learn a strong binding of a word to the colour in which it is printed; after practice reading a word printed in a given colour, amnesics were significantly slowed in reading that word when its colour was changed. Similarly, Squire (1992) reported that anmesics show a nearly normal "false fame" effect, judging that a novel name (such as Simon Wiesenthal) they had studied earlier applied to a famous person. But in order to show such effects, amnesics must have stored and accessed the novel bindings of word-to-colour in the former case, or first-to-last name in the latter case; and that successful binding violates the hypothesis that novel pairings cannot be learned by amnesics. The false fame effect suggests, nonetheless, that amnesics cannot establish and use contextual associations to control whatever novel pairings they do learn. Consistent with this result, amnesics cannot inhibit heavily primed words from intruding into their performance in recognition Exclusion tests (Verfaellie & Treadwell, 1993).

Similarly, amnesics can learn and show repetition priming in perceptual identification for, novel geometric objects (Schacter, Cooper, Theran, & Rubens, 1991) and for strings of three to five consonants (Keane, Gabrieli, Noland, & McNealy, 1995). The dependence of such priming on the specificity of reinstating the exact configural pattern during testing as during encoding suggests that normals and amnesics are storing unitary but novel perceptual gestalts in memory. The result suggests that the primary sensory areas involved in such learning (e.g. occipital lobe, striate and prestriate cortex) may store unitary sensory patterns independent of facilitatory input from those brain areas (e.g. medial temporal area) that are usually damaged in global amnesia patients.

Relation to Memory Systems Theories

It is tempting to relate aspects of this reactivation theory to the various brain systems of memory suggested by others (e.g. Schacter & Tulving, 1994; Squire, 1992; Tulving & Schacter, 1990). There are some disagreements among memory-systems theorists regarding what constitutes a memory system, the number of different systems, their locations in the brain, how to characterise their relevant features, and how much the different memory systems contribute to performance on various memory tasks. The formulations also diverge between theorists who primarily focus on memory disorders in human patients versus those who focus on behavioural deficits caused by brain lesions in lower animals (for a survey of the differences, see the compilation edited by Schacter & Tulving, 1994). For illustrative purposes, I will relate the reactivation theory to the memory systems proposed by Tulving (1983, 1985b) and Tulving and Schacter (1990).

First, Tulving's (1985b) proposed "semantic memory" system comprises what in my theory are collections of nodes and Type-1 associations in long-term memory—old concepts, words (logogens), imagens, conceptual associations, and sensory-to-logogen (or imagen) associations that existed before the experiment.

Second, Tulving's (1985b) episodic memory system contains what in my system are those event memories that have retained a strong association to the temporal-spatial context of their encoding. Of course, these memories begin as a set of novel Type-2 associations, but with rehearsal and repetition, the contextual association becomes old (of Type-1) and can thus be primed.

Third, in Tulving's approach, amnesics have difficulty establishing new episodic memories. In my theory these reflect amnesics' impaired ability to form new associations, most especially the contextual associations that support episodic memories.

Fourth, my theory recognises the ability of amnesics as well as normals to learn novel, integrated perceptual configurations. Postulation of this distinct ability in my theory runs parallel to the word-form and object-form representational systems proposed by Tulving and Schacter (1990).

Different areas of the brain may be implicated in mediating different storage and retrieval processes within the reactivation model. For example, long-term semantic and episodic memories may be stored in the cerebral cortex, presumably in different areas according to whether they are predominantly verbal, visual, olfactory, auditory, and so on. The frontal lobes seem intimately involved in retrieving memories from semantic and episodic memory, especially those that may require strategic search processes. The frontal lobes also seem greatly involved in storage and retrieval of source and temporal recency information. The frontal lobes also seem critical for utilising contextual information to control and inhibit the expression of other memories, e.g. to update new memories and suppress old ones in interference paradigms. The medial temporal regions have been strongly implicated as necessary for establishing new Type-2 associations; bilateral damage to these areas produces the full amnesic syndrome. The brain systems for storing and retrieving word-form and object-form representations have been identified with the primary sensory projection areas for vision, audition, and so on. Finally, completeness requires mention of the brain systems for acquiring motor skills (e.g. sensory-motor cortex, basal ganglia, cerebellum), emotions (e.g. limbic system, amygdala), and eyeblink conditioned responses (e.g. cerebellum)—about which the present theory has nothing new to offer.

These identifications of constructs from the reactivation theory with memory systems of the brain are tentative and subject to change as new evidence arises. I think it is important, however, that we try to indicate how a psychological theory based on behavioural (and subjective) evidence might coordinate its constructs to those brain structures identified within the memory-systems viewpoint, as it seems to have captivated the attention of many memory researchers in the contemporary scene.

FINAL SUMMARY AND COMMENTS

To wrap up, let me briefly review what I have presented. I first outlined the logogen framework with its assumption that perceptions both strengthen old sensory feature-to-logogen associations and leave some residual activation on the logogen. I showed how this explains many forms of repetition priming, interference effects, cross-modal, semantic, associative, and conceptual priming, and I illustrated one way to explain picture priming. I then proposed that explicit memory tasks require storage and retrieval of novel associations of the item to its context of presentation. I assumed these contextual associations were established independently of strengthening of the prior sensory associations. Such independence explains a number of dissociations between direct and indirect memory tasks. I illustrated how that theory explained several results including those from Jacoby's opposition procedure. I then subscribed to the hypothesis that global amnesia was characterised by gross impairment of the person's ability to form or consolidate novel associations, especially those to an item's context of presentation. Finally, I offered a few speculations for coordinating constructs within this theory to the brain systems underlying different forms of memory.

In closing, let me state that this simple theory will doubtless not account for all the thousands of facts known about implicit and explicit memory and the brain systems subserving them. However, I feel that it is a good enough beginning to help cognitive psychologists organise and convey to our students a large portion of the literature on the topic. After all, the goal of science is not the accumulation of thousands of disconnected facts but rather the development of a simple and coherent understanding of most of the facts. For that purpose, I believe that the theory offered may serve as a useful beginning.

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3

Encoding and Retrieval Processes: Similarities and Differences

Fergus I.M. Craik
University of Toronto and Rotman Research Institute, Canada

Moshe Naveh-Benjamin
Ben-Gurion University of the Negev, Israel

Nicole D. Anderson
University of Toronto, Canada

INTRODUCTION

In this chapter we describe some recent experiments on the effects of divided attention on encoding and retrieval processes in human memory. There were two main reasons for embarking on this series of studies. The first was that division of attention (DA) in young adults results in memory performance that is very similar quantitatively and qualitatively to that observed in elderly adults working under full attention (Craik, 1982, 1983; Rabinowitz, Craik, & Ackerman, 1982). This finding is in line with the suggestion that older adults have diminished attentional resources with which to carry out various mental activities, including memory encoding and retrieval (Craik & Byrd, 1982). In the same vein, other researchers have pointed to similarities between DA in young adults and the effects of Alzheimer's Disease on memory performance (Gabrieli et al., 1996). In this context, then, the effects of DA on encoding and retrieval processes are of interest in that they may provide clues to the impairments seen in normal and abnormal ageing, as well as in other functional impairments of memory.

The second reason for studying the effects of DA on memory was given by Craik, Govoni, Naveh-Benjamin, and Anderson (1996). In that paper we pointed out some similarities and differences between the processes of encoding and retrieval. Craik (1983) had previously suggested that encoding and retrieval processes may be similar or even identical; his idea was that memory encoding processes are essentially those carried out primarily for the purposes of