IMPLICIT MEMORY FOR NEW ASSOCIATIONS: TYPES OF CONCEPTUAL REPRESENTATIONS

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'Psychologists love to question.' This bumper-sticker claim is affirmed by the myriad of questions that have been asked about implicit and explicit memory phenomena. Nearly two decades of intense research have answered many questions, but others remain as puzzles, fuel for new investigations. In this chapter, we focus on one of these puzzles, the memory representation of newly acquired associations.

We use the phrase 'newly acquired associations' as a shorthand to refer to a specific phenomenon in implicit memory for previously unrelated perceptual wholes such as pairs of unrelated words or pictures. Early compelling demonstrations of this phenomenon were given by the work of Graf and Schacter (e.g., Graf and Schacter, 1985, 1987; Schacter and Graf, 1986a, b, 1989). They required subjects to learn pairs of unrelated words, such as WALLET–CASTLE and MOTHER–RIVER. After a retention interval, memory for the second word from each pair—commonly called the target—was assessed. On the test, targets were presented either paired with the same context word as in the study phase (e.g., WALLET–CASTLE) or paired with a different context word (e.g., MOTHER–CASTLE). The results revealed higher memory for targets that were paired in the same way as at study (i.e., in the same context condition) than for targets paired with different context words (i.e., in the different context condition). The performance advantage in the same versus different context condition provides evidence of memory for the specific pairing of words in the study list. This advantage is assumed to reflect the study phase acquisition of associative information between previously unrelated words.

How is new associative information represented in memory? We do not yet have a clear, compelling answer to this question, despite a substantial number of previous investigations. Previous investigations were designed to document the basic phenomenon (i.e., memory for new associations), and to show various kinds of performance dissociations (e.g., functional, developmental, neuropsychological) between implicit and explicit memory for new associations. The results have inspired a number of theoretical accounts, and they in turn highlight more questions about memory for newly acquired associative information. One of these questions is whether all types of associative information are represented in memory in the same manner. A plausible alternative is that there are distinguishable subtypes of associative representations, for example, for linking concepts represented by words versus for linking concepts with contexts (e.g., spatial, temporal, or emotional contexts). The main goal of the research we report in this chapter was to explore these alternatives.

We begin this chapter with a brief review of previous investigations on implicit memory for new associations and of theoretical accounts that have been offered for their findings. We use the theoretical accounts for making specific predictions about memory for newly acquired associations for two types of materials: word–word pairs and picture–word pairs. The final section of the chapter reports two experiments that tested the predictions.

Core findings

A number of facts are well established about implicit memory for new associations. One of them is that this phenomenon occurs on a variety of different tests. Moscovitch *et al.* (1986) used a test that required reading words shown in degraded displays. In the study phase, subjects had to learn word pairs, and after a retention interval, the same words were re-presented in a visually degraded display, arranged either in the same pairs as in the study list or in different pairs. The task was to read the words aloud. The results showed that subjects were faster at reading words in the same pairs than in different pairs. Paller and Mayes (1994) used a word identification task to explore implicit memory for new associations. At study, their subjects saw unrelated noun pairs each of which was embedded in a meaningful sentence. At test, the nouns were re-presented either in the same pairs as in the study sentences or in different pairs and the task was to identify the second word from each pair. The results showed higher identification of words that were paired as in the study sentences. Graf and Schacter (1985) showed implicit memory for new associations on word-stem completion tests. As described earlier in this chapter, they presented subjects with unrelated words for study, and after a retention interval, implicit memory was assessed with a test that required completing three-letter word stems (e.g., STI___). The stems appeared paired either with the same words as in the study list or with a different word, and the results showed higher completion rates for targets in the same versus different pair condition.

A second core finding about implicit memory for new associations is that at least under some conditions of testing, this phenomenon occurs only following study phase semantic processing of a new connection/association between unrelated words (but see Marsolek *et al.*, 1996). In their seminal work, Graf and Schacter (1985) presented unrelated words either in a condition that required using each word pair in a meaningful sentence or in a condition that required deciding for each pair whether or not the two words had the same number of vowels. Completion test performance showed priming for new associations following semantic study phase processing, but not after the vowel comparison task. Additional investigations clarified this finding. Schacter and Graf (1986a) found implicit memory for new associations only for unrelated noun pairs that were embedded in meaningful sentences, but not for pairs embedded in anomalous sentences (e.g., the new ROCK was returned to the CANDLE). They also showed that semantic processing of the individual words from each pair was not sufficient, that some type of relational processing is necessary for the occurrence of implicit memory for new associations.

Implicit memory for new associations is dissociable from explicit memory for new associations. This claim is supported by experiments that manipulated the degree of semantic elaborative processing at the time of study. For example, Schacter and Graf (1986a) had subjects generate either a meaningful sentence for each to-be-remembered pair or a single word for connecting the two words in each pair. In another experiment, the study task was either to generate a sentence for each pair or to read and rate for meaningfulness a sentence that contained each pair. The results showed the same level of implicit memory for new associations across these study phase activities. By contrast, explicit memory for new associations varied, depending on the degree of semantic elaborative processing required by each study task (see also Graf and Schacter, 1989).

Additional investigations of implicit memory for new associations with young and older adults, and with various patient groups have yielded relevant but inconsistent findings. For example, a handful of studies have focused on age-related changes. Monti *et al.* (1997) used a re-reading task for assessing implicit memory and found similar levels of implicit memory for new associations in young and older adults. Howard *et al.* (1991) also found comparable levels of implicit memory for new associations in young and older adults, but only when study phase learning was self-paced. They assessed implicit memory by means of a word-stem completion test and obtained age-related performance reductions 'under less-than-optimal study conditions'. Yet other studies (see Ergis *et al.*, 1998; Van der Linden *et al.*, 1992) found clear age-effects in implicit memory for new associations. Investigations with amnesic patients have produced similarly conflicting outcomes (Gabrieli *et al.*, 1997; Graf and Schacter, 1985; Musen and Squire, 1993; Schacter and Graf, 1986a; Shimamura and Squire, 1989; for reviews see Bower, 1996; Schacter, 1990, 1994).

Theoretical *accounts*

Several explanations have been proposed for these findings, notably for the fact that the basic phenomenon—implicit memory for new associations—occurs on a variety of different tests, that it is dissociable from explicit memory for new associations, that it occurs (under some methods of testing) only following semantic elaborative study phase processing, that it may or may not vary across the adult life span, and that it may or may not be present in amnesic patients. In this chapter, we focus on two explanations, the structural description view of Schacter and his colleagues (Schacter, 1990; Schacter *et al.*, 1990, 1993; Tulving and Schacter, 1990) and the reactivation view of Bower, Mandler, and their colleagues (Bower, 1996; Johnson, 1994; Graf and Ryan, 1990; Mandler, 1981, 1991, 1994). Despite obvious differences between these two views (for example, their emphasis on systems versus processes respectively), they give closely similar explanations for implicit memory for newly acquired associations. They also offer similar explanations for word priming effects.

By Schacter's view, word 'priming effects on a variety of implicit memory tests rely heavily on a class of modular processors or subsystems that … I will refer to as a perceptual representation system, or PRS for short' (Schacter, 1990, p. 544). The study phase processing of a word is assumed to create a representation of its particular visual-perceptual features. In the test phase, this representation facilitates the re-processing of words and produces a priming effect. Schacter maintains that the representations that mediate priming capture the form and structure of words, but do not include information about context, thereby explaining why study phase processing manipulations (e.g., semantic versus perceptual) tend not to influence the magnitude of priming effects on such tests as word identification and stem completion (Graf and Mandler, 1984; Graf *et al.*, 1982; for a review see Challis and Roediger, 1993; Challis *et al.*, 1996). Additional assumptions about the PRS and the nature of structural representations account for modality specific priming effects, as well as for priming effects that are specific to physical features of words under some but not other study/test conditions (e.g., Graf and Ryan, 1991).

The activation view by Bower, Mandler, and their colleagues gives a similar explanation for word priming effects. The core assumption, as indicated by Figure 14.1, is that words are represented by a continuum of processes—shown as network nodes—and by interconnections among them. At one end of the continuum are processes recruited for analyzing the physical features of words, and at the other end are the processes engaged for semantic analysis. The figure over-simplifies; it does not show either the many levels of nodes that may sit between visual features and logogens or lexical units (e.g., letter representations, orthographic representations, phonemic representations), nor the rich associative connections among all nodes (see Anderson and Bower, 1973; Bower, 1996). The presentation or study phase encoding of a word is assumed to engage sensory feature processes, and the co-processing of the features that constitute a letter is thought to activate the node for that letter. In turn, activated letter nodes spread activation to orthographic nodes, and from here to word and concept nodes. The subject is thought to perceive that lexical unit whose current level of activation is higher than that of all competing units and is above the awareness threshold level.

The model explains word priming by assuming that whenever a pre-existing node-network is successfully activated, that network is strengthened (i.e., connection weights are

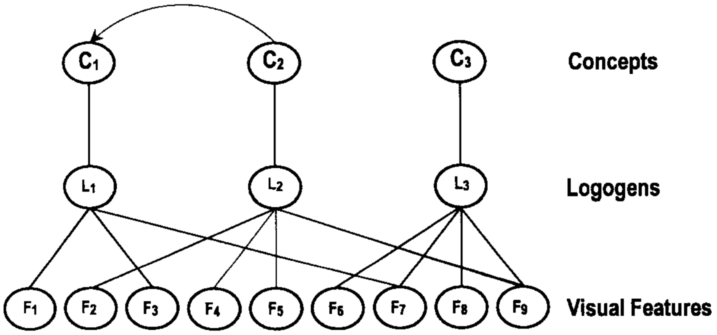

Figure 14.1 Representation of words as a network of nodes and interconnections among them. Physical features (F) of words have associative links to nodes representing their structural configuration called logogens (L). Logogens in turn have associative links to nodes representing concepts (C).

changed), and this elevated strength is maintained for a significant duration. Mandler and his colleagues have used the term integration or intra-unit organization to refer to the strength of connections among the constituents of items. When a studied item is re-presented in the test phase, activation produced by processing its features will spread through the network and will preferentially—because of elevated connection strength or higher integration—reactivate a previously activated representation. By this route, the elevated strengthening of items' representations functions analogously to the structural representations postulated by Schacter.

The structural representation and activation view give equally compatible accounts for priming effects for newly acquired associations. Schacter and his colleagues (Schacter, 1990; Tulving and Schacter, 1990) postulate that acquiring new associations involves semantic learning, more specifically, a modification to or addition of information in semantic or episodic memory. PRS representations are assumed not to contain semantic/associative information. This type of information is part of other representations (i.e., representations in episodic or semantic memory), with PRS representations facilitating access to them.

The network view depicted in Figure 14.1 postulates that priming effects for newly acquired associations are mediated by newly formed connections between concept nodes. It is assumed that prior to being paired in the experiment, there is no connection between the concepts corresponding to two unrelated words (e.g., C_2 and C_1), but such connections are established by semantic-elaborative study phase processing of paired words (e.g., by using paired words in a meaningful sentence). At the time of testing, when a target word is re-presented with the same context word as at study, processing the context word is assumed to activate its concept representation and activation spreads via the newly acquired association to the target's representations. By this route, the target's representations will be pre-activated, and consequently, less data driven processing of the target is required for its successful identification (i.e., for the current level of activation of the target representation to reach the awareness threshold). When a target is presented for testing together with a different context (i.e., not the same as at study), there is no link between the corresponding concept nodes (e.g., from C_3 to C_1) and thus no opportunity for the spreading of activation from the context to the target representations.

More detailed descriptions of the structural representation and activation views are available elsewhere (e.g., Bower, 1996; Schacter and Tulving, 1994). Our purpose here is to give only just enough information in order to highlight similarities between the views, specifically, the fact that both explain priming for newly acquired associations by invoking higher-order—beyond the word level—representations and newly formed connections between them. More critical in the context of this chapter is that both views postulate only one type of representation/associative connection in order to account for priming of newly acquired associations (note: they postulate a variety of representations at or below the word level, such as visual and phonemic feature representations, geon representations, letter representations, letter-pattern representations). By this postulate, this one type of higher-order representation would have to be harnessed for all types of associative learning and remembering, for example, for mediating implicit and explicit memory for newly acquired associations, for associating two paired words and for linking events with contexts. It seems more plausible to us that different types of representations are recruited for different kinds of associative learning and remembering.

The latter possibility seems consistent with previous findings of performance dissociations between implicit and explicit memory for newly acquired associations (e.g., Graf and Schacter, 1985, 1987; Schacter and Graf, 1986a, b, 1989). These types of dissociations might occur, for example, because different types of higher-order representations are recruited for implicit and explicit memory tests. However, performance dissociations may also be explained by postulating only one type of representation that is harnessed to different degrees for different memory tests. Evidence from investigations with young and older adults and with amnesic patients is also inconclusive. If implicit and explicit memory for newly acquired associations were mediated by different types of higher-order representations, we might expect the former—implicit memory for new associations—to be spared in older adults and in amnesic patients, consistent with what is known about spared word priming effects, even in the face of significant declines or impairments in explicit memory for new associations.

Previous attempts to identify performance dissociations between implicit and explicit memory for newly acquired associations are relevant to, but not focused on the central question that motivated our investigation: Whether implicit memory for newly acquired associations is mediated by one type or multiple types of higher-order representation(s)? We favor the multiple-types option, in part because of performance dissociations across different explicit memory tests. The finding that explicit episodic and source memory for items can be dissociated (Jurica and Shimamura, 1999; Schacter, 1990; Schacter *et al.*, 1994) seems to point to two kinds of associative representations. If two different kinds of associative representations are engaged for explicit memory, why not assume the same for implicit memory?

The new research we report in this chapter focused on the representation of newly acquired associations between word–word pairs and picture–word pairs. We considered two possible higher-order representations, as shown in Figure 14.2. The *top* panel reflects the assumption that the representation of a word (i.e., the logogen L_1) and the representation of a depicted object (i.e., the imagen I_1) may connect with the same concept representation (C_1) (see Bower, 1996). The *bottom* panel shows a different higher-order representation for each logogen and imagen. Consistent with the *top* panel, the word-name of an object and a picture of the same object have the same concept representation, and this representation can be activated either via an underlying logogen (L_1) or imagen (I_1) representation. We might expect, therefore, that in an experiment that employs both words and pictures as contexts (with words as targets), we would find the same amount of priming for newly acquired associations.

The *top* panel of Figure 14.2 shows an associative link between I- and L-representations. Consistent with Paivio's (1991) dual code view of picture encoding, this link represents the possibility that a picture of a common object will activate both its imagen and logogen representations. If so, when a picture is used as the context, it might activate two representations (e.g., L_2 and I_2), and in turn, this may cause a greater or faster activation of a target's concept node and thereby yield a larger associative priming effect.

The representation depicted on the *bottom* panel of Figure 14.2 makes the same prediction, albeit by implicating different higher-order representations for words and pictures. However, the *bottom* panel of Figure 14.2 permits a more interesting prediction. It seems plausible that associative links between word concepts (e.g., from ${}_wC_2$ to ${}_wC_1$) are

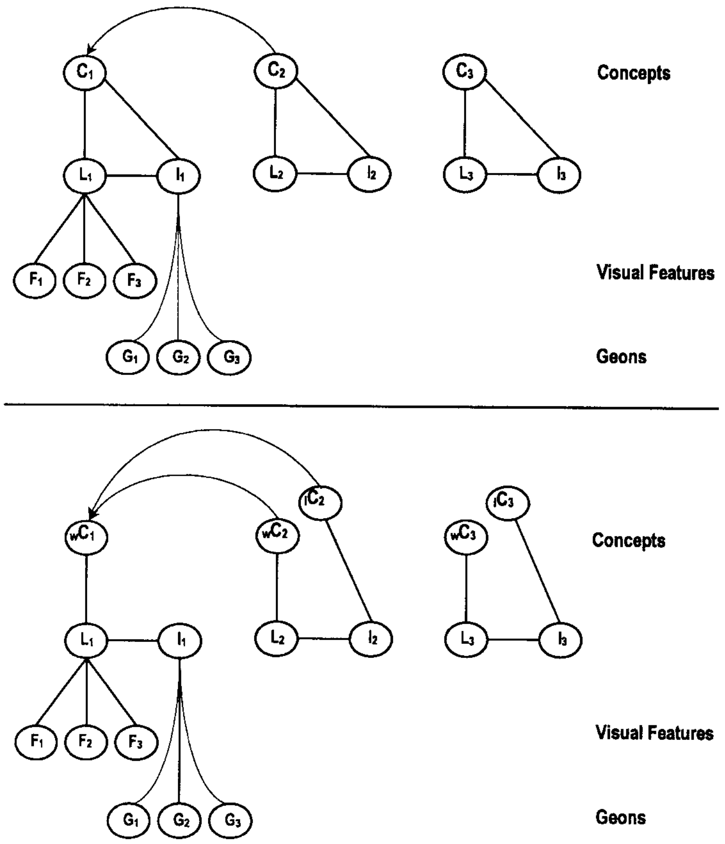

Figure 14.2 Representation of newly acquired associations between word–word pairs and picture–word pairs. The *top* panel reflects the assumption that the representation of a word (i.e., logogen L_1) and the representation of a depicted object (i.e., imagen I_1) may be linked to the same concept representation (C_1). Associative links between imagens and logogens reflect a possibility that a picture of a common object activates both its imagen and logogen representation (Pavio, 1991). Note that geons (G) are parts of objects (Biederman, 1986) analogous to features of words. The *bottom* panel reflects the possibility that higher level concept representations for words and pictures are different (i.e., $_{w}C$ and $_{i}C$), with logogens and imagens linked to their corresponding concept representations. Consequently, associative links between target word concepts and context word concepts (i.e., $_{w}C_2$ to $_{w}C_1$) are different from associative links between target word concepts and context picture concepts (i.e., $_{i}C_2$ to $_{w}C_1$).

different—perhaps stronger or more easily formed—from associative links between picture and word concepts (e.g., from $_{i}C_2$ to $_{w}C_1$). It may be that forging a link between two items in the same subsystem is easier than forging a link between two items represented in different subsystems (see Schacter, 1994). By this possibility, we would expect that some experimental manipulations would reveal differences in associative memory for word–word pairs versus picture–word pairs.

Overview of new empirical work

In order to investigate these possibilities, we conducted two experiments that used a method similar to Graf and Schacter (1985). The general strategy was to examine memory across variables that are known to affect explicit test performance, and to track the influence of these variables on implicit memory for both item and associative information. For each experiment, participants first learned a set of paired items, each pair consisting either of two familiar, unrelated words or of a picture of a common object paired with a familiar word (see Table 14.1 for examples). At the time of testing, the right-hand or target words were displayed either in the context of the same item (word or picture) as at study or in the context of a different item. Implicit memory was assessed by means of a word identification test and explicit memory was assessed by means of a word recognition test.

In Experiment 1, memory was assessed either a few minutes after study or after a one week delay. Previous research has shown that similarly long delays decrease explicit memory test performance, while having no effect or only a minimal effect on implicit tests that focus on item information (for reviews see Mitchell *et al.*, 1990; Roediger *et al.*, 1994). Consistent with such findings, the delay manipulation was expected to lower memory for associative but not item information. More importantly, on the assumption that only one type of higher-order representation is involved in memory for associative information, we expected that the delay manipulation would have the same influence on implicit and explicit memory for associative information and on implicit memory for word–word and picture–word pairs. For Experiment 2, the subjects were young and older adults. Previous research has shown that such age manipulations produce large effects in explicit memory but not in implicit memory for item information (for reviews see Gabrieli, 1999; Graf and Masson, 1993). We expected to replicate this finding. More critical, on the assumption that only one type of higher-order representation is involved in memory for associative information, we expected that the age manipulation would have the same influence on implicit and explicit memory for associative information and on implicit memory for word–word and picture–word pairs.

Table 14.1 Examples of study and test pairs

Study pairs	Test pairs
	Same context
glove–quarter	glove–quarter
WHALE–mirror	WHALE–mirror
	Different context
apple–artery	wallet–artery
wallet–mystery	apple–mystery
LEMON–stair	SOCCER–stair
SOCCER–cotton	LEMON–cotton
	New (non-studied)
	ring–bench
	PEANUT–throat

Note: Items in lowercase were presented as words and items in uppercase were presented as pictures.

Experiment 1

Method

Subjects and design

The participants were 144 undergraduate students who received course credit. The design had two between-subjects factors—test type (explicit or implicit) and test delay (a few minutes or one week), and three within-subject factors—study/test condition (same context, different context), context type (word, picture), and history (studied, non-studied). Thirty-two participants were randomly assigned to each of three between-subjects conditions, but 48 participated in the delayed recognition test condition.

Materials

A set of 256 medium frequency words each being the name of a concrete common object was used to construct the critical context-target pairs: 128 targets (word frequency: $M = 36$, $SD = 21$; 4–10 letters in length), 128 contexts (word frequency: $M = 28$, $SD = 23$, 4–10 letters in length). An additional 24 one-word object names were selected for making practice context-target pairs, and 38 concrete word/object names were required for calibrating each subjects' baseline target identification performance.

Two lists of 64 context-target pairs were created by the following procedure. First, two context and two target words were selected randomly from the set of 256, without replacement, and these were arranged to form two pairs. These same words were also used to form two additional context-target pairs, as illustrated in Table 14.1. By this method of constructing pairs, it was possible at testing to present targets either with the same contexts as at study or with different contexts. For quality control, each pair was checked for the presence of familiar, meaningful associations between the context and target; when such associations were present, the selected words were returned to the pool, and a new sample of four was drawn.

The contexts or left-hand member of each pair was either a one-word object name, or it was a color picture of the named object. The color pictures were obtained from two clip art libraries: CorelDraw! 5.0 (CorelDRAW!, 1994) and Charisma 4.0 (Charisma, 1990). Each picture was scaled so as to span approximately 220 pixels on its longest axis, and was centered on a white 320 × 240 pixel rectangle. For each context, we also prepared an identical display that contained the object name, centered and typed in black ink, in 24 point Dauphin font.

For each subject, one list of 64 pairs was used for assessing performance in the word–word pair condition; the other list was used for the picture – word pair condition. Across subjects, each list was used equally often for each of these conditions. For the purpose of counterbalancing materials across the test context conditions, each list was arranged to form four sets of 16 pairs. Within each set, each target was linked with two contexts, one of which was used for testing the target in the same context condition and the other for testing it in the different context condition. Across subjects, each set was used equally often in each experimental condition (i.e., the conditions listed in Table 14.1).

All contexts were displayed on a 15-inch NEC 4FGe color graphics monitor, driven by an ATI Mach64 Turbo Graphics Pro video card operating in 1024 by 768 resolution, 15 bit color mode, with a 75 Hz refresh rate (i.e., requiring 13.33 ms per refresh). The presentation of materials was controlled by PicBlit3.0 (Uttl, 1995).

Procedure

The experiment was described as examining the influence of different contexts on perception and memory. Participants were tested individually in a session that lasted about 45 minutes. They were seated at a desk about 60 cm from the computer monitor. The session had a study and test phase.

The study phase was the same for all subjects. On each trial, a context—either a word or an object picture—was displayed immediately above the vertical midline of the screen, centered horizontally. Subjects rated how much they liked this item on a 3-point scale (1 = dislike, 2 = neutral, 3 = like) and they registered their ratings by means of a 3-button mouse. Immediately after pressing the mouse button or after 2 seconds had elapsed, a target word was displayed immediately below the vertical midline of the screen, centered horizontally. The subjects were required to create and say aloud a sentence connecting the context and target in a meaningful way, within 15 seconds. The experimenter recorded (via the computer keyboard) whether a meaningful sentence had been generated in the allotted time, and this event blanked the screen for ~ 1 second and initiated the next trial. The context and target remained on the screen until the end of each trial. Subjects were instructed in and they practiced this method until they felt comfortable with it and then 64 critical context-target pairs were presented for study. For each subject, the study list included 32 (two sets of 16) picture–word pairs and 32 (two sets of 16) word–word pairs. Counterbalancing was used to ensure that across subjects, all context-target pairs appeared equally often in each condition.

Immediately following the study phase, subjects assigned to the no-delay implicit test condition were assessed for baseline target identification. The goal was to determine for each individual what target display duration would yield 50% identification accuracy. On each trial, subjects were shown a fixation point—a small square—followed by a 100 ms long tone. After 500 ms, the fixation point was replaced by a 200 ms long pre-mask, a series of line segments and ampersands, immediately followed by the to-be-identified target word and then the post-mask (the same as the pre-mask). Subjects' task was to identify the displayed target word and say it aloud, within 3 seconds. The experimenter entered subjects' responses on the keyboard. This action cleared the post-mask and started the next trial. In order to determine what target display duration would yield 50% identification accuracy, the display duration was set to ten refresh cycles (~133 ms) for the first trial. After two consecutive correct responses, the display duration was reduced by one cycle, and this procedure continued until a subject failed to make a correct response within five consecutive trials. The display duration identified by this method was used for presenting all targets for the implicit word identification test. The average display duration set by this procedure was 44.1 ms (median = 39 ms, range 26 ms to 78 ms).

Implicit memory testing followed immediately after assessing baseline identification performance. The test consisted of presenting, randomly ordered, 128 context-target pairs (two sets of 16 picture–word pairs and two sets of 16 word–word pairs) from the study list, plus 64 non-studied context-target pairs (two sets of 16 picture–word pairs and two sets of 16 word–word pairs). For each type of studied pairs (picture–word, word–word), one set of 16 was used for assessing performance in the same context condition while the other was used for assessing performance in the different context condition (see Table 14.1 for examples). Across subjects, counterbalancing ensured that each pair was used equally often in each experimental condition.

For the test, contexts and targets were presented exactly as at study, except that the display of each target followed the sequence of events used for assessing baseline identification performance. According to the instructions used for study, subjects rated how much they liked each displayed context, and they were required to identify and name out loud each target within 3 seconds of its appearance. Subjects were encouraged to guess if they could not identify a target; alternatively, they responded with the word 'pass'. The experimenter recorded target identification accuracy on the computer keyboard.

For the explicit test, the same list of 128 studied and non-studied context-target pairs was presented for an old/new recognition test. (They were arranged into sets and assigned to conditions in the same manner as for the identification test.) On each trial, the context and target were presented exactly the same way as during the implicit memory test, except that target displays were not masked and they remained on the screen until subjects responded. Subjects' task was to decide, as quickly and accurately as possible, whether or not the target had appeared in the study list, regardless of the context that appeared with it at study. The test was self-paced, with each mouse button response initiating the next trial.

The delayed tests were administered one week after study, according to the exact same procedure as the immediate test.

Results

On the old/new recognition test, the dependent measure was the proportion of hits—words correctly identified as studied—and the proportion of false alarms—non-studied words that were called old. On the word identification test, the dependent measure was the proportion of target words correctly identified in each experimental condition. Target word identification was too easy for some subjects and too difficult for others, thereby limiting the test's sensitivity to priming effects. For this reason, the data from all subjects who identified less than 3% (i.e., where performance was limited by a floor effect) or more than 75%[1] (i.e., where performance was too close to the ceiling and restricted the opportunity for substantial priming to occur) of the non-studied words were excluded from the analysis. We also screened the data for univariate outliers—values that differed by more than two interquartile ranges from their medians, and to reduce their influence on statistical analyses, all outliers were set equal to the value of the largest or smallest non-outlier, respectively. One percent of the data were identified as outliers. Screening for multivariate outliers using the Malanahobis statistics with $\alpha < .01$ revealed no outliers either in old/new recognition or identification test performance.

Identification test performance

The *top* panel of Figure 14.3 shows performance on the word identification test. A preliminary analysis focused on baseline performance, that is, on identification of

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[1] Consistent with the results from previous investigations, we anticipated priming effects of about 25%. For this reason, for subjects with baseline performance in excess of 75%, their performance on studied items was expected to reach 100%, that is, to be marred by a ceiling effect.

non-studied (new) targets. An ANOVA of baseline performance showed a small overall advantage for targets displayed with word vs. picture contexts, $F(1,62) = 4.30$, $MSe = 0.01$, $\eta^2 = .065$, $p = .04$. No other effects were significant. In view of the significant effect due to context type, all subsequent analyses focused on priming scores defined as the difference between identification of studied (old) versus non-studied (new) target words.

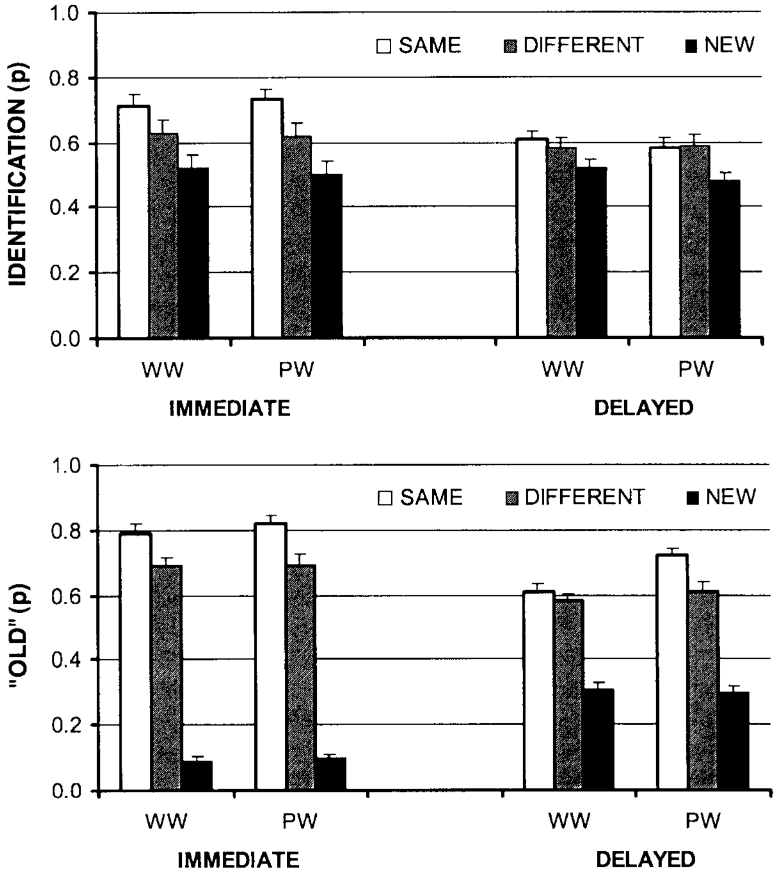

Figure 14.3 The *top* panel shows identification test accuracy; the *bottom* panel shows the proportion of targets called 'old' in Experiment 1. Performance is shown separately for immediate test (i.e., a few minutes after the study phase end) and for delayed test (i.e., one week after the study phase) and for word–word (WW) context-target pairs and picture–word (PW) context-target pairs. Same, different, and new labels refer to context item status (i.e., same context item, different studied context item, new not-studied context item). Performance for word–word context is identified with WW whereas performance for picture–word context is identified with PW. Bars represent standard errors of means.

The figure highlights clear context effects in priming—an influence due to the same/different context manipulation—under immediate but not delayed testing conditions. This observation is supported by an ANOVA of priming scores that had test delay (immediate, delayed) as a between-subjects factor with context type (word, picture) and study/test condition (same, different) as within-subjects factors. The results revealed a significant main effect for study/test condition, $F(1,62) = 18.22$, $MSe = 0.01$, $\eta^2 = .227$, $p < .01$, a marginal main effect for test delay, $F(1,62) = 2.84$, $MSe = 0.12$, $\eta^2 = .043$, $p = .10$, and a marginal main effect for context type, $F(1,62) = 3.93$, $MSe = 0.01$, $\eta^2 = .059$, $p = .06$. More importantly, there was also a significant study/test condition × test delay interaction, $F(1,62) = 10.83$, $MSe = 0.01$, $\eta^2 = .149$, $p < .01$. No other effects approached significance. A follow-up ANOVA of the priming scores from the immediate test showed a significant main effect due to study/test condition, $F(1,31) = 31.10$, $MSe = 0.01$, $\eta^2 = .500$, $p < .01$. An ANOVA of the priming scores from the delayed test showed no significant effects.

Recognition test performance

The *bottom* panel of Figure 14.3 shows performance on the recognition test. The depicted performance levels show that the delay manipulation affected both hits—correct recognition of studied targets, and false alarms—false recognition on non-studied words. For this reason, we used adjusted recognition scores, defined as hits-minus-false alarms, for all subsequent analyses.

The findings that bear most directly on the present investigation are the study/test condition effects on the immediate recognition test with both word and picture contexts, and the fact that on the delayed test, performance showed an influence due to the same/different manipulation only with picture contexts. This observation is supported by an ANOVA of the adjusted recognition scores. The ANOVA included test delay as a between-subjects factor with context type (word, picture) and study/test condition (same, different) as within-subjects factors. The results showed significant main effects for test delay, $F(1,78) = 101.66$, $MSe = 0.08$, $\eta^2 = .565$, $p < .01$, for context type, $F(1,78) = 7.97$, $MSe = 0.01$, $\eta^2 = .092$, $p < .01$, and for study/test condition, $F(1,78) = 35.91$, $MSe = 0.02$, $\eta^2 = .315$, $p < .01$. There were also two significant interaction effects, one between test delay × context type, $F(1,78) = 8.62$, $MSe = 0.01$, $\eta^2 = .099$, $p < .01$, and the other between context type × study/test condition, $F(1,78) = 4.54$, $MSe = .05$, $\eta^2 = .055$, $p = .03$. The three-way interaction among context, study/test condition, and test delay did not reach significance. To clarify further the significant two-way interaction effects, we conducted separate ANOVAs of the immediate and delayed test data. For the immediate test, an ANOVA with context type and study/test condition as within-subjects factors showed a significant main effect due to study/test condition, $F(1,31) = 23.90$, $MSe = 0.02$, $\eta^2 = .435$, $p < .01$. On the delayed test, the same type of ANOVA showed significant main effects for context type, $F(1,47) = 17.92$, $MSe = 0.01$, $\eta^2 = .276$, $p < .01$, for study/test condition, $F(1,47) = 12.95$, $MSe = 0.02$, $\eta^2 = .207$, $p < .01$, and a significant context type × study/test condition interaction, $F(1,47) = 5.46$, $MSe = 0.01$, $\eta^2 = .104$, $p = .02$. Follow-up simple effects analyses showed a significant effect due to study/test condition for picture contexts, $F(1,47) = 16.30$, $MSe = 0.02$, $\eta^2 = .257$, $p < .01$, but not for word contexts, $F(1,47) = 1.57$, $MSe = 0.01$, $\eta^2 = .033$, $p = .21$.

Discussion

The study/test delay manipulation had a much larger influence on overall recognition test performance than on priming of individual words, consistent with a wealth of prior research. More interesting and new are the findings of same/different effects due to both word and picture contexts. On the identification test, word and picture contexts produced equivalent associative effects under immediate testing conditions, and no evidence of associative priming under delayed testing conditions. By contrast, on the explicit recognition test, word and picture contexts produced equivalent associative effects under immediate testing conditions, and on the delayed test an associative effect was still present but only when targets were tested in the context of pictures.

This pattern of findings is consistent with both panels in Figure 14.2, but it is explained more parsimoniously by the model depicted in the *top* panel. The finding that word and picture contexts yielded equivalent associative memory effects, at least under immediate testing conditions, is consistent with the view that a picture of a common object and its name activate the same higher-order (concept) representation, that the same type of associative link may be used for encoding both picture–word and word–word relational information. This finding may be interpreted without appealing to Paivio's dual code view (1991), that is, without postulating a link between imagen and logogen representations (e.g., between I_2 and L_2 in Figure 14.2).

The finding of an associative effect with picture but not word contexts on the delayed recognition test may be explained in terms of the memory advantage of pictures over words. It is well known that memory for pictures is better (i.e., higher, more enduring) than memory for words, and for this reason, pictures may be more effective as associative retrieval cues. Consistent with this interpretation, we assume that the newly formed associations shown in the *top* panel of Figure 14.2 (e.g., between C_2 and C_1) are still present at the time of the delayed test. They may have lost strength over time (i.e., across the retention interval), and as a consequence, identification performance was facilitated only under intentional retrieval conditions, or only with context cues that evoked a strong feeling of familiarity or recognition.

The finding of an associative effect with picture contexts on the delayed recognition but not identification test provides evidence that performance on these two tests was guided by different retrieval strategies. However, this finding may also be used to argue that all associative memory effects shown in Figure 14.3, including those observed on the immediate identification test, are the product of an intentional memory retrieval strategy. Consistent with the interpretation laid out in the preceding paragraph, this type of strategy would be effective under immediate testing conditions when memory for all contexts was still strong, when subjects were likely to consciously connect up all parts of the experiment. By this view, if all associative priming effects in Experiment 1 reflect the same retrieval strategy, one should never expect to find evidence that would support the representational model shown in the *bottom* panel of Figure 14.2.

We are unable to rule out this kind of 'explicit contamination' interpretation for the associative priming effects observed in Experiment 1. However, this kind of interpretation is weakened by post-experiment interviews that provided no evidence that subjects in the identification test conditions were engaging in explicit retrieval, that they were using contexts as part of an intentional memory retrieval strategy.

Experiment 2

The overall goal of Experiment 2 was the same as for Experiment 1, that is, to find out whether one type or multiple types of higher-order representations are involved in memory for newly acquired associative information. The subjects were adults from different age groups: young and old. Previous research has shown that such age manipulations have large effects on explicit but not implicit memory for item information, and we expected to replicate this finding. More interesting, on the assumption that only one type of higher-order representation is involved in memory for associative information, we expected that the age manipulation would have the same influence on implicit and explicit memory for associative information as well as on implicit memory for word – word and picture – word pairs.

Method

Subjects and design

The participants were 36 young adults (age: M = 22.2 yrs, SD = 2.4) and 36 older adults (age: M = 69.8 yrs, SD = 6.7). All participants were volunteers recruited either via a database at the National Institutes of Health in Bethesda, Maryland, or through newspaper advertisements in Washington, DC. The participants were paid between $30 and $40, according to the time required for completing the experiment. The design had age (young, old) as a between-subjects factor, and it had four within-subjects factors: test type (explicit, implicit), context type (word, picture), study/test condition (same, different), and history (studied, non-studied).

Materials

The critical materials were 512 words/object-names arranged into two equal lists. One of the 256-item lists consisted of the word/object-names from Experiment 1; the other list consisted of new words, selected according to the exact same criteria. The words in the two lists were comparable (i.e., not statistically different from each other) in terms of word frequency, concreteness, and letter length. Each list was arranged to form 128 (eight sets of 16) pairs according to the same method used for Experiment 1. The pairs from the first list were used for assessing performance in the picture–word conditions; the pairs from the second list were used for the word–word condition. All words and pictures were displayed using the same equipment as in Experiment 1 except that we used a 17-inch Sony ST-II monitor with a higher 100 Hz refresh rate (10 ms per refresh cycle).

Procedure

Each subject was tested individually in a session that lasted between 2–2.5 hours. The session consisted of the following task/test sequence: study Phase 1, implicit memory testing, finger tapping (see Graf and Uttl, 1995), making simple reactions (see Graf and Uttl, 1995), card sorting (see Graf and Uttl, 1995), study Phase 2, recognition testing, trail making (see Spreen and Strauss, 1991), speeded word reading and the North American Adult Reading Test (NAART; Spreen and Strauss, 1991). The neuropsychological tests, that is, all but the implicit memory test and the recognition memory test, were administered according to published procedures. The neuropsychological tests were included in the battery for reasons that are beyond the scope of this chapter, and thus we do not report the findings from these tests.

Each study phase was administered according to the exact same method as in Experiment 1. Each study list had 64 randomly ordered pairs, including 32 picture–word pairs and 32 word–word pairs. Each test list had 128 pairs, including the 64 from the study list plus 32 non-studied picture–word pairs, and 32 non-studied word–word pairs. Across subjects, the pairs were assigned so that each appeared equally often in each study and test list, in each context (same, different) condition, and in each history (studied, non-studied) condition. The identification test and the recognition test were administered as in Experiment 1.

The average display duration set by the adjustment procedure was 35.8 ms (median = 29 ms, range 19 ms to 69 ms) for young adults and 54.5 ms (median = 49 ms, range 29 ms to 89 ms) for older adults.

Results

The critical dependent variables and the methods used for screening outliers were the same as for Experiment 1. In Experiment 2, $< 1\%$ of the data were identified as outliers. Two subjects (one young and one old) who were identified as multivariate outliers were replaced.

Identification test performance

The top panel of Figure 14.4 shows performance on the word identification test. A preliminary ANOVA of baseline performance showed a marginal main effect due to context type (words, pictures), $F(1,70) = 3.13$, $MSe = .02$, $\eta^2 >= .043$, $p = .08$. No other effects approached significance. In view of the effect due to context type, all subsequent analyses focused on priming scores.

The means in Figure 14.4 provide clear evidence of associative priming effects, but the size of these effects was influenced by context type (word, picture) and by age group. An ANOVA of priming scores, with age group (young, old) as a between-subjects factor and context type (word, picture) and study/test (same, different) condition as within-subjects factors, showed a significant main effects for study/test condition, $F(1,70) = 16.86$, $MSe = 0.02$, $\eta^2 = .194$, $p < .01$, as well as a significant age group × context type × study/test condition interaction, $F(1,70) = 4.27$, $MSe = 0.01$, $\eta^2 = .058$, $p = .04$. We explored the interaction by means of two follow up analyses. For word contexts, an ANOVA that had age group as a between-subjects factor and study/test condition as a within-subjects factor showed a significant effects for age group, $F(1,70) = 3.94$, $MSe = 0.07$, $\eta^2 = .053$, $p = 0.05$, and a significant effect for study/test condition, $F(1,70) = 13.12$, $MSe = 0.02$, $\eta^2 = .158$, $p < .01$. The study/test condition × age group interaction was not significant, $F < 1$, $\eta^2 = .007$, $p = .49$. For picture contexts, the same kind of ANOVA showed a marginal effect for age group, $F(1,70) = 2.85$, $MSe = 0.07$, $\eta^2 = .039$, $p = 0.10$, and a significant main effect for study/test condition, $F(1,70) = 7.08$, $MSe = 0.02$, $\eta^2 = .092$, $p = 01$. In addition, there was also a significant study/test condition × age group interaction, $F(1,70) = 3.94$, $MSe = 0.02$, $\eta^2 = .053$, $p = .05$. Simple effects analyses showed a

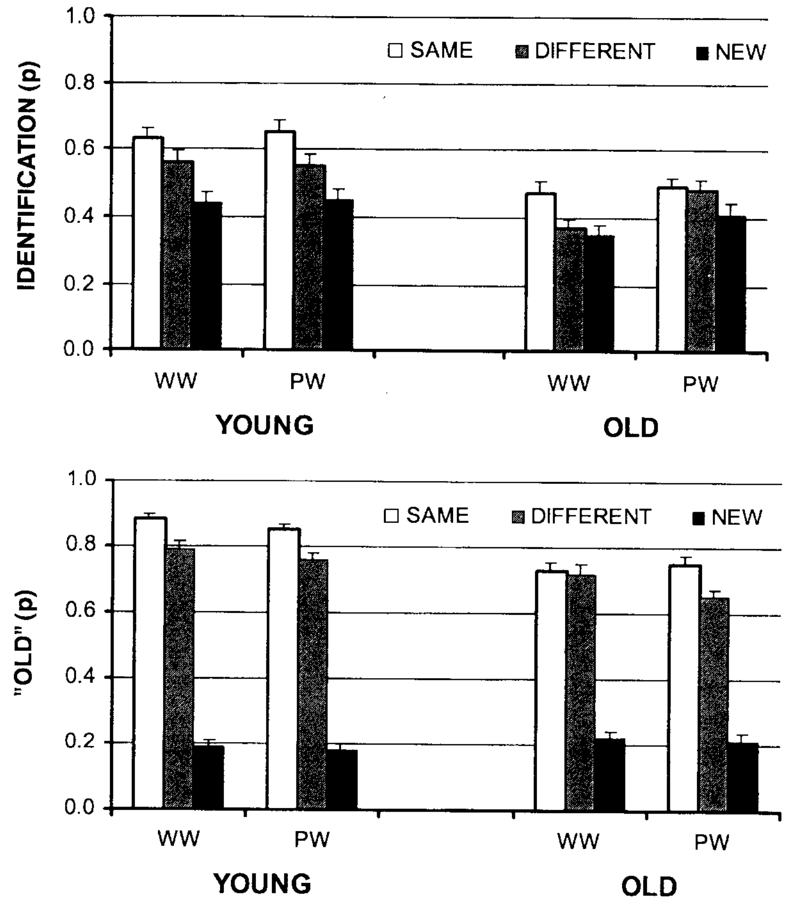

Figure 14.4 The *top* panel shows identification accuracy; the *bottom* panel shows the proportions of targets called 'old' in Experiment 2. Performance is shown separately for young and old adults and for word–word (WW) context-target pairs and picture–word (PW) context-target pairs. Same, different, and new labels refer to context item status (i.e., same context item, different studied context item, new not-studied context item). Bars represent standard errors of means.

significant effect of study/test condition for the young group, $F(1{,}35) = 9.90$, $MSe = 0.02$, $\eta^2 = .220$, $p < .01$, but not for the old group, $F < 1$, $\eta^2 = .007$, $p = 62$.

Recognition test performance

The *bottom* panel of Figure 14.4 shows performance on the recognition test. The figure shows that overall recognition accuracy decreased with age. More interestingly, for the word contexts, associative effects were absent in the old groups' performance whereas for the picture contexts, both young and old subjects showed evidence of memory for newly acquired associative information.

An ANOVA of hits-minus-false alarm scores, with age group as a between-subjects factor and context type and study/test condition as within-subjects factors, showed significant main effects for age group, $F(1,70) = 26.87$, $MSe = 0.05$, $\eta^2 = .277$, $p < .01$, and study/test condition, $F(1,70) = 26.14$, $MSe = 0.01$, $\eta^2 = .272$, $p < .01$, as well as a significant context type × study/test condition interaction, $F(1,70) = 4.05$, $MSe = 0.01$, $\eta^2 = .055$, $p = .05$, and a marginal age group × context type × study/test condition interaction, $F(1,70) = 3.47$, $MSe = 0.01$, $\eta^2 = .047$, $p = 0.07$. For word contexts, an ANOVA with age group as a between-subjects factor and study/test condition as a within-subjects factor showed a significant effects for age group, $F(1,70) = 20.76$, $MSe = 0.03$, $\eta^2 = .228$, $p < .01$, study/test condition, $F(1,70) = 7.01$, $MSe = 0.01$, $\eta^2 = .091$, $p = .01$, and a significant study/test condition × age group interaction, $F(1,70) = 4.25$, $MSe = 0.01$, $\eta^2 = .057$, $p = .04$. For picture contexts, an ANOVA showed a significant main effects for age group, $F(1,70) = 22.93$, $MSe = 0.03$, $\eta^2 = .247$, $p < .01$, and study/test condition, $F(1,70) = 31.74$, $MSe = 0.01$, $\eta^2 = .312$, $p < .01$. Importantly, the study/test condition × age group interaction did not reach significance, $F < 1$, $\eta^2 < .001$, $p = .92$.

Discussion

The critical new finding from Experiment 2 is the older adults' performance on the identification and recognition test. On the identification test, they showed an associative effect on word–word but not picture–word pairs, whereas on the recognition test an associative effect occurred for picture–word but not word–word pairs. Young adults' performance revealed an associative effect for both pair types, on both types of tests.

The pattern of performance by the older adults is strong evidence against an 'explicit contamination' interpretation of the associative effects found on the identification test. A contamination interpretation would have to predict the same pattern of associative effects for identification and recognition test performance. The finding of different associative effects for word–word and picture–word pairs on identification and recognition suggests that different retrieval strategies or processes mediate performance on these tests.

The recognition test results from the young and old groups show the same pattern as found on the immediate and delayed test, respectively, of Experiment 1, and therefore, we offer a similar interpretation. We assume that aging is accompanied by a decrease in the quantity or quality of encoding associative information, and further, that the effect of this age-related change in processing is similar to that brought about by the use of a study/test delay manipulation in Experiment 1. Because the associative connections encoded by older adults are weaker than those of young adults, recognition performance of the older adults showed an associative effect only with context cues that evoked strong feelings of familiarity or recognition (i.e., with picture–word pairs).

The pattern of associative effects on the identification test of Experiment 2 is different from that revealed by the recognition test because identification performance is guided by different (non-intentional) retrieval processes. In the absence of conscious retrieval, performance is determined by the power of the context cues to trigger (in an automatic or bottom-up manner) the spreading of activation from context-concept representations to target-concept representations. The results indicate that this spreading of activation occurred for both word–word and picture–word pairs in young adults, but for older adults, it was effective only with word–word pairs. One reason for this may be that for older adults, the associative connections required for the spreading of activation are stronger for word – word pairs (e.g., from ${}_{w}C_2$ to ${}_{w}C_1$ in Figure 14.2) than for picture–word pairs (e.g., from ${}_{i}C_2$ to ${}_{w}C_1$). Another possibility is that the spreading of activation is more easily accomplished when contexts and targets are in the same format (i.e., both words) rather than different formats (i.e., pictures and words). In either case, the findings from Experiment 2 are more supportive of the model shown in the bottom panel of Figure 14.2. The finding that an experimental manipulation (e.g., age) had different influences on the identification and recognition of word–word and picture–word pairs seems in conflict with the view that a single higher-order representation mediates all aspects of implicit memory for newly acquired associative information.

Conclusion

The main goal of the research reported in this chapter was to examine the claim that all aspects of memory for newly acquired associative information are mediated by a single type of higher-order representation (i.e., beyond the logogen or imagen level) versus by two types of such representations. The results from Experiment 1 are consistent with both of these claims. By contrast, the findings from Experiment 2 argue against the single representation view. They suggest that memory for newly acquired associative information may recruit a variety of representation types, just as memory for items is known to involve a variety of different representations.

The findings from Experiment 2 need to be replicated and extended in order to justify strong inferences about the memory representation of newly acquired associative information. However, these findings are suggestive, fuel for interesting speculations. It seems plausible to us that the conceptual domain of memory is arranged into a variety of functional modules, analogous to the large number modules that have been postulated for perception of, for example, visual features, sound features, letters, written words, and spoken words. It seems equally plausible to assume that making associative connections within a module (e.g., word–word associations) would be easier than making associative connections between modules (e.g., picture–word associations). This may be the reason for why the old subjects in our Experiment 2 showed an associative influence on priming for word–word but not picture–word pairs.

The proposal that the conceptual domain of memory is arranged into modules, that a variety of different types of links may be used for the higher-order representation of newly acquired associative information, may illuminate the existing inconsistent findings of associative priming effects in amnesic patients and in older adults. Aging as well as events or diseases that cause amnesia may selectively impair some but not all of conceptual memory modules, resulting in impaired memory for some but not all types of newly acquired associative information. We believe that this possibility needs to be examined by future research, that without such research, any sweeping conclusions about, for example, implicit memory for new associations in amnesic patients or in old age are premature. The research we report in this chapter gives a method for going beyond the narrow conception of implicit memory for newly acquired associative information that has guided most previous investigations.

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References

Anderson, J. R. and **Bower, G. H.** (1973). *Human associative memory.* Washington, DC: V. H. Winston and Sons.

Bower, G. H. (1996). Reactivating a reactivation theory of implicit memory. *Consciousness and Cognition,* **5**, 27–72.

Charisma [Computer software]. (1990). Richardson, TX: Micrographx, Inc.

CorelDRAW! [Computer software]. (1994). Ottawa, ON, Canada: Corel, Inc.

Challis, B. H. and **Roediger, H. L.** (1993). The effect of proportion overlap and repeated testing on primed word fragment completion. *Canadian Journal of Experimental Psychology,* **47**, 113–23.

Challis, B. H., Velichovsky, B. M., and **Craik, F. I. M.** (1996). Levels-of-processing effects on a variety of memory tasks: New findings and theoretical implications. *Consciousness and Cognition: An International Journal,* **5**, 142–64.

Ergis, A., Van der Linden, M., and **Deweer, B.** (1998). Priming for new associations in normal aging and in mild dementia of the Alzheimer type. *Cortex,* **34**, 357–73.

Gabrieli, J. D. E. (1999). The architecture of human memory. In *Memory: Systems, process, or function? Debates in psychology* (ed. J. K. Foster and M. Jelicic), pp. 205–31. New York: Oxford University Press.

Gabrieli, J. D. E., Keane, M. M., Zarella, M. M., and **Poldrack, R. A.** (1997). Preservation of implicit memory for new associations in global amnesia. *Psychological Science,* **8**, 326–9.

Graf, P. and **Mandler, G.** (1984). Activation makes words more accessible, but not necessarily more retrievable. *Journal of Verbal Learning and Verbal Behavior,* **23**, 553–68.

Graf, P. and **Masson, M. E. J.** (1993). *Implicit memory: New directions in cognition, development, and neuropsychology.* Hillsdale, NJ: Erlbaum.

Graf, P. and **Ryan, L.** (1990). Transfer-appropriate processing for implicit and explicit memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **16**, 978–92.

Graf, P. and **Schacter, D. L.** (1985). Implicit and explicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **11**, 501–18.

Graf, P. and **Schacter, D. L.** (1987). Selective effects of interference on implicit and explicit memory for new associations. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **13**, 45–53.

Graf, P. and **Schacter, D. L.** (1989). Unitization and grouping mediate dissociations in memory for new associations. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **15**, 930–40.

Graf, P. and **Uttl, B.** (1995). Component processes of memory: Changes across the adult lifespan. *Swiss Journal of Psychology,* **54**, 113–30.

Graf, P., Mandler, G., and **Haden, P. E.** (1982). Simulating amnesic symptoms in normal subjects. *Science*, **218** (4578), 1243–4.

Howard, D. V., Fry, A. F., and **Brune, C. M.** (1991). Aging and memory for new associations: Direct versus indirect measures. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **17**, 779–92.

Johnson, M. K. (1994). Binding complex memories: The role of reactivation and the hippocampus. In *Memory systems 1994* (ed. D. L. Schacter and E. Tulving), pp. 311–50. Cambridge, MA: MIT Press.

Jurica, P. J. and **Shimamura, A. P.** (1999). Monitoring item and source information: Evidence for a negative generation effect in source memory. *Memory and Cognition*, **27**, 648–56.

Mandler, G. (1981). The recognition of previous encounters. *American Scientist*, **69**, 211–8.

Mandler, G. (1994). Hypermnesia, incubation, and mind popping: On remembering without really trying. In *Attention and performance 15: Conscious and nonconscious information processing. Attention and performance series* (ed. C. Umilta and M. Moscovitch), pp. 3–33. Cambridge, MA: MIT Press.

Mandler, G. (1991). Your face looks familiar but I can't remember your name: A review of dual process theory. In *Relating theory and data: Essays on human memory in honor of Bennet B. Murdock* (ed. W. E. Hockley and S. Lewandowsky), pp. 207–25. Hillsdale, NJ: Lawrence Erlbaum Associates.

Marsolek, C. J., Schacter, D. L., and **Nicholas, C. D.** (1996). Form-specific visual priming for new associations in the right cerebral hemisphere. *Memory and Cognition*, **24**, 539–56.

Mitchell, D. B., Brown, A. S., and **Murphy, D. R.** (1990). Dissociations between procedural and episodic memory: Effects of time and aging. *Psychology and Aging*, **5**, 264–76.

Monti, L. A., Gabrieli, J. D., Wilson, R. S., Beckett, L. A., Grinnell, E., Lange, K. L., *et al.* (1997). Sources of priming in text reading: Intact implicit memory for new associations in older adults and patients with Alzheimer's disease. *Psychology* and *Aging*, **12**, 536–47.

Moscovitch, M., Winocur, G., and McLachlan, D. (1986). Memory as assessed by recognition and reading time in normal and memory-impaired people with Alzheimer's disease and other neurological disorders. *Journal of Experimental Psychology: General*, **115**, 331–47.

Musen, G. and Squire, L. R. (1993). On the implicit learning of novel associations by amnesic patients and normal subjects. *Neuropsychology*, **7**, 119–35.

Paivio, A. (1991). *Images in mind: The evolution of a theory.* London, UK: Harvester Wheatsheaf.

Paller, K. A. and **Mayes, A. R.** (1994). New-association priming of word identification in normal and amnesic subjects. *Cortex*, **30**, 53–73.

Roediger, H. L. III, Guynn, M. J., and **Jones, T. C.** (1994). Implicit memory: A tutorial review. In *International perspectives on psychological science, 2: The state of the art* (ed. G. d'Ydewalle, P. Eelen, and P. Bertelson), pp. 67–94. Hove, UK: Lawrence Erlbaum Associates.

Schacter, D. L. (1990). Perceptual representation systems and implicit memory: Toward a resolution of the multiple memory systems debate. *Annals of the New York Academy of Sciences*, **608**, 543–71.

Schacter, D. L. (1994). Priming and multiple memory system: Perceptual mechanisms of implicit memory. In *Memory systems 1994* (ed. D. L. Schacter and E. Tulving), pp. 233–68. Cambridge, MA: MIT Press.

Schacter, D. L. and **Graf, P.** (1986a). Effects of elaborative processing on implicit and explicit memory for new associations. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **12**, 432–44.

Schacter, D. L. and **Graf, P.** (1986b). Preserved learning in amnesic patients: Perspectives from research on direct priming. *Journal of Clinical and Experimental Neuropsychology*, **8**, 727–43.

Schacter, D. L. and **Graf, P.** (1989). Modality specificity of implicit memory for new associations. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **15**, 3–12.

Schacter, D. L. and **Tulving, E.** (1994). *Memory systems 1994.* Cambridge, MA: MIT Press.

Schacter, D. L., Cooper, L. A., and **Delaney, S. M.** (1990). Implicit memory for unfamiliar objects depends on access to structural descriptions. *Journal of Experimental Psychology: General,* **119**, 5–24.

Schacter, D. L., Cooper, L. A., and **Treadwell, J.** (1993). Preserved priming of novel objects across size transformation in amnesic patients. *Psychological Science,* **4**, 331–5.

Schacter, D. L., Osowiecki, D., Kaszniak, A. W., Kihlstrom, J. F., and **Valdiserri, M.** (1994). Source memory: Extending the boundaries of age-related deficits. *Psychology and Aging,* **9**, 81–9.

Shimamura, A. P. and **Squire, L. R.** (1989). Impaired priming of new associations in amnesia. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **15**, 721–8.

Spreen, O. and **Strauss, E.** (1991). *A compendium of neuropsychological tests.* New York: Oxford University Press.

Tulving, E. and **Schacter, D. L.** (1990). Priming and human memory systems. *Science,* **247**, 301–6.

Uttl, B. PicBlit3.0 [Software] Neurexis Research, Cochrane, AB, Canada, 1992–1995.

Van der Linden, M., Bruyer, R., and **Dave, B.** (1992). Effect of aging on implicit and explicit memory for new associations. *Cahiers de Psychologie Cognitive,* **12**, 223–37.