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5

Functional Forms of Human Memory

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Several recent theories of memory can be classed as "functional subsystems" approaches. They share the ideas that human memory is composed of distinguishable subsystems that serve different behavioral and cognitive functions, operate according to different laws, and are represented by different neural structures or mechanisms. These subsystems may develop at different rates from infancy to adulthood, and they may be differentially susceptible to disruption from alcohol and other drugs, aging, disease, or injury (e.g., Cohen, 1984; Johnson, 1983; Squire, 1982; Tulving, 1983; Warrington & Weiskrantz, 1982).

Although the field is still struggling to characterize these subsystems, progress does not depend on consensus; many schemes have been proposed that have generated valuable ideas and research. I haven't space here to discuss various viewpoints in detail, but one way they differ is in the aspects of the meaning of "function" they seem to emphasize by the way subsystems are labeled. Terms such as episodic versus semantic memory (Cermak, 1984; Schacter & Tulving, 1982; Tulving, 1983), procedural versus declarative memory (Cohen & Squire, 1980), and memories versus habits (Mishkin, Malamut, & Bachevalier, 1984) emphasize the purpose/result/consequence meaning of function. Terms such as horizontal versus vertical processes (Wickelgren, 1979), mediated versus stimulus–response learning (Warrington & Weiskrantz, 1982), and sensory versus perceptual versus reflective subsystems (Johnson, 1983) emphasize the activity/process meaning of function. Of course, most investigators who have tackled the problem of defining subsystems have considered both aspects of function—purpose and process—to some degree, but the terms we use reflect certain tacit assumptions, I think.

In any event, one major goal of a psychological analysis of memory is to account for memory in terms of purposes such as skill learning, autobiographical recall, generalization of concepts, and learned emotional reactions. It seems unlikely, however, that the processes that serve these goals are uniquely dedicated to particular purposes of this sort. For example, some of the same types of memory processes might, under some circumstances, contribute to skill learning, autobiographical recall, generalization of concepts, and learned emotional

reactions. In fact, as processes were added (and/or modified) during evolution, purposes probably multiplied. Thus the framework I describe in this chapter assumes as a point of departure that the "functional forms" of human memory (i.e., subsystems) yet to be specified are sets of processes that contribute in different combinations to the many purposes memory serves.

A MULTIPLE-ENTRY MODULAR MEMORY SYSTEM

The framework that I have found useful for thinking about memory is called a multiple-entry modular memory system (MEM) (Johnson, 1983). I propose that memory is composed of at least three interacting but distinguishable subsystems: the sensory system, the perceptual system, and the reflection system (Fig. 5.1). Each subsystem is really a set of processes; thinking in terms of subsystems allows us to group processes that have something in common and to highlight apparent differences in processes that may imply interesting directions for research.

The sensory and perceptual subsystems record the consequences of perceptual processing. They differ in the type of perceptual information to which they are most sensitive.[1] The sensory system records the type of information that typically is not in itself the major object of perception but that operates as perceptual

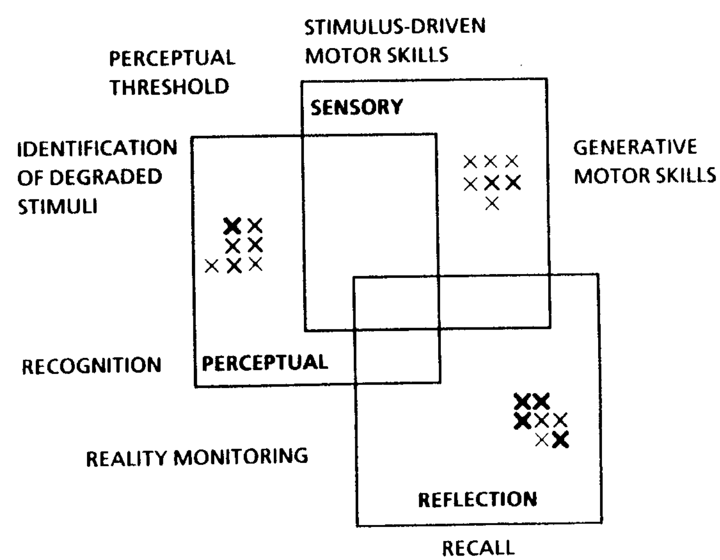

FIGURE 5.1. A particular event creates entries in three subsystems of memory: sensory, perceptual, and reflection. The x's indicate activation, the heavier the x's, the greater the likelihood that the activation will recruit attention. Various memory tasks are listed near the subsystem(s) that they are particularly likely to draw upon. (From Johnson, 1983, by permission)

cues. The sensory system develops associations involving such aspects of perception as brightness, localization, and direction of movement. The sensory record is important in many skills, such as developing hand–eye coordination, learning to adjust one's posture to changes in external cues, improving performance in tracking tasks, and other largely stimulus-driven tasks. The perceptual subsystem records phenomenally experienced perceptual events, that is, external objects in relation to one another. The reflection system records the active thinking, judging, and comparing that we do. It records our attempts to organize and control what happens to us, and our commentary on events. Thus it records memories that are internally generated.

In Figure 5.1 the subsystems are depicted as overlapping. If you look at the figure for a few moments, it will begin to reverse like a Necker cube; each subsystem may appear in the front, middle, or back. This visually represents the interactive quality of the entire system. No subsystem is primary, and the order in which processes are engaged is not fixed. As Kolers (1975) suggested, entries in memory are the records of the specific processes that created them. Activation (indicated by ×'s in Fig. 5.1) indicates that processing is taking place. The heavier ×'s indicate that we are aware of only a subset of activated information at any particular time. Nevertheless, activation, not awareness, is the necessary and sufficient condition for changing memory.

Most experiences will generate entries in all subsystems. For instance, in a complex activity like playing tennis, various components are probably largely mediated by different subsystems. Learning to get to the right place at the right time involves sensory information that itself is not the object of perception, especially visual information about trajectories such as the rate of change in the size of the ball as a function of time. Learning to respond to configurational aspects in the stimulus array is a perceptual function, for example, learning to see relations among an opponent's position on the court, posture, and racket orientation that signal what shot she is likely to make. Reflection is critically involved in learning to understand an opponent's strategy, or to plan or initiate one of your own. The memory for playing tennis is not a single type of representation in a unitary memory system, but is multiply represented in various subsystems of memory. Furthermore, most experiences have this same complex character and are thus multiply represented.

I do not think of MEM as finished, but as a general framework for proceeding. It may be necessary to add subsystems, and those already proposed need to be specified more precisely (for example, several ideas for clarifying some of what is involved in reflection are suggested in the section on recall below). One possibility is that subsystems should be defined in terms of relations that certain neural networks are prepared (through either evolution or past experience) to handle. For example, certain stimulus information may more easily be associated with body adjustments than with a complex plan. On the other hand, centrally generated representations or plans may more easily serve as cues for the revival of other ideas than as cues for certain body adjustments. If so, in MEM,

the question of the interaction of subsystems might be framed in terms of whether and how sensory information contributes to the activation of reflections and whether and how self-generated information such as plans affect actions (such as eye movements) that are predisposed to respond to external cues.

The MEM framework helps organize a number of empirical findings from normal human subjects. For example, memory can be measured in various ways: with recall tests, recognition tests, or tests that show the effect of experience in indirect ways (or "implicitly"; Schacter, 1987b), such as improved ability to identify a stimulus under degraded perceptual conditions. In normal human subjects, these various measures are often not correlated or necessarily affected in the same way by experimental manipulations (e.g., Jacoby & Dallas, 1981; Tulving, 1983; see Schacter, 1987b for a recent review and Spear, 1984 for a discussion of related issues). This lack of correlation among measures can be understood if we assume that recall draws heavily on the reflection system, recognition draws on the perceptual system, and perceptual-threshold tasks like perceptual identification depend mainly on the sensory system. In Figure 5.1, tasks are listed near the subsystems that are most implicated, but there is no "pure" one-to-one correspondence between tasks and subsystems.

This model can also be applied to amnesia.[2] Quite a bit of evidence is consistent with the idea that anterograde amnesia results from a deficit primarily in the reflection subsystem, with the sensory and perceptual memory subsystems relatively intact (for reviews see Parkin, 1982; Cermak, 1982; Hirst, 1982). For example, amnesics show dramatic deficits in recall tasks. At the same time, they show relatively normal performance in certain perceptually based tasks such as learning mirror drawing (Milner, 1966), learning to read mirror text (Cohen & Squire, 1980), and perceptual identification of previously exposed words (Cermak, Talbot, Chandler, & Wolbarst, 1985). In the MEM framework, the more an activity requires reflection—that is, the more it requires self-generated cues—the more difficult it should be for amnesics to master. The more perceptual support for an activity there is (i.e., the more it is externally guided), the easier it should be for amnesics to learn.

Current research in areas such as skill learning (e.g., Nissen & Bullemer, 1987) and priming (e.g., Graf, Squire, & Mandler, 1984; Schacter, 1987b) is clarifying our picture of some of the memory functions that appear to be preserved in anterograde amnesia (e.g., development of sensory–motor associations and perceptual analysis processes, activation of semantic concepts). Here I focus on amnesic performance in tasks that are relevant to understanding memory functions that are not preserved. This chapter applies the MEM framework to the analysis of amnesia in three areas of research: recognition memory, acquisition of affective responses, and free recall. These areas are particularly interesting because amnesia's most profound consequence is loss of memory for recent personal experience and often what makes a memory seem personal is that it is recognized as familiar from a particular context or source, evokes affective responses, and can be revived or reconstructed voluntarily. Thus understanding processes involved in recognition, memory for affect, and recall eventually should help us better understand the loss of personal memory that is so characteristic of amnesia.

RECOGNITION

One specific prediction generated from MEM is that amnesics should show less disruption in recognition than in recall, because unlike recall, recognition presumably does not always require reflection but can be based on perceptual records alone (e.g., Jacoby, 1982; Mandler, 1980). Direct support for this idea comes from several experiments. In one study (Hirst et al., 1986) we tested two groups of amnesics, patients with Korsakoff's syndrome (a memory disorder associated with thiamine deficiency and chronic alcoholism) and a group of nonalcoholic amnesics of mixed etiology (e.g., hypoxic ischemia, anterior communicating artery aneurysm). Each amnesic group was compared to an appropriate age- and education-matched control group. The subjects studied word lists and we equated the performance of amnesics and controls on forced-choice recognition by giving the amnesics more time to study the words—amnesics took 8 sec per item of study time to reach the same level of recognition performance as normals given only 0.5 sec per item. Then we looked at recall for the same lists. Because the same patterns of results were obtained for the two amnesic groups, they have been combined in Table 5.1A. As you can see, even though their recognition performance was equal to that of controls, amnesics still showed a marked decrement in their ability to recall the words.

We extended these results in subsequent experiments with the mixed-etiology amnesics. In one experiment (Hirst, Johnson, Phelps, & Volpe, 1988, experiment 1) amnesics and normals both had 8 sec to study each item, but we equated amnesic and normal recognition by lengthening the retention interval for the normal subjects. That is, the recognition performance of normals tested after a 1-day delay was about the same as that of amnesics tested immediately. Again,

TABLE 5.1 Mean Proportion Correct Recognition and Recall for Three Experiments

Group	Time	*n*	Recognition	Recall
A. Amnesics	(8 sec)	13	.78	.07
Controls	(0.5 sec)	13	.77	.25
B. Amnesics	(30-sec delay)	6	.85	.06
Controls	(1-day delay)	6	.86	.22
C. Amnesics	(2 × 5 sec)	6	.85	.07
Controls	(1 × 0.5 sec)	6	.77	.16

Source: Data from (A) Hirst, Johnson, Kim, Phelps, Risse, and Volpe (1986; blocked, categorized lists) and (B) and (C) Hirst, Johnson, Phelps, and Volpe (1988, experiments 1 and 2; unrelated words).

with recognition equated, amnesics were at a substantial disadvantage in recall (Table 5.1B). In another experiment (Hirst et al., 1988, experiment 2) the list was presented to the amnesics twice at a 5 sec rate and only once for 0.5 sec to normals. Under these conditions the amnesics actually scored significantly better on recognition than the normals. But even with this recognition advantage, amnesics scored much poorer on the recall test (Table 5.1C).

Although these experiments show that amnesic recognition is less disrupted than recall, the amnesics still had a substantial recognition deficit that could be overcome only with long or repeated exposures. One explanation is that word stimuli are relatively "impoverished" perceptually. In addition, words are extremely familiar and probably do not create discriminable memory records without some reflection (e.g., Eysenck, 1979; Jacoby & Craik, 1979). It is possible that if we could make the perceptual qualities of the stimulus more important, the amnesics would more closely approximate normal performance. This in fact sometimes seems to be the case when the stimuli are unfamiliar pictures rather than words.

In one experiment we showed Korsakoffs and controls pictures of abstract "paintings" that we had made up (Johnson & Kim, 1985). Subjects saw each item 1, 5, or 10 times; then they were given a forced-choice recognition test in which they had to discriminate the more familiar picture from a new distractor and rate their confidence in their choice. Korsakoff patients were mildly, but not significantly, impaired in recognition memory (for both forced choice and choice weighted by confidence) (Table 5.2A). Furthermore, we retested subjects 20 days later, and even after 20 days, Korsakoff patients' recognition performance for

TABLE 5.2 Recognition Scores for "Paintings" after 5-Minute and 20-Day Retention Intervals

Test	Number of Exposures 1	5	10
A. 5-minute delay			
Mean proportion correct			
Korsakoff (*n* = 9)	.67	.81	1.00
Control (*n* = 9)	.78	.94	1.00
Choice weighted by confidence[a]			
Korsakoff	4.03	4.72	5.33
Control	4.31	5.31	5.64
B. 20-day delay			
Mean proportion correct			
Korsakoff	.56	.54	.78
Control	.53	.71	.86
Choice weighted by confidence			
Korsakoff	3.65	3.82	4.46
Control	3.60	4.19	4.72

[a]Correct choice: 6 = very sure; 5 = quite sure; 4 = guessing. Incorrect choice: 3 = guessing; 2 = quite sure; 1 = very sure.
Source: From Johnson and Kim (1985).

pictures seen 10 times was a remarkably good 78%, compared with 86% for controls (Table 5.2B).

To put these findings in perspective, we compared them with previously reported studies of picture recognition in Korsakoff patients. Figure 5.2 shows the relative performance of Korsakoff and control subjects who were tested under comparable conditions, where controls were below maximum performance (not at ceiling). It includes 11 data points from six different experiments including ours using abstract paintings (Johnson & Kim, 1985) and other experiments using faces, miscellaneous magazine pictures, magazine covers, and patterns (Biber, Butters, Rosen, Gertsman, & Mattis, 1981; Cutting, 1981; Huppert & Piercy, 1976, 1977; Talland, 1965). If Korsakoffs and normals performed exactly alike, the points would all be on a 45° line. In some of the conditions, the amnesics showed a significant deficit; in others the amnesics did not differ significantly from normals. More important, the correlation between the performance of Korsakoff patients and that of normals is quite clear ($r = .80$). Items or conditions that were difficult for controls were difficult for Korsakoffs; items or conditions that were easy for controls were easy for Korsakoffs (also see Mayes, Meudell, & Neary, 1980). This general pattern supports the idea that picture recognition involves some memory processes that are relatively intact in amnesia.

A dissertation by Weinstein (1987) helps clarify the conditions under which we might expect to find comparable recognition for amnesics and controls, and those conditions under which amnesics might show a deficit. All subjects saw a series of pictures that were line drawings of familiar objects, each colored in a single color. The type of orienting task was varied. Half of each group were given a perceptual task in which they were directed to keep track of the number of black objects. This task is perceptual because it requires subjects to attend to only a physical feature of each object, its color. The other half of the subjects were given a reflective task; they were to decide whether each object was presented in a common color or a novel color. For example, a *yellow lemon* would

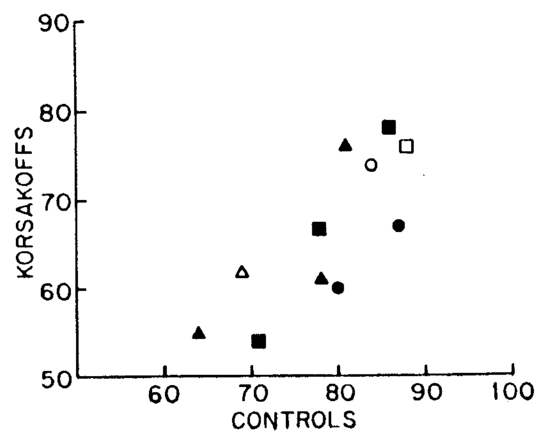

FIGURE 5.2. Relative performance of Korsakoff patients and control subjects on picture recognition. Data are from the following studies: Biber et al., 1981 (▲); Cutting, 1981 (△); Huppert and Piercy, 1976 (○); Huppert and Piercy, 1977 (●); Talland, 1965 (□); Johnson and Kim, 1985 (■). (Reprinted from Johnson and Kim, 1985, with permission)

TABLE 5.3 Mean Proportion Correct for Yes/No Picture Recognition

Distraction Condition	Perceptual Orienting Task: Amnesic (n = 12)	Perceptual Orienting Task: Control (n = 12)	Reflective Orienting Task: Amnesic (n = 12)	Reflective Orienting Task: Control (n = 12)
A. New–novel	.69	.76	.76	.90
B. New–common	.51	.79	.80	.93
C. Old–common	.44	.68	.58	.87

Source: From Weinstein (1987).

be common; a *purple camel* would be novel. This task is reflective in that it requires subjects to consider the ongoing perceptual product and information activated about the object from general knowledge and then to compare the information from these two sources and make a decision. After all the pictures were presented, subjects were given a Yes/No recognition task, consisting of novel-colored objects from the acquisition list mixed with new novel colored objects.

The results are shown in Table 5.3A, which combines Korsakoffs and nonalcoholic amnesics, who showed the same patterns. After the perceptual task, recognition was not significantly different for amnesics and controls. After the reflective task, the controls were significantly better than the amnesics. These results suggest that if controls and amnesics process information perceptually, their recognition performance will be similar. If they process information reflectively, either controls engage in more embellished reflection or they are better able to reinstate memory for this reflection at the time of the test, or (most likely) both.

Normals and amnesics appeared to be equally good at using perceptual records for discriminating familiar old pictures from unfamiliar new pictures. Perhaps this was because no conflicting familiarity response was evoked by the distractor items. If the test involved some ambiguity about the source of familiarity, the importance of reflective processes should show up (e.g., Johnson, 1988; Johnson & Raye, 1981; Lindsay & Johnson, 1987). Thus Weinstein (1987) tested these same subjects on two other picture series in which the recognition decisions should have required reflection. In these conditions the acquisition series were of the same type as before (involving, of course, new pictures). But the distractors in the second condition were new objects in common colors and the distractors in the third condition were old objects from the acquisition list that had previously appeared in novel colors but now appeared in common colors. In both these cases we expected the distractors to evoke some sort of familiarity response (based on either semantic knowledge or semantic knowledge plus recent experience). Discriminating the targets from the distractors under these conditions should be more difficult because familiarity alone should not be a sufficient cue. Thus the benefit from reflective activity should be greater.

The results for these more difficult distractor conditions are shown in Table

5.3B and C). When the test involved familiar distractors, the amnesics performed considerably worse than the controls even in the perceptual orienting task condition. These results are consistent with the idea that reflection helps specify the source of a familiarity response and that amnesics perform more poorly with increasing reflective demands.

To summarize these experiments on word and picture recognition, the fact that the amnesics' recall deficit is greater than we would expect from their recognition performance indicates that regardless of what processes are disrupted in amnesia, they are more important in recall tasks than in recognition tasks.[3] We think the disrupted processes are controlled, self-generated mental activities of the sort I have been calling reflection. The fact that amnesic recognition can actually equal normal recognition when the recognition task is largely perceptual, and that amnesics begin to show marked deficits as recognition requires more reflection, makes the point even more strongly. A sense of familiarity does not necessarily depend on reflection, but further specifying the source of the familiarity does (Huppert & Piercy, 1978; Schacter, Harbluk, & McLachlan, 1984).

AFFECT

There has not been much work on amnesics' acquisition of affective reactions, but scattered reports suggest that amnesics do acquire affective responses (e.g., Claparede, 1911, cited in Baddeley, 1982), although some suggest that they do not (Redington, Volpe, & Gazzaniga, 1984). As with recognition, a closer analysis of the problem suggests that we might be able to characterize the conditions under which amnesics will and will not acquire affective responses.

According to the MEM model, emotion may originate with experiences that are perceptual or with experiences that are more self-generated or reflective. For example, after a traffic accident, the squeal of brakes may be associated in the perceptual system with fear. Frustration or anger may be another part of the affective response associated in the reflection system with thoughts after the accident about its consequences (e.g., missed appointments, lost work time, the inconvenience of getting the car repaired). Later, hearing the squeal of brakes may directly revive some components of the total affective response (e.g., the fear); the revival of other components (e.g., the frustration) will be more dependent on recalling earlier reflective activity.

If this characterization of emotion is correct, amnesics should still be able to develop affective responses—emotions, preferences, etc.—in situations that do not depend on reflection but in which the affect is tied to perceptual features of a situation. In one experiment exploring this idea (Johnson, Kim, & Risse, 1985, experiment 1), Korsakoff and control subjects heard unfamiliar Korean melodies. Then these melodies were mixed with a number of new melodies and the subjects were asked to rate how much they liked each one. We chose this situation because we reasoned that the affective response to melodies is largely based on perceptual characteristics of the melody; if so, the preferences of amnesics should be affected by the same variables as the preferences of normals. Research by Zajonc (1980) and others has shown that normal subjects often prefer stimuli they have previously experienced, and this is the result we obtained. The control subjects liked the old melodies better than the new melodies. The interesting new finding was that the Korsakoff subjects also gave higher ratings to the previously heard melodies; furthermore, the magnitude of the effect was the same as for normals (Table 5.4A). On the other hand, even though the amnesics preferred the old melodies to new ones, on a recognition test they showed the usual deficit in ability to say what they had and had not heard before (Table 5.4B).

These results suggest that affective reactions develop normally in amnesics if the situation is largely perceptual. In a second experiment (Johnson et al., 1985, experiment 2) we used a situation that we thought would be much more likely to involve reflection. The subjects were the same as in the melody experiment. They were shown pictures of two young men, Bill and John, and were asked to give their impression of each by rating him on several characteristics, such as honesty, politeness, and intelligence. Then subjects heard some facts about Bill and some facts about John. John was depicted as a "good guy" (he helped his father, got a Navy commendation for saving someone's life, etc.), and Bill was depicted as a "bad guy" (he stole things, broke someone's arm in a fight, etc.). After an interval, the subjects were shown the pictures and were asked about their impressions again.

The subjects heard the biographical information a total of three times over 3 or 4 days. We brought them back 20 days later and asked for their impressions again. The results are shown in Figure 5.3; the higher the score, the more positively the man in the picture was rated on such traits as honesty, politeness, and intelligence. Look first at the control subjects (squares and triangles). The pictures were rated first before the subjects heard any biographical information, and, as you would expect, Bill and John were rated about equally. After the control subjects heard the biographical information for the first time, the ratings changed dramatically with the good guy rated more favorably and the bad guy less favorably. Ratings did not change much with repetitions of the biographical information, and the effect of the biographical information persisted over the 20-day retention interval (day 3 in Fig. 5.3). Now look at the Korsakoff patients

TABLE 5.4 Preference Ratings and Recognition Scores for Melodies

	A. Preference Ratings[a]		
Group	Old	New	B. Proportion Correct Recognition
Amnesic (n = 9)	4.10	3.74	.59
Control (n = 9)	3.77	3.46	.83

[a]Higher ratings indicate more preferred.
Source: From Johnson, Kim, and Risse (1985, experiment 1).

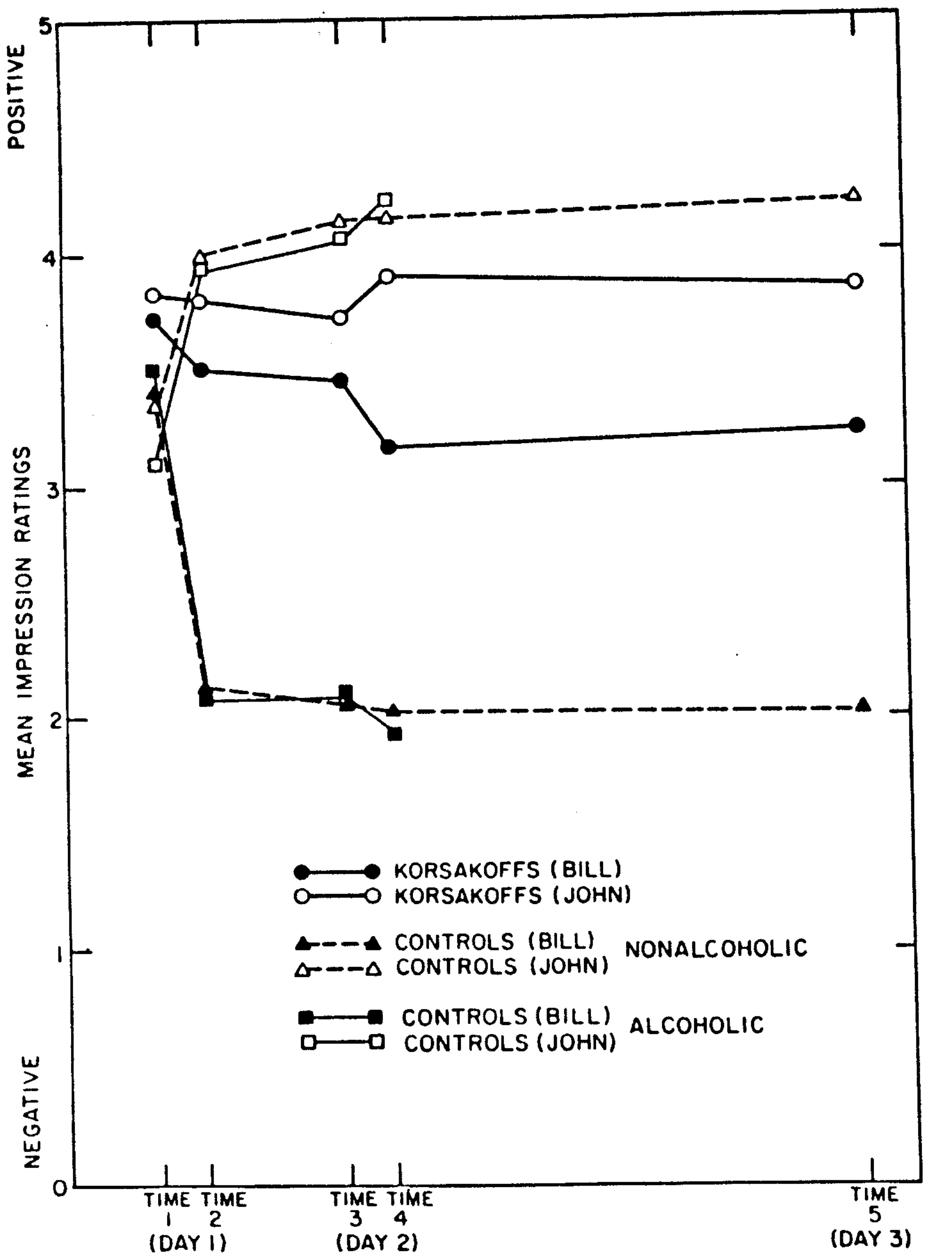

FIGURE 5.3. Mean impression ratings for Korsakoffs ($N = 9$), nonalcoholic controls ($N = 9$), and alcoholic controls ($N = 6$). (From Johnson, Kim, and Risse, 1985, experiment 2)

(circles). Again, the ratings for Bill and John started out the same and diverged significantly. Even after a 20-day retention interval, the amnesics gave the good guy higher ratings than the bad guy. After 20 days, the control subjects could recall about 35% of the biographical information, whereas the Korsakoffs recalled virtually nothing. Therefore, although the Korsakoffs could not recall the biographical information, it still affected their judgments about which of the two men was nicer.

In the Bill and John study, Korsakoff patients clearly developed less extreme impressions than did controls. In contrast, these same Korsakoff patients showed the same development of preference for melodies as controls did. Differences in the results of the two studies are interpretable within the MEM framework. Compared to developing preferences for melodies, when we develop preferences for people there is much more room for reflection to operate. The MEM framework assumes that some affective responses are tied to the perceptual features of the pictures of the two men, whereas other affective responses are tied to the reflective activity the subjects engaged in while hearing the biographical information (e.g., comparing the men to other people they have known, evaluating the severity of misdeeds). Later, reinstating perceptual cues from the pictures should revive some affective components, but other aspects of the total affective response should depend on reinstating previous reflection. Normal subjects could cue themselves by recalling specific biographical details and should therefore have a more embellished affective response.

In summary, our two experiments on affect indicate that Korsakoff patients retain the capacity for developing affective reactions. But the degree to which we can expect amnesics to retain affective responses in any particular case depends on the relative involvement of different memory subsystems in supporting affective responses of nonamnesic subjects.

RECALL

The most salient and central symptom of amnesia is profoundly poor free recall (e.g., Butters & Cermak, 1980; Milner, Corkin, & Teuber, 1968). Precisely because amnesic recall is so poor, it is difficult to study systematically. By considering the various mental activities required by recall, however, we should be able to break the problem down into tractable component parts. This will also help further clarify the concept of reflection.

Basic Reflective Subprocesses

Even in its simplest form, normal recall clearly depends on a number of basic reflective subprocesses, the most important of which have to do with establishing relations among elements to be recalled (e.g., Bower, 1970; Mandler, 1967; Tulving, 1962). Consider a hypothetical organizational problem involving a free recall list that includes the words *pig, dog, weed,* and *dinner* (Fig. 5.4A). Each

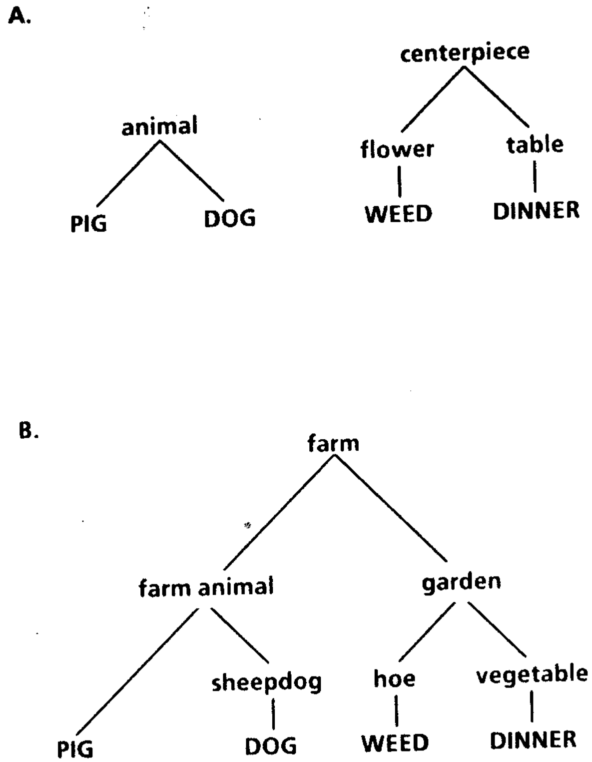

FIGURE 5.4. Hypothetical activation patterns and noted relations for four items (pig, dog, weed, dinner) from a free-recall list. (A) Initial activation and noted relations. (B) Activation and noted relations after a shift in perspective.

word activates some set of relations based on prior experience and current context. One primary reflective function is *noting* the relations that are given in this current activation pattern. For example, a subject might note that *pig* and *dog* are both *animals*, and that *flower* (which is activated by *weed*) can be used as a *centerpiece* on a *table* (which is activated by *dinner*). This noting activity would establish two small units.

Another critical reflective function is *shifting* activation to other information in order to change what is given. The change is accomplished by changing perspective or shifting attention from the currently activated aspects of a stimulus to other potentially useful aspects (see Fig. 5.4B). Suppose that for our hypothetical subject, attention is shifted from the idea of *animals* to the fact that *pigs* and *dogs* are found on *farms*. At the same time, suppose the subject thinks about aspects of *weeds* and *dinner* that in turn suggest the idea of *garden*. *Garden* and *farm animals* are both related through *farm*. Now the subject has a single interrelated set of relations including the four items.

A third reflective process is *refreshing*. Clearly, various ideas and relations must remain active during *shifting* and *noting* until a stable or cohesive set of relations has been noted. Keeping them active requires some sort of continuous scan of current activation in order to keep it refreshed.

A fourth reflective function is delayed *reactivation* of information that has disappeared from consciousness. Through internally generated remindings, sets of relations become more cohesive.

To simplify, I have illustrated these subprocesses applied to learning and remembering a word list, but all these basic reflective activities are central in processing more complex, naturally occurring events.

Layers of Reflection

Reflective processes differ not only in type, but also along a continuum of "planfulness," which may affect the characteristics of these basic reflective activities. At the minimum level of planfulness, basic reflective activities may consist largely of allowing the activation consequences of successive events to settle and noting whatever cohesive sets of relations emerge.[4] Even such relatively passive mental activity receives some direction from ongoing goals or agendas (e.g., the goal to read words aloud). Agendas vary in the degree of deliberation they require to execute and monitor. Thus some agendas call up well-learned perceptual and reflective schemata that may organize component processes relatively automatically, while others bring basic subprocesses under strategic control in order to organize them to meet new, unusual, or complex demands.

Figure 5.5 shows how we might label reflective processes differently, depending on the degree of deliberation or planfulness involved. The cube represents basic reflective processes that occur spontaneously or under control of relatively simple agendas on the bottom and reflective processes under control of more strategic planning on the top. Look first at the lower front corner. *Shifting* is a change in perspective as a consequence of overlapping spreading activation patterns. *Initiating* is a change in perspective via strategically controlled activities (such as listing all the properties you can think of for two objects that are to be related). *Refreshing* is activation prolonged by simple attention; *rehearsal* is activation prolonged by systematic, strategically controlled recycling. *Reactivating* refers to the revival of inactive information via spontaneous or accidental mental events that provide a reminder; *retrieval* refers to reviving information through conscious attempts to get back to it. *Noting* involves seeing relations that are relatively direct, and *discovering* involves seeing relations that are less direct. Thus there are at least two layers of internal control, or layers of reflection involved in learning and remembering. The idea that these two layers correspond to two functional subsystems of reflection, R-1 and R-2, is developed elsewhere (Johnson, in press; Johnson & Hirst, in press). (Furthermore, some mental activities could be thought of as combinations of these component processes. For example, the combination of *initiating* and *discovering*, represented along the top edge of the cube, would produce "elaboration" [e.g., Stein & Bransford,

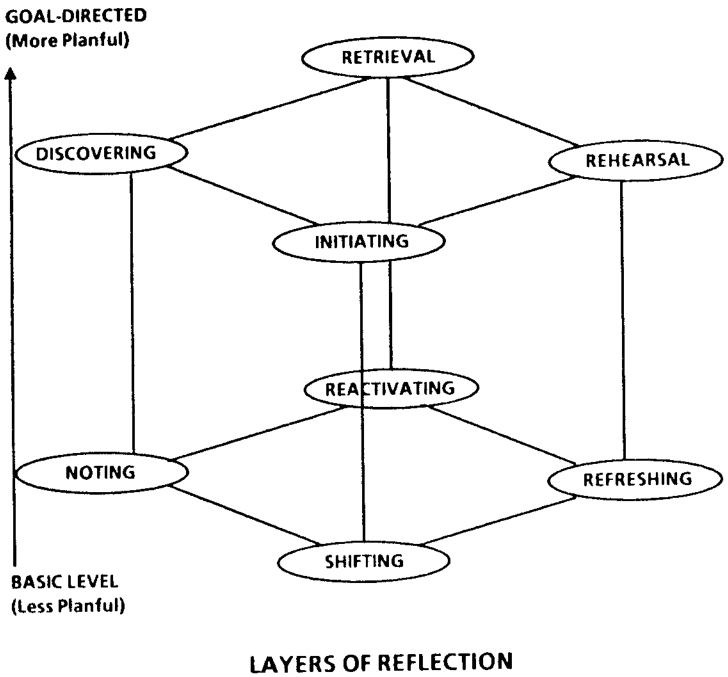

FIGURE 5.5. Reflective processes differ in degree of "planfulness." Basic reflective processes are represented at the bottom corners of the cube; corresponding but more strategic, goal-directed reflective functions are represented at the top corners of the cube.

1979]). To understand amnesia, we need to specify exactly which reflective subprocesses are disrupted and which are not, and among those that can vary in strategic control, which layer of control is disrupted.

Amnesia and Reflective Subprocesses

Amnesia could cause problems with all reflective subprocesses or with only some of them. What is our best guess about amnesia's effect on these basic reflective subprocesses? Several lines of evidence suggest that *noting* given relations is intact. First, amnesics understand ordinary conversation. Also, amnesics do fairly well on easy pairs on the Wechsler Memory Scale (hot–cold). Despite early evidence to the contrary (Cermak & Butters, 1972), it appears that amnesics spontaneously categorize items from taxonomic categories (McDowell, 1979). What we need is more detailed or analytic information about this noting function—for example, what kinds of relationships can be noted, and under what conditions?

A recent study from our lab (Johnson, Hirst, Phelps, & Volpe, unpublished

data) illustrates one potential approach. Nonalcoholic amnesics and normal controls were presented with some difficult-to-understand sentences (e.g., Birnbaum, Johnson, Hartley, & Taylor, 1980; Johnson, Doll, Bransford, & Lapinski, 1974). Half the sentences were preceded by an appropriate context (e.g., *Bagpipes: The notes went sour when the seams split*) and half were preceded by an inappropriate context (e.g., *New car: The house turned to water when the fire got too hot*). As each sentence was presented, subjects were asked to rate how much sense it made. The points over ACQ (for acquisition) in Figure 5.6 show the mean ratings; higher ratings reflect greater comprehension. As you can see, both amnesics and controls showed a large context effect.

Comprehension ratings were also taken later for the sentences alone (without the contexts) at three retention intervals, 2 min, 1½ hr, and 1 week; these ratings are also shown in Figure 5.6. Notice that the effect of having heard a relevant context is relatively long-lasting for amnesics. This is an example of new learn-

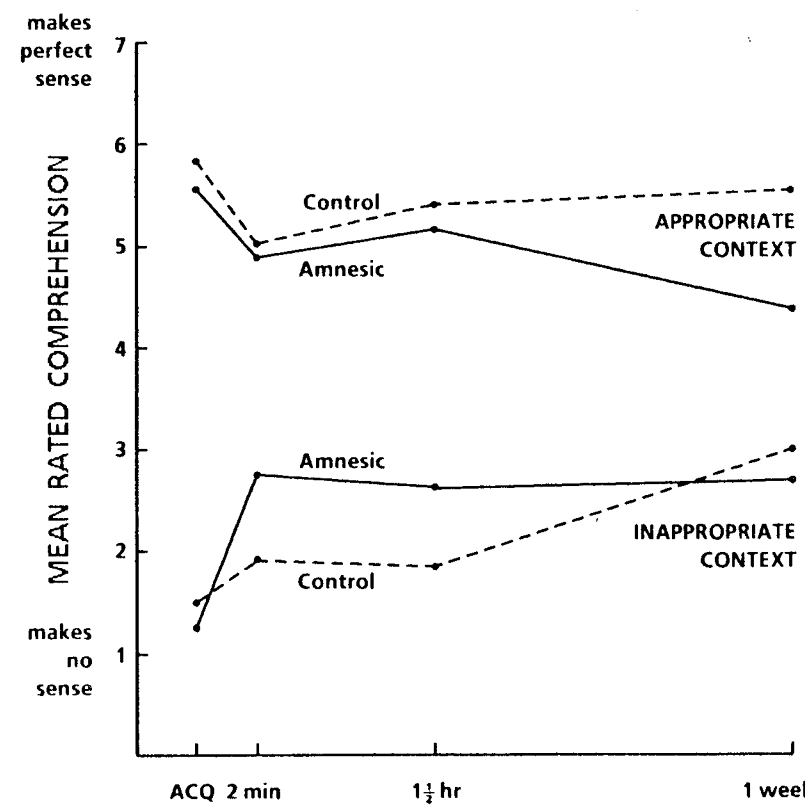

FIGURE 5.6. Mean comprehension ratings for sentences preceded by either an appropriate or inappropriate context at acquisition (ACQ) and later (2 min, 1½ hr, 1 week) presented without contexts (amnesic $N = 4$; control $N = 4$). (Johnson, Hirst, Phelps, and Volpe, unpublished data)

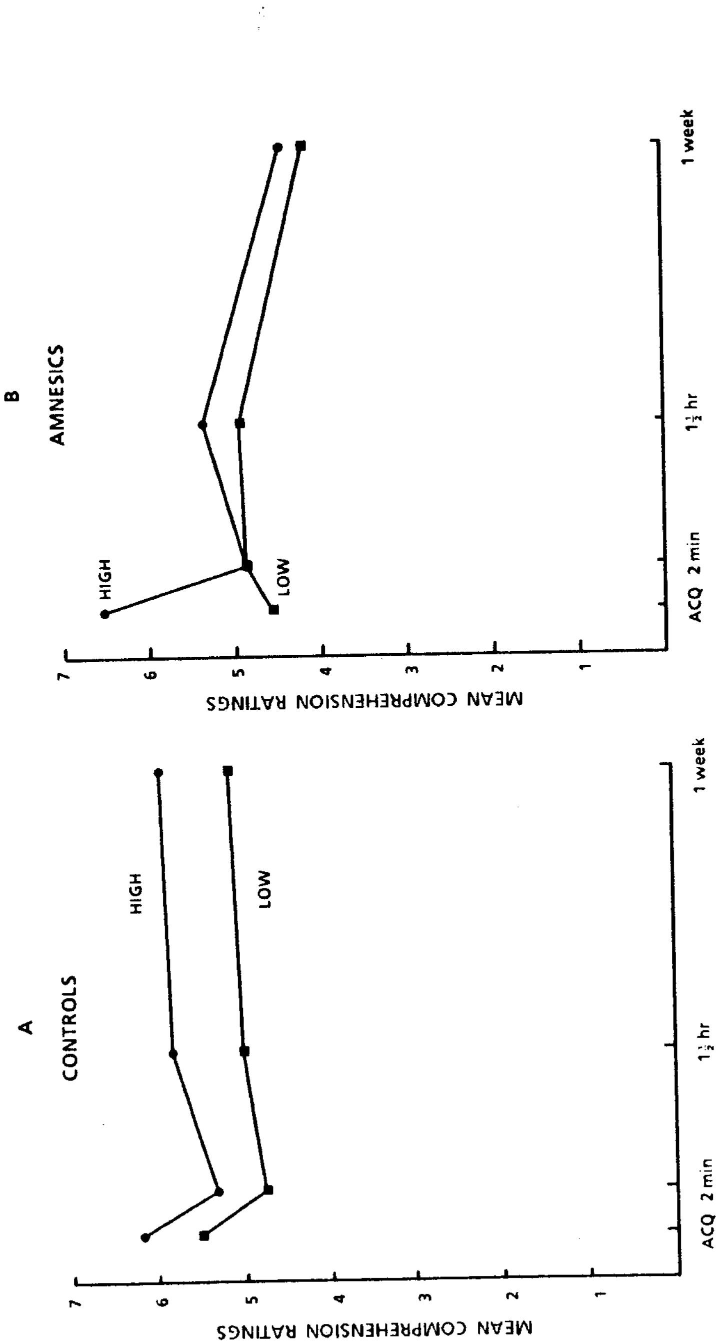

FIGURE 5.7. Mean comprehension ratings for sentences preceded by an appropriate context at acquisition (ACQ) and later (2 min, 1½ hr, 1 week) presented without contexts. Ratings are shown separately for high- and low-related context–sentence pairs and for controls (A) and amnesics (B). (Johnson, Hirst, Phelps, and Volpe, unpublished data)

ing that cannot simply be attributed to short-term priming (see McAndrews, Glisky, & Schacter, 1987, for a similar finding).

We also looked at comprehension ratings separately for sentences in which the context and sentence were highly related and for sentences in which the context–sentence relation was low. Figure 5.7A shows the comprehension ratings for the control subjects; these verify the ratings of the subjects who gave us the normative data for high and low. In contrast to the controls, the amnesics showed a relatedness-by-delay interaction; the initial advantage of highly related items disappeared over the retention interval (Figure 5.7B).

At the 2-min, 1½-hr, and 1-week retention intervals (when sentences were presented without any context), we also asked subjects to tell us what they thought each sentence was about. Table 5.5 shows the mean number of appropriate contexts given in this context-generation task, collapsed across retention interval. There was a subject-by-relatedness interaction; the difference between amnesics and controls was greater on low than on highly related items. The less obvious the relation between the context and sentence was, the more difficulty amnesics had in later describing what the sentence was about (see also Warrington & Weiskrantz, 1982). The initial comprehension ratings taken as the context–sentence pairs were first presented showed a similar (though not significant) pattern.[5]

One reasonable hypothesis supported by the results of our comprehension study is that amnesics are able to note relations that are a relatively direct consequence of activation patterns set up by incoming stimuli. The more distant the relation—the more seeing, or discovering, a connection depends on shifting attention from initially activated but not useful relations to new possibilities—the more problems the amnesic may have.

At the one-week retention interval, we also gave subjects a recognition test on the sentences presented without contexts. Amnesics' recognition of these sentences, although clearly worse than normals, was quite good after a week (Table 5.6). More important, amnesics recognized more of the low-related sentences than the high-related sentences. This recognition advantage of the low-related sentences is interesting because it indicates that amnesics based their recognition judgments on information somewhat different from that used for their compre-

TABLE 5.5 Mean Number of Contexts Given for Sentences Initially Presented with an Appropriate Context (averaged over 2-min, 1½-hr, and 2-week retention intervals)

	Relation Between Context and Sentence	
Group	High	Low
Amnesic (n = 4)	2.33	2.00
Control (n = 4)	2.83	3.25

Source: From Johnson, Hirst, Phelps, and Volpe (unpublished data).

TABLE 5.6 Mean Proportion Correct Yes/No Recognition (1-week delay)

Group	Appropriate Context		Inappropriate Context		New Items
	High	Low	High	Low	
Amnesic (n = 4)	.75	1.00	.69	.88	.72
Control (n = 4)	.94	1.00	1.00	1.00	1.00

Source: From Johnson, Hirst, Phelps, and Volpe (unpublished data).

hension judgments and their attempts to describe what the sentences were about.

One way contexts help comprehension is by activating a schema that is used in interpreting further information and in retrieving it later (e.g., Bransford & Johnson, 1973; Schank & Abelson, 1977). Thus our context study indicates that amnesics can use schemas. Another piece of evidence that amnesics can apply schematic knowledge to incoming information comes from an experiment conducted by Phelps (Phelps, Hirst, Johnson, & Volpe, 1988). Mixed-etiology amnesics and controls were asked to remember two stories. All subjects heard a general story that involved a topic with which most people are familiar (a shopping trip). In addition, each amnesic and his or her control heard a story tailored to the individual interests of each amnesic. For example, one amnesic knew a lot about basketball, so he (and his control, who was not particularly interested in basketball) received a story about a basketball game. As Figure 5.8 shows, the controls recalled a larger percentage of the general story than the subject-specific stories. In contrast, the amnesics recalled a larger percentage of the subject-specific stories than the general story. Thus, although for normal subjects the subject-specific stories were more difficult, they were relatively easy for amnesics because the amnesics were able to draw on their special interest in and knowledge of these areas to aid recall.[6] It would be valuable to have more specific information about the types of schemas that amnesics can and cannot use.[7]

We also do not know much about the subprocess of *refreshing* activated information, but verbal rehearsal seems to be relatively intact. Available evidence from short-term memory experiments with amnesics suggests that when they are not distracted, amnesics are relatively good at *rehearsing* currently activated verbal information (but perhaps not nonverbal information; Milner, 1966). Later recall, however, depends on more than rehearsal (e.g., Glenberg, Smith, & Green, 1977). *Noting* and, if necessary, *shifting* must take place as well. Amnesics may have more trouble than control subjects simultaneously engaging in these various subprocesses (which may require coordinating layers of reflective processes). Thus not only should amnesics show greater disruption when unrelated distraction is introduced, as in typical STM experiments (Cermak, Butters,

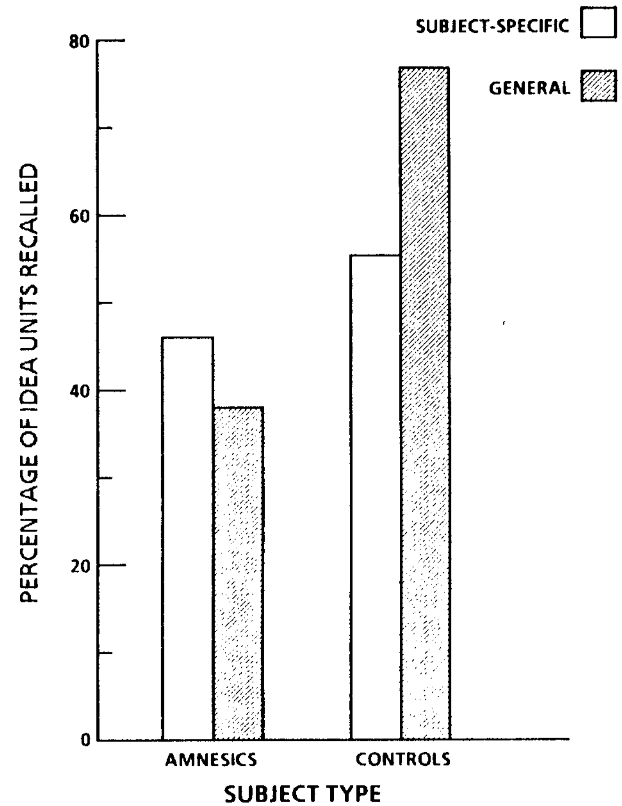

FIGURE 5.8. Mean percentage of idea units recalled from a story about a shopping trip (general) and stories tailored to the interest of amnesics (subject-specific) (amnesic N = 6; control N = 6). (Data from Phelps, Hirst, Johnson, & Volpe, 1988, experiment 1)

& Goodglass, 1971; Kinsbourne & Wood, 1975), but they should also show greater disruption when additional *task-relevant* demands such as *noting* and *initiating* are introduced. For example, in one experiment (Warrington, 1982) subjects were quickly read three words, distracted for 15 seconds, and then tested for recall. Whereas amnesics performed as well as normals if the words were unrelated, they showed a deficit on related-word trials (e.g., drink–coffee–cold).

Clearly, amnesics are impaired on delayed strategic *retrieval* of information that has dropped out of consciousness. But what should be emphasized is the critical role that such delayed reactivation plays in normal memory (Johnson, 1987; Levin et al., 1985; Ribot, 1882/1977). Without subsequent rehearsals, many autobiographical memories do not remain clear or vivid (Suengas & Johnson, 1988). Some investigators suggest that a consolidationlike process in which memories gradually become more resistant to disruption takes place over years (Squire, 1982; Wickelgren, 1979). Whether or not such long-lasting processes are initiated when a memory is first established, it seems clear that the accessibility of memories is related to their subsequent reactivation (also see Squire, 1986, p. 1616) and that the loss of the consequences of reactivation contributes to the amnesic deficit.

TYPES AND DEGREES OF AMNESIA

Investigators have tried to isolate memory deficits from other cognitive deficits, but this is easier said than done (see, for example, discussions by Baddeley, 1982; Kinsbourne & Wood, 1982; Moscovitch, 1982; Warrington, 1982). In practice, isolating memory amounts to either (1) defining amnesia as deficits on certain simple word, picture, and prose recall and recognition tasks (along with clinically diagnosed impaired memory for recent personal events), and considering normal performance on these tasks but disrupted performance on more complex memory tasks to be due to secondary cognitive deficits, or (2) defining amnesia as whatever is disrupted by lesions confined to certain areas of the temporal lobes and diencephalon and attributing memory deficits from lesions in other areas (e.g., prefrontal cortex) to secondary cognitive deficits. Both alternatives imply that the major objective is to understand the "core amnesia" thus defined. From this "core amnesia" point of view, many reflective processes would be considered secondary cognitive processes.

Focusing on "core amnesia," although one reasonable strategy, is based on a perhaps too simple view of memory (also see Morton, 1985). Many cognitive psychologists would argue against the idea that memory can be isolated from other cognitive processes such as attention, comprehension, thinking, planning, and problem solving.[8] Memory is the result of many processes, from those engaged by "simple" perception to those engaged by highly organized plans and schemas. In fact, remembering itself can be thought of as a skill (e.g., Ericsson, Chase, & Faloon, 1980) or a type of problem solving. Thus the idea of "core amnesia" may be misleading. Rather, there may be many types and degrees of amnesia, depending on which combination of memory subprocesses is required for particular memory tasks, and on which memory processes are disrupted.[9] But the fact that few differences among amnesics as a function of etiology have been reported (e.g., Corkin et al., 1985) suggests that reflection is a highly integrated system.

If we adopt a relatively complex view of memory, we should be more likely to attempt to integrate the results from a wider range of patterns of memory deficits, and this (in combination with ongoing efforts in cognition to analyze normal memory functioning) could be quite informative. One goal might be to refine and embellish a preliminary categorization scheme for reflective processes such as the following:

		Strategic Reflective Subprocesses	
		Intact	Disrupted
Basic Reflective Subprocesses	Intact	Normal memory	Deficits in complex information and sequences
	Disrupted	"Core amnesia"	Severe amnesia

According to the scheme, even if certain strategic reflective processes were intact, major disruption in one or more basic reflective processes would produce profound deficits in even the easiest memory tasks ("core amnesia"). If strategic reflective processes were disrupted but basic reflective processes were intact, the patient might show considerable memory for some things but have difficulty with others requiring more sophisticated reflective processing (e.g., complex information, sequences, or temporal orderings). Disruption of both levels of reflection—basic subprocesses and those under more strategic control—would produce the most severe amnesia. It is likely that different types of reflective subprocesses depend on different neurological structures and thus different lesion sites should produce amnesias differing in type or severity. For example, certain temporal and diencephalic lesions may disturb basic reflective subprocesses and certain frontal lesions may affect strategic reflective planning subprocesses (Goldman-Rakic, 1987; Milner & Petrides, 1984; Schacter, 1987a; Squire, 1987; Warrington & Weiskrantz, 1982). This categorization is undoubtedly too simple, but it illustrates the approach of assuming memory depends on a rich repertoire of processes and exploring the relation between specific reflective subprocesses and memory, including the effects of various lesions on these specific subprocesses.

CONCLUSIONS

A fundamental idea embodied in MEM is that it is useful to consider as separate classes those processes initiated and maintained by external stimuli and those initiated and maintained by internally directed reflective processes (e.g., Johnson & Raye, 1981). This idea can help in understanding findings from amnesia and in fact has also figured in recent analyses of prefrontal cortex function (Goldman-Rakic, 1987) and aging effects in memory (Craik, 1986).

Available evidence about preserved learning abilities in amnesics indicates that the deficit is much more specific than was once thought. In terms of MEM, the sensory and perceptual systems appear to be largely intact, whereas the reflective system is disrupted. Furthermore, the reflective system may be only partially disrupted. (I have concentrated on disruptions in reflective functions because these seem to underlie the amnesias that have been most salient in the cognitive literature, but according to the MEM framework there could be memory deficits associated with disruptions in the sensory and the perceptual subsystems as well.)

Clearly, amnesics are affected by events in important ways in spite of their profound memory deficit. Their comprehension of the meaning of stimuli may change, as indicated by comprehension ratings, context generation, and affective responses. They may experience a feeling of familiarity and, under some conditions, show good recognition after long intervals. If appropriately cued, they may show surprising levels of recall and be able to use prior knowledge to aid new learning.

These facts are not consistent with the idea that amnesics show no new "episodic" learning but can only reinforce or "prime" what is in "semantic memory" already (Cermak, 1986). These results are also not easily accounted for by the procedural–declarative distinction (Cohen & Squire, 1980). Ideas that seem closer to describing amnesic deficits have been around for some time: that amnesia reflects a "premature closure of function" (Talland, 1965), failure of consolidation (Milner, 1966; Squire, 1982), disruption of vertical processes (Wickelgren, 1979) or mediated learning (Warrington & Weiskrantz, 1982), an encoding deficit (Butters & Cermak, 1980; Cermak, 1979), a deficit in initial learning (Huppert & Piercy, 1982), or a contextual encoding deficit (Hirst, 1982). These ideas, although somewhat vague or unsatisfactory for various reasons, all focus attention on the fact that amnesic processing is somehow attenuated. Such attenuated processing would disrupt both acquisition and retrieval.

MEM provides one potentially useful framework for further clarifying the nature of amnesic processing. Within this framework, what amnesics seem to have lost is internally guided access to more information than is directly activated by external stimuli. If more information is not needed, as in certain perceptual/motor tasks, priming tasks, understanding ordinary conversation, and recognition of novel stimuli, then amnesics do quite well. But if further reflection is required, an amnesic is at a severe disadvantage. Situations in which further information (and thus reflection) is required include recognition tests in which familiarity alone is not a sufficient cue but in which the source of the familiarity must be specified, the reinstatement of certain types of affect, and, of course, free recall of events. I have also suggested that progress in understanding the role of reflection in amnesia might be made by further decomposing reflection into component subprocesses and then attempting to match these subprocesses with neurological findings (e.g., specific lesion sites).

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Notes

1. Sensory and perceptual subsystems are called P-1 and P-2, respectively, in subsequent papers (Johnson, in press; Johnson & Hirst, in press).

2. In this chapter I do not discuss retrograde amnesia (impaired memory for events occurring before the onset of amnesia), but focus on anterograde amnesia (impaired learning and memory for events and information occurring after the onset of amnesia).

3. Recall and recognition are sometimes treated as measures of "declarative" memory that should be equally disrupted by amnesia (e.g., Squire, 1982). Our comparison of recall and recognition in amnesics indicates that this is not always the case and, at the least, requires that the concept of declarative memory be further analyzed into component subprocesses that may be differentially disrupted.

4. These basic reflective subprocesses are typically fast-acting and perhaps they are largely controlled by variations in activation level in the memory system (e.g., Johnson, 1983). For example, amnesic deficits could be produced by turning down the amount of potential activation level contributed by experience (McClelland, 1985), by reducing the probability that a given level of activation will recruit attention (Johnson, 1983), or by attenuating the spread of activation.

5. With a greater range of difficulty level (or simply more subjects), comprehension ratings (as well as later context generation) would very likely show an increasing deficit for amnesics as difficulty is increased. Comprehension ratings are an example of a task that taps reflective processes without requiring the subject to remember new information (see also Cermak, Reale, & Baker, 1978). Such tasks should help clarify amnesic deficits in reflective processes.

6. Although the focus here is on amnesics' ability to use meaningful schemas, it should be noted that amnesics also showed a marked improvement in recall of unrelated words when the experimenter embedded the words in a bizarre story with high imagery value and gave amnesics spaced practice and cues when needed (Kovner, Mattis, & Goldmeier, 1983).

7. In Phelps et al. (1988) the relevant prior knowledge was presumably acquired before the onset of amnesia. A second experiment (Phelps et al., experiment 2), however, demonstrated that under certain conditions amnesics can also use information acquired after the onset of amnesia to help in learning new information. (Thus they did not show the "hyperspecific" learning reported by Glisky, Schacter, & Tulving, 1986. Also see Hirst, Phelps, Johnson, & Volpe, 1988, and Shimamura & Squire, 1988, for other reports of "flexible" memory in amnesics.)

8. Memory is also often presumed to be independent of something called "intellectual capacity" and thus intelligence is said to be intact in pure amnesia uncomplicated by other problems. But memory is critically involved in most intellectual tasks, from seeing previously unnoted relationships to solving extremely complex problems. Standard IQ tests are probably not the most sensitive way to look for deficits in intellectual functioning that may result from disruption of reflective processes.

9. It has in fact been suggested that there are two types of amnesia: bitemporal (patient H.M. and ECT patients) and diencephalic (patient N.A. and Korsakoff patients) (Squire, 1982). Although it is consistent with the present view of memory that "these two brain regions contribute in different ways to normal memory functions" (Squire, 1982, p. 246), current evidence is quite weak (Corkin, Cohen, Sullivan, Clegg, & Rosen, 1985). The case rests largely on studies of forgetting rates in picture recognition (Huppert & Piercy, 1979b, Squire, 1981b), and one central finding did not replicate (Freed, Corkin, & Cohen, 1984). More sensitive tests, however, developed to discriminate among the various reflective subprocesses outlined here, might be useful in discriminating bitemporal and diencephalic amnesics.

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COMMENTARIES AND ALTERNATIVE PERSPECTIVES