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Evaluating the neuropsychological dissociation evidence for multiple memory systems

JENNIFER D. RYAN
Rotman Research Institute, Toronto, Ontario, Canada

and

NEAL J. COHEN
University of Illinois at Urbana-Champaign, Urbana, Illinois

This article presents a critical evaluation of the logic and nature of the neuropsychological dissociation evidence that has provided one of the essential lines of support for claims of multiple memory systems—specifically, suggesting that amnesia selectively compromises, and an intact hippocampal system selectively supports, a particular form of memory. An analysis of the existing neuropsychological dissociation evidence is offered in which different classes of evidence—different dissociation approaches—are identified and characterized. The logic of these neuropsychological dissociation approaches is evaluated critically in terms of their ability to distinguish among alternative theoretical views. We conclude that although they support a multiple memory systems account, the findings from these types of neuropsychological dissociation, taken individually and without support from other converging lines of cognitive neuroscience evidence, cannot definitively rule out alternative formulations. A more powerful neuropsychological dissociation approach is then outlined, involving *dissociation within condition*, that, by more effectively limiting the critical domains of difference between the dissociated performances, can successfully rule out alternative accounts. Its application in Ryan, Althoff, Whitlow, and Cohen (2000) is described, providing strong support for the power of the dissociation within condition approach.

One of the major developments in memory research in the last several decades has been the advancement of the claim that there are multiple memory systems in the brain and the research it has engendered whose aim has been to identify and characterize (some of) these systems (e.g., Cohen, 1984; Cohen & Eichenbaum, 1993; Cohen, Poldrack, & Eichenbaum, 1997; Cohen & Squire, 1980; Eichenbaum & Cohen, 2001; Graf & Schacter, 1985; Nadel, 1994; Schacter & Tulving, 1982, 1994; Squire, 1987, 1992; Tulving, 1972, 1985; Weiskrantz, 1987). Historically, the key data in arguing for and testing ideas about multiple memory systems has come in the form of neuropsychological dissociation evidence—the ability of patients with amnesia to reliably exhibit instances of fully preserved learning and memory in the face of otherwise profound and pervasive memory deficits. This dissociation between classes of impaired and classes of spared memory abilities in patients with hippocampal system damage has been central in suggesting that amnesia selectively compromises, and an intact hippocampal system selectively supports, a particular aspect or form of memory.

Correspondence concerning this article should be addressed to J. D. Ryan, Rotman Research Institute, Baycrest Centre for Geriatric Care, 3560 Bathurst St., Toronto, ON, M6A 2E1 Canada (e-mail: jryan@rotman-baycrest.on.ca).

However, not all researchers have interpreted the neuropsychological dissociation evidence as requiring a claim of multiple memory systems. Accordingly, rather than relying exclusively on the neuropsychological dissociation evidence, we and others have derived critical support for the claim of multiple memory systems from several converging lines of evidence (e.g., Cohen & Eichenbaum, 1993; Eichenbaum & Cohen, 2001; Gabrieli, 1999; Squire, 1987, 1992; Tulving, 1999). These converging lines include performance dissociations in animal models of amnesia, findings of hippocampal system activation during the performance of some, but not other, memory tasks in functional neuroimaging studies of normal control subjects, and recordings of activity of single cells in the hippocampus in freely behaving animals for some, but not other, memory challenges. Here, as in other areas of cognitive neuroscience, each of the different lines permits the addressing of somewhat different questions about the nature of memory and its organization in the brain; taken altogether, they permit the investigation of memory in both humans and animals, using methods that have very different assumptions. They provide multiple sources of data and multiple sources of constraint on theories about the organization of memory. To the extent that the answers forthcoming from these different lines all converge on a particular view of memory organization—that is, to the extent that a single view can encompass the data across different measures, methods, species, and assumptions—that view can be endorsed with more confidence. It is the convergence of these many lines of evidence that has been most persuasive that there are multiple memory systems in the brain.

Despite the power of the approach involving converging methods, the fact that much of the debate about the multiple memory systems claim has centered on neuropsychological dissociation evidence leads us, in this article, to consider that evidence in isolation, without support from the other converging lines. The question that is central to this article is why the neuropsychological dissociation evidence alone has been less than fully persuasive. We do not attempt to summarize here the full range of data from neuropsychological studies of amnesia; such a review is beyond the scope of this article and can be found elsewhere (Cohen & Eichenbaum, 1993; Eichenbaum & Cohen, 2001). Rather, in this article, we consider the *logic* of work using neuropsychological dissociation evidence, raising some critical questions about why such evidence may be unable to unambiguously support multiple memory systems theories. We point out weaknesses that make it difficult for most existing dissociation findings in the literature, taken in isolation, to definitively rule out alternative formulations of the organization of memory. We then describe a more powerful approach to obtaining neuropsychological dissociation evidence that avoids these pitfalls, and we go on to illustrate its application.

CLASSES OF NEUROPSYCHOLOGICAL DISSOCIATION EVIDENCE

Consideration of the various neuropsychological findings of dissociation in the literature shows important differences among them with regard to the logic or nature of the dissociation—that is, what exactly is being dissociated. These differences are consequential, we will show, with regard to the power of the dissociation to distinguish multiple memory systems accounts from unitary system accounts and to distinguish among different multiple memory systems accounts. On our analysis, we can identify two different classes of neuropsychological dissociation evidence—two neuropsychological dissociation approaches—represented in the existing literature. We will call these *dissociation across tasks* and *dissociation across instruction conditions.* In the sections that follow, we will characterize the two classes in turn, laying out their underlying logic and illustrating the logic with representative examples of their application in the literature. We then will evaluate them critically, examining whether the evidence derived from these representative examples, taken individually, can unambiguously support multiple memory systems theories over alternative formulations of the organization of memory. We will show how each class of neuropsychological dissociation evidence has been used in particular experiments to argue for and against certain theories of memory and amnesia and will point out some critical weaknesses that limit their ability to support a multiple memory systems account exclusively.

Dissociation Across Tasks

The first of the two classes of neuropsychological dissociation evidence used extensively in the literature to support the multiple memory systems claim involves dissociation across tasks. Here, various classes of memory tasks are identified on which amnesic patients are impaired, as contrasted with other classes of memory tasks on which amnesic patients are spared. The logic here is as follows: (1) There are multiple memory systems; (2) one of the memory systems depends critically on the hippocampal system (and/or other) structures that are damaged in amnesia, and this memory system is selectively compromised in amnesia; (3) the different memory systems support different classes of performance; and (4) all those—and only those—task performances dependent on the hippocampal-mediated memory system should be impaired in amnesia.

This approach conforms with the long tradition of work in neuropsychology, in which different tasks are used to tap into and illuminate the functioning of different cognitive systems. Clinically, performance deficits on one or another neuropsychological test, when occurring selectively—that is, in the absence of deficit on other neuropsychological tests—is interpreted as reflecting an isolated, specific impairment to language, attention, executive, or memory systems. Thus, amnesic patients are identified clinically by exhibiting impaired performance on various standardized tests of long-term memory (e.g., on the [30-min] delayed recall tests of word pairs, paragraphs, and line drawings on the Wechsler Memory Scale) in the absence of, or disproportionate to, any impairment on IQ tests and tests of perceptual, attentional, and linguistic performance. Such a pattern of performance of impairment and sparing across tasks isolates the deficit to the domain of memory. That the deficit can be further specified to the domain of *long-term* memory is illustrated by the many findings of dissociation in amnesic patients between their performance on tasks tapping long-term memory versus tasks tapping working memory; amnesia is accompanied by an impairment on the former in the face of sparing on the latter.

Much evidence from this approach has been offered in support of the multiple memory systems claim, in which the pattern of impaired versus spared memory performances across tasks in amnesia has seemed to isolate it to a particular form of long-term memory. The now classic dissociation evidence of this type involves sparing of performance on a variety of skill-learning tasks despite profound amnesia. For example, H.M. showed impressive learning across trials in mirror tracing (tracing the outline of a star when all visual input about the star and the subject's hand is mirror reversed), and many amnesic patients have shown successful incremental learning across trials and across sessions on manual-tracking tasks such as rotary pursuit (maintaining contact of a hand-held stylus with a small disk on a rotating platter; Brooks & Baddeley, 1976; Cohen, 1981; Milner, 1962; Milner, Corkin, & Teuber, 1968). Those preserved learning and memory performances, and others, stand in sharp contrast to the thoroughly documented impairment in amnesia on recall or recognition memory tests for words, sentences, faces, scenes, routes, personal and public events, and so forth. However, as will be outlined later in detail, spared and impaired performance here is documented across tasks that differ on a number of dimensions, including stimulus materials, task instructions, and response requirements. These differences create divergence in the type or mode of processing that may be engaged in performing the task. Therefore, such examples of spared and impaired performance may be due to the use either of different memory systems or of different modes of processing engaged by the two tasks. Different modes of processing may arise from a single, unitary system of memory, thus providing a plausible alternative to the multiple memory systems account.

Dissociation Across Instruction Conditions

The second class of neuropsychological dissociation evidence used to support the multiple memory systems claim involves dissociation across instruction conditions. Here, in each experiment, after subjects are presented with a single kind of learning experience with a single set of materials, performance is assessed under two different types of test instructions that place different demands on memory. The logic here is as follows: (1) There are multiple memory systems; (2) one of the memory systems depends critically on the hippocampal system (and/or other) structures that are damaged in amnesia, and this memory system is selectively compromised in amnesia; (3) the different memory systems support different classes of performances; (4) but many tasks can be supported by more than one of the memory systems, operating separately or in combination; (5) we can constrain how subjects perform a task and, hence, which memory system is engaged, through the use of certain instructions; and (6) with instructions that engage the hippocampal-mediated memory system, performance should be impaired in amnesia, but with instructions that engage other memory systems that are capable of supporting successful performance on a given task, performance should be intact in amnesia.

Two well-cited studies that we take as exemplars of this strategy are those of Cohen and Squire (1980) and Graf, Squire, and Mandler (1984). In Cohen and Squire, subjects read a series of novel and repeated word triplets presented in mirror-reversed text. Memory was assessed under two different instruction conditions. Under one set of instructions, subjects were presented with more mirror-reversed text and were to read the word triplets as quickly and accurately as possible. Memory was assessed in terms of increased speed of reading. Under the other set of instructions, individual words were presented in standard orientation, and memory was assessed with recognition judgments as to which ones had and had not been previously read during the experiment. Amnesic patients exhibited fully intact performance when they were given speeded reading instructions but showed profoundly impaired performance when given recognition memory instructions.

In Graf et al. (1984), subjects were given a word list to study and then were presented at test with word stems, consisting of the first several letters of some studied and some nonstudied words. Memory was tested under two different instruction conditions, differing with regard to whether or not they required the subjects to gain explicit access to (or conscious awareness of) a particular study experience. One set of instructions involved cued recall (*complete the stem with a word from the study list*); the other set of instructions asked for stem completion without reference to the study list (*complete the stem with the first word that comes to mind*). Under stem completion instructions, amnesic patients showed the same bias as did normal control subjects to complete the stem with a word that had been on the study list, exhibiting intact *repetition priming*. But under cued recall instructions, amnesic patients were impaired, as compared with control subjects, recalling fewer words from the study list than did the control subjects.

Both of these dissociation across instruction conditions experiments, and the many others like them in the literature, have much in common with the dissociation across tasks experiments discussed earlier. Specifically, two test conditions involving different instructions certainly could be described as two different tasks. However, they differ in that the dissociation across instruction conditions experiments use a single learning experience. In this way, whatever memory processes and representations were entailed in the initial encoding or learning of information can be held constant—equivalent for the different instruction conditions. This additional level of experimental control is what distinguishes this class of neuropsychological dissociation studies from the first class. However, differences in instructions across task conditions would seem to invoke different modes of processing, along with the intended differences in memory requirements. Thus, again, as in the dissociation across tasks condition, it is possible that spared versus impaired performances may be due to different memory systems that are engaged by the different tasks or to different modes of processing using a single memory system engaged by the different tasks.

EVALUATING THE CLASSES OF NEUROPSYCHOLOGICAL DISSOCIATION EVIDENCE

We turn now to a more detailed description of the two classes of dissociation evidence identified above, illustrating how each has been used to support various claims about the organization of normal memory and the nature of amnesia. It must be noted that the various competing theories all derive support from the same neuropsychological dissociation data. Our analysis here will show that the evidence from studies using the dissociation across tasks and the dissociation across instruction conditions approaches, each taken in isolation, is susceptible to multiple interpretations, including both multiple memory systems accounts and accounts claiming multiple modes of processing. The analysis will also show that this reflects a shortcoming in the ability of these approaches to successfully limit the number of dimensions on which the given example of dissociated (impaired vs. spared) performances differ, preventing identification of the truly critical dimension of difference.

This shortcoming will be illustrated by considering a few well-known experimental findings in the empirical literature. Here, we identify seven dimensions on which the dissociated performances may differ that are plausible candidates for accounting for an observed dissociation in any given case (see Tables 1–5): type of stimuli, methodological and instructional conditions, obtained measures, study–test match (i.e., the extent to which study time and test time tasks are matched in their conditions and requirements), processing requirements, memory representation requirements, and time of test administration (i.e., whether or not the dissociated performances are tested at the same time). To offer one illustrative example, the tests of motor skill learning on which amnesic patients are spared differ from the tests of recall and recognition memory on which amnesic patients are impaired not only with regard to their memory representation requirements, but also in each of the following ways: Testing of these different classes of performances occurs at different times with different types of stimuli, different instructions and processing requirements, and different types of measures (see Table 1 and the discussion below). The obvious dilemma concerns how to show that it is the differences in their memory requirements, and not one or more of these other differences, that should be considered critical for understanding this particular performance dissociation.

Several experiments are considered here with regard to these dimensions. Both of the two neuropsychological dissociation approaches will be seen to be limited in their ability to minimize the dimensions of difference between the dissociated performances. The greater experimental control of the dissociation across task instructions approach over the dissociation across tasks approach will be seen to result in some reduction of the number of potentially relevant dimensions of difference, but it still leaves open too many alternative accounts. Accordingly, a more powerful class of dissociation evidence, with a greater potential for limiting the dimensions of difference between the dissociated performances to their memory representation requirements, needs to be developed.

Before undertaking this analysis, however, we must first introduce several theoretical accounts that will feature prominently in the discussion to follow. We cannot cover all of the various theories of memory in all of their various forms here (see Cohen & Eichenbaum, 1993, and Cohen et al., 1999, for more extended treatments of the range of competing theories). Instead, we will limit our discussion here to three major theories. Although this does not cover the full theoretical landscape in the field of memory, these are the theories that have received the most discussion in the literature, have each claimed support from existing neuropsychological dissociation evidence, and fully serve our present purposes of permitting a critical analysis of different approaches to neuropsychological dissociation evidence.

Theoretical Accounts

For many authors, the neuropsychological dissociation evidence has been interpreted as supporting a multiple memory systems view, in which there are functionally and anatomically distinct memory systems in the brain. Hippocampal amnesia selectively compromises, and an intact hippocampal system selectively supports, one of those memory systems mediating a particular form of memory. Two multiple memory systems ac-

Table 1
Dissociated Performances Using the Dissociation Across Tasks Approach in Early Studies (e.g., Milner, 1962; Milner, Corkin, & Teuber, 1968)

Dimension	Mirror-Tracing Task	Recognition Memory Task
Type of stimuli	**outlined star**	**faces**
Obtained measures	**no. of errors per trial**	**% correct recognition**
Study–test match	**yes**	**no**
Methods/instructions	**mirror tracing**	**face recognition**
Processing requirements	visual form analysis	visual form analysis
	perceptual–motor integration	**face processing**
		conceptual/attributional processing
Memory requirements	**acquisition and expression of perceptual–motor skill**	**memory for faces**
		conscious recollection
		memory for relations
		representational flexibility

Note—Dimensions of difference between dissociated performances appear in bold.

counts that have received particular currency in the literature will be considered here, together with the competing view that there is only one form of memory and that the performance dissociations reflect different forms of processing.

Declarative versus procedural memory. One prominent account of the findings of dissociation between classes of impaired versus spared memory performances in amnesia distinguishes between declarative and procedural memory, proposing that amnesia is a selective deficit of, and the hippocampal system is selectively involved in, declarative long-term memory (Cohen, 1981, 1984; Cohen & Eichenbaum, 1993; Cohen & Squire, 1980; Eichenbaum, 1997, 1999; Eichenbaum & Cohen, 2001; Squire, 1987, 1992). Declarative memory supports the encoding, retention, and retrieval of memory for facts and events, whereas procedural memory supports the acquisition and expression of skilled performance. We will focus here specifically on the particular elaboration and extension of the declarative–procedural distinction that we have offered, based on multiple converging lines of cognitive neuroscience evidence, which holds that the hippocampal system supports long-term memory for all manner of (even arbitrary or accidental) relations among the constituent elements of a scene or an event (see, e.g., Cohen & Eichenbaum, 1993; Cohen et al., 1997; Cohen & Ryan, 2003; Eichenbaum, 1997, 1999; Eichenbaum & Cohen, 2001).

Being able to remember which names go with which faces, the phone numbers of one's various friends or colleagues, the name of the player who scored the winning touchdown in the most recent Super Bowl, or who one ran into at the movie theater two weekends ago is a major challenge for anyone's memory, because the associations between names and faces, or between people and phone numbers, or among the actors and actions that enter into unstaged events are only arbitrary or accidental and cannot be derived fully from other information. This challenge is handled, on our account, by hippocampal-dependent declarative memory through its mediation of a fundamentally relational form of memory. It supports representations of the outcomes of processing of all the various networks or modules that are engaged in comprehending the event or scene—all the items that have been coactivated during processing of any given learning episode. This information is then bound together into long-term memories, thereby capturing the relations among the coactivated items. Tasks that depend critically on such relational memories, such as recall or recognition of the words, objects, or faces that appeared on a list in a specific experiment and the recollection of specific events, are impaired in amnesia.

The learning of new domains of semantic knowledge—that is, of integrated knowledge structures—also demands memory for relations and is likewise impaired in full-blown cases of amnesia. It is for this reason that we have long included both episodic and semantic memory in our description of declarative memory (e.g., Cohen, 1981, 1984; Cohen & Eichenbaum, 1993; Eichenbaum & Cohen, 2001; cf. Schacter & Tulving, 1994; Tulving, 1985).

One other characteristic of the representations supported by declarative memory is what we call *representational flexibility* (Cohen, 1984; Cohen & Eichenbaum, 1993). Declarative memories are not inextricably tied to the original learning context or the original modality of input; rather, they can be accessed and used in novel contexts, under testing situations that are very different from the circumstances of initial learning. Thus, one can remember whom one ran into at the movie theater two weekends ago, regardless of whether one is asked about it verbally or is shown a photo line-up, and regardless of whether one is asked about it at home, while driving in a car, or when back at the movie theater, and one can recall conceptual information about the story, perceptual information about particular scenes from the movie, and all sorts of information about the actors in the movie, regardless of whether one is responding to an oral query, to a written questionnaire, or to photos.

Procedural memory, by contrast, supports nonrelational forms of memory. It is mediated by the ongoing tuning and modification of particular processing networks, making the operations of those processors faster and more efficient for recently experienced items when they are encountered again soon thereafter. Such effects of previous exposure to (i.e., prior processing of) items, in the absence of any requirement to remember such relational information as which scene or events those items appeared in or which other items co-occurred with them, are independent of the hippocampal system. Accordingly, tests that take as their measure of memory increased speed or efficacy of processing of individual stimulus items or a bias toward specific items as a result of recent previous exposure can be fully supported by procedural memory and can elicit intact performance in amnesia. Note that procedural memory is inextricably tied to the changes in specific processing networks and can be expressed only when those networks are again engaged; that is the sense in which such memories are said to be inflexible.

Explicit versus implicit memory. The other dominant multiple memory systems account of the neuropsychological dissociation evidence emphasizes the critical role of conscious recollection of prior study episodes. Based originally on Graf and Schacter (1985) and Schacter (1987), this view addresses the neuropsychological dissociation evidence by holding that amnesic patients are selectively impaired and that the hippocampal system is selectively involved, in explicit memory—that is, in gaining conscious access to memory for, or explicitly remembering, previous learning experiences. Tasks such as recall or recognition of words, objects, or faces from a previously studied list are said to tap the ability to gain conscious access to the memory of the study episode (requiring explicit knowledge of having studied that particular list in that particular laboratory experiment) in order to then determine which items were and were not part of that study episode. The system(s) damaged in amnesia selectively supports the ability to consciously recollect and explicitly remember. A deficit in explicit memory, then, causes amnesic patients to be impaired on such tasks. By contrast, tasks that take any change in processing performance induced by prior exposure as a manifestation of memory do not require explicit remembering of the experience. These tasks are said to invoke implicit memory, independently of the operation of the hippocampal system, and are performed normally by amnesic patients.

This view seems similar to the declarative–procedural memory account that we have offered and, in fact, is often confused with it. However, note that on the explicit–implicit memory view, the critical element determining impaired versus spared memory performance is how memory is assessed—that is, whether it is assessed explicitly and, thus, requires conscious recollection versus being assessed implicitly, without needing conscious recollection of any particular study episode. This dependence on the means of testing was emphasized by Richardson-Klavehn and Bjork (1988), who, rather than distinguishing between explicit and implicit memory, favored drawing a distinction between direct and indirect tests of memory, respectively. On the declarative–procedural memory view, by contrast, the critical issue is whether or not performance requires memory representations of the relations among the elements of some experience or scene. The explicit–implicit account does not make such representational claims.

The reason that these accounts have often been confused with one another is that any explicit (direct) memory test necessarily involves declarative memory for relations. That is, explicit (direct) memory tests require, by definition, the ability to gain conscious access to the prior learning episode associated with the test item, thereby requiring memory for some relation between the to-be-tested item and the prior learning experience in which it occurred. Thus, any deficit on an explicit (direct) memory test, such as that seen in amnesia, could reflect a deficit of explicit memory, of relational memory, or of both. To illustrate with one of our earlier real-world examples, a failure to recall now who it was that one bumped into at the movie theater two weekends ago could reflect (on the declarative–procedural account) a failure of memory for the set of relations between that night, that movie theater, that movie, and that set of people who converged at that time, it could reflect (on the explicit–implicit account) an inability to gain conscious access to the perfectly intact memory of the episode of that particular night at the movies, or it could reflect both types of failure. Accordingly, the same evidence can be—and has been—taken as support for these two competing multiple memory systems theories.

Processing views. The alternative framework for understanding neuropsychological dissociation evidence endorses processing-based views (see, e.g., Roediger, 1990, 2000), in which only a single memory system is postulated. On such views, the different classes of memory test performances that are impaired versus spared in amnesia depend on different processing modes, rather than on different forms of memory—that is, it is a particular mode of processing, rather than a particular form of memory, that is compromised in amnesia. Here, the important difference between, for example, skill learning and recognition memory is said to concern the different processing demands imposed by these tasks. More particularly, on Roediger's (1990, 2000) version of this account, the tasks differ in the match between study time and test time processes and, thus, in *transfer appropriate processing*.

Consider the typical skill-learning task (e.g., mirror tracing or manual tracking), in which the subject performs the same operations over and over throughout the experiment and memory is assessed in terms of the increase in performance across trials. There, the operations being performed at "test" are the same as those being performed at "study;" the distinction between "study" and "test" is only a virtual one, with complete transfer of the processing requirements. Subjects need only express their increasingly skilled performance on each successive trial. By contrast, a recognition memory task involves separate study and test phases, with different processing requirements during the two phases. During study, when subjects first encounter the to-be-remembered stimuli, they must engage in processes that will permit them to identify and comprehend the meaning of each item on the list and then in whatever rehearsal and maintenance strategies or other encoding strategies will help them to remember the items as well as they can. At test, they must invoke retrieval processes, using various search strategies to examine their memories—including the conceptual processing that is associated with gaining conscious or explicit access to memory for the previous study episode—and making attributional judgments as to whether or not a given item that seems familiar is part of that previous study episode.

To return to our real-world example, when asked to remember who it was that one bumped into at the movies two weekends ago, one must engage a particular mode of processing that involves an effortful attempt to gain access to memory for and consciously recollect a specific episode and to make attributional judgments about the source of any information that is retrieved (*Was that when I saw the movie Gladiator or Memento or the Bourne Identity? Was it young Ricky whom we ran into at the movies, or was it at the restaurant beforehand? Was it that occasion, two weekends ago, or any one of the many other movie going occasions in our life?*). This sort of processing is very different from what one did while at the movies, when one was engaged in taking in the movie, visiting with friends, eating popcorn, and so forth. Clearly, there is a large mismatch here between the mode of processing at study time and the mode of processing at test time.

Tasks that differ more in terms of study–test match are said to require more conceptual or attributional processing at test time in order to bridge the difference in processing between study time and test time. On processing views, it is this conceptual or attributional processing that is selectively compromised in amnesia, interfering with the ability to deal with mismatch between study time and test time processes and preventing the subjective component of remembering.

It is important to note that multiple memory systems views do not deny the critical role of different memory processes. Where they differ from processing theories, in our view, is in the claim that there are different *forms* of memory—different types of memory representations supported by the multiple systems. Thus, on a multiple memory systems view, the deficits in new learning in amnesia result from the failure to form and/or maintain and/or retrieve and use a particular type of memory representation (e.g., relational memories, in our declarative–procedural account). Note here the specification of amnesia in terms of particular processes operating on a particular class of memory representations. However, on a processing view, the deficits are said to arise from a failure specific only to a particular mode or type of processing (e.g., conceptual, attributional, or conscious processing), without regard to which representations are to be operated upon. (For other views of the issues associated with distinguishing between multiple memory systems and processing accounts, see Foster & Jelic, 1999; Roediger, 2000; Sherry & Schacter, 1987; Tulving, 1999).

Having briefly sketched these three alternative theoretical perspectives, we will use them, in the following analysis of neuropsychological dissociation evidence, to examine the strengths and weaknesses of the two neuropsychological dissociation approaches we identified above.

Dissociation Across Tasks

The first of the two classes of neuropsychological dissociation evidence used extensively in the literature to support the multiple memory systems claim is what we have called the *dissociation across tasks* approach. We will examine its ability to isolate the critical dimensions of difference between the dissociated performances and, thereby, to determine what it is capable of telling us about the nature of amnesia and the organization of normal memory. The classic evidence using this approach comes from the findings of spared motor skill learning despite impaired recall or recognition memory in amnesia, as we have seen. Two specific examples will be considered here.

In the mirror-tracing task used by Milner (Milner, 1962; Milner et al., 1968), a drawing of a star is presented, which can be seen only in mirror-reversed form. The subject is to trace the outline of the star while viewing it and his or her hand through a mirror, trying to stay between a pair of lines representing the outer edge of the star. This is done over and over again across a set of identical trials. The measure of memory is the reduction across trials in the number of errors (i.e., in the number of times the pencil falls outside the lines while tracing). This task is the same for the "study" exposures as for the "test" exposures. As is the nature of skill-learning tasks, the same task is presented on every trial of the experiment, with the same stimulus, and performance is assessed throughout. The processing requirements of this task include visual form analysis and perceptual–motor integration, to appreciate the shape and dimensions of the star and to use that information to guide the hand along the outline of the star with sufficient precision; those processing requirements are the same for "study" as for "test." The memory requirements of the task involve the acquisition and expression of perceptual–motor skill, in order to show improvement in performance across trials.[1] The descriptions of this task with regard to each of the seven dimensions are summarized in Table 1.

Consideration of other examples of motor skill learning in amnesia leads to a nearly identical analysis. For example, the rotary pursuit task on which amnesic patients have successfully shown incremental learning (e.g., Brooks & Baddeley, 1976; Cohen, 1981; Corkin, 1968) involves the repeated presentation, on each trial, of a small target circle on a platter rotating at a certain speed. The subject is to maintain contact of a hand-held stylus with the target circle, over and over again across a set of identical trials. The measure of memory, as above, is the reduction across trials in the number of errors—in this case, the number of times the stylus loses contact with the target circle. (An additional measure is the corresponding increase in the percentage of time the stylus stays on target.) For this task, too, there is a complete match between "study" and "test," since the same task and stimulus are presented on every trial of the experiment, and performance is assessed throughout. The processing requirements of this task include visual form analysis, analysis of target speed and trajectory, and perceptual–motor integration, in order to apprehend the "path" that the target circle is taking in time and space and to use that information to track the target with the stylus with sufficient precision. The memory requirements of the task involve the acquisition and expression of perceptual–motor skill, involved in getting better able to see and anticipate the moving position of the target circle in order to show improvement across trials in tracking performance.

By contrast, consider the tests of recall or recognition memory on which amnesic patients are so impaired. As an example, let us take the recognition memory for faces, on which H.M.'s impaired memory performance was contrasted to his impressive learning of mirror tracing in Milner et al. (1968). In this task, a set of previously unfamiliar faces is presented, and the subject is to make either a gender decision or an age decision about each face. This constitutes the "study" phase of the experiment, although no mention is made to the subject of a subsequent memory test (i.e., incidental learning instructions are used). Then there is a subsequent test phase, in which there is another presentation of faces, some of which were previously presented in the study phase (*old*) and some of which are presented for the first time at test (*new*), and the subject is to make a yes/no recognition decision for each face. The measure of memory is the degree of success in correctly identifying which of the faces had been presented previously. The task is thus quite different for the study phase than for the test phase, with different processing and memory requirements for study than for test. At study, the processing and memory requirements include the following: visual analysis of faces, involving the extraction of information necessary to determine age and gender; memory retrieval of preexperimental knowledge about the features of faces that are diagnostic of male versus female and old versus young, such as hair length, smoothness of skin, and so forth; and incidental encoding of the study time faces. The processing and memory requirements at test include visual analysis of faces, involving the extraction of information necessary to determine previous exposure, and memory retrieval of previously presented faces.

There are some additional requirements that are more theory bound. Proponents of the explicit–implicit memory distinction would emphasize the requirement in this task (but not in the skill-learning tasks) for conscious recollection of the study episode, to permit the subject to judge which faces were encountered during that episode. Adherents of the declarative–procedural memory distinction would highlight the requirement in this task (but not in the skill-learning tasks) for memory for relations among the various faces presented during study and the other cues that were part of the study event, so as to permit the subject to judge which faces were associated with that event. They would also emphasize the requirement for representational flexibility, permitting the subject to take memory for information presented in the context of making gender or age judgments and to use that memory in the context of making judgments of previous occurrence. Supporters of a processing view would point to the requirement in this task (but not in the skill-learning tasks) for conceptual and attributional processing, to permit the subject to correctly attribute his or her familiarity for, or knowledge of, the *old* test faces to their having been viewed during the study phase. And they would appeal to transfer-appropriate processing, emphasizing the difficulty in transferring the fruits of processing done in the study phase to the processing demands of the test phase.

The descriptions for each of the seven dimensions for the face recognition task are summarized in Table 1, presented in comparison with those for the mirror-tracing task. It is clear that the two tasks differ not only in their memory representation demands, but in all the other dimensions as well. Thus, the dissociation of performance seen in amnesia here is between two different tasks, tested at different times with different stimulus materials, different methods and instructions, and different types of measures, and differing in their processing and memory requirements, as well as in the match between study time and test time requirements. On the basis of these differences across dimensions, one may argue, for example, that amnesic patients are impaired at processing the fine differences among various face stimuli, whereas perceptual–motor integration is intact. That account then would highlight differences in processing requirements across the two tasks. These two modes of processing may arise from a single memory system, or the processes may be unique to separate systems of memory. Therefore, a multiple memory systems explanation is not necessarily required to explain the observed dissociation. Accordingly, although multiple memory systems claims provide a good account of this performance dissociation by attributing the dissociation to the difference in memory representation requirements, alternative explanations that emphasize the other dimensions of difference can be supported just as well. For that reason, these data do not provide much leverage in permitting us to distinguish among the major alternative accounts considered above, each of which draws support from these findings.

Table 2
Dissociated Performances Using the Dissociation Across Instruction Conditions Approach in Cohen and Squire (1980)

Dimension	Mirror-Reading Instructions	Recognition Memory Instructions
Type of stimuli	**mirror-reversed word triplets**	**standard orientation words**
Obtained measures	**reading time per triplet**	**% correct recognition**
Study–test match	**yes**	**no**
Methods/instructions	**mirror reading**	**word recognition**
Processing requirements	visual pattern analysis word form analysis speech production	visual pattern analysis word form analysis **conceptual/attributional processing**
Memory requirements	**word/letter knowledge retrieval** **acquisition and expression of perceptual skill**	**memory for words** **conscious recollection** **memory for relations** **representational flexibility**

Note—Dimensions of difference between dissociated performances appear in bold.

Dissociation Across Instruction Conditions

The second class of neuropsychological dissociation evidence used to support multiple memory systems claims comes from what we have called the *dissociation across instruction conditions* approach. In order to provide a more focused test of the possibility of multiple memory systems, Cohen and Squire (1980) used a single kind of learning experience, with a single set of stimulus materials, and then tested with different instructions that placed different demands on memory. The performance dissociation that emerged in amnesia (normal acquisition and expression of skill in mirror reading but impaired recognition memory for the same words) was very influential in pressing the multiple memory systems claim. But how well does this paradigm really fare with regard to reducing the dimensions on which the dissociated performances differ, with respect to our seven dimensions? As will be outlined in the following discussion and summarized in Table 2, despite the power of Cohen and Squire's dissociation, it will fail, in the analysis here, to isolate memory differences as the sole dimension of difference. In our second example of dissociation across instructions conditions, Graf et al. (1984) presented a more controlled study that was an improvement over Cohen and Squire's design, but this study, in the end, will also fail to isolate the memory dimension as the one to which dissociations in amnesic performance could be attributed. Thus, despite increased methodological controls from Cohen and Squire's to Graf et al.'s study, the critical debate between a multiple memory systems account and a unitary system view remains unresolved.

In Cohen and Squire's (1980) paradigm, the subject reads a series of word triplets presented in mirror-reversed text, some presented only once during the course of the experiment (*novel*) and others presented in each successive block of the experiment (*repeated*). The task is to read each triplet aloud as quickly and accurately as possible; a given triplet stays on the screen until the subject reads all three words correctly. This constitutes the "study" phase for both to-be-tested performances, although the subjects only instructions are to read the words, and no mention is made of a subsequent memory task. Memory is then assessed in two different ways, under two test instruction conditions.

Under mirror-reading instructions, the subject is once again instructed to read the mirror-presented word triplets as quickly and accurately as possible. Thus, the task and the performance measures remain equivalent across the study and the test conditions. The processing requirements include visual pattern analysis, word form analysis, and speech production, in order to correctly discriminate and interpret the mirror-reversed letters (especially, in distinguishing *b*s from *d*s, *p*s from *q*s, etc.) so as to correctly identify and read the words. The memory requirements involve memory retrieval of preexperimental knowledge about visual features of letters and words, to help guide analysis of letter and word forms, and the acquisition and expression of perceptual skill, involved in learning the mapping between mirror-reversed and standard orientation text, in order to show improvement across trials in reading performance.

Under recognition memory instructions, the subject is to make a yes/no recognition decision for each item, old and new, presented in standard orientation. As with the face recognition task described above, the measure of memory is the ability to correctly identify which of the words have been presented previously. Different types of processing and memory representations are required for study than for test in recognition memory, unlike with mirror reading. At study, the processing and memory requirements are those of mirror reading. At test, the processing and memory requirements include visual pattern and word form analysis of the standard orientation words and memory for the recently read words, extracting and using whatever information may be helpful in determining previous exposure.

In addition, the major competing theories under consideration here hold that recognition memory has other requirements, including (depending on which theory one consults; see above) conscious recollection of the study episode, memory for relations among the various items presented during study and the other cues that were part of the study event, representational flexibility, and conceptual and attributional processing, in order to correctly identify *old* items as having been encountered during this particular experiment.

When one compares across the two columns in Table 2, it is clear that the dissociated conditions differ on dimensions other than memory representation demands, as imposed by the two distinct test instruction conditions. The dissociated performances are assessed at different times with different stimulus formats (single words in standard orientation vs. word triplets in mirror-reversed form), using different instructions and obtaining different types of measures. As well, the two different test time instructions impose differences in processing and memory requirements—for example, in the need for conceptual or attributional processing in one but not the other task and in the match between study time and test time requirements. Therefore, these differences in processing requirements do not necessarily require invoking a multiple memory systems account to explain the observed dissociation in performance. That is, multiple processes may arise from a unitary memory system, with spared and impaired performance being observed on those processes, rather than on any memory system itself. Accordingly, although this paradigm does reduce the number of dimensions on which the dissociated performances differ, as compared with the paradigms using the dissociation across tasks approach, there are many differences that remain. As a result, various alternative explanations of the dissociation that emphasize those other differences can be offered, keeping alive all of the major competing accounts under consideration here.

Our second example is Graf et al. (1984), in which they found normal performance in amnesia under stem com-

Table 3
Dissociated Performances Using the Dissociation Across Instruction Conditions Approach in Graf, Squire, and Mandler (1984)

Dimension	Stem Completion Instructions	Cued Recall Instructions
Type of stimuli	word stems	word stems
Obtained measures	no. of study list words generated	no. of study list words generated
Study–test match	no	no
Methods/instructions	**word stem completion:** ***(fill in the stem with the first word that comes to mind)***	**cued recall:** ***(fill in the stem with a word from the study list)***
Processing requirements	visual pattern analysis letter and word form analysis (word) speech production	visual pattern analysis word form analysis (word) speech production **conceptual/attributional processing**
Memory requirements	retrieval of word knowledge memory for study list items	memory for study list items **conscious recollection** **memory for relations** **representational flexibility**

Note—Dimensions of difference between dissociated performances appear in bold.

pletion instructions but impaired performance for the same items under cued recall instructions. Let us consider this paradigm with regard to our seven dimensions. The comparison between conditions is summarized in Table 3.

Here, as in Cohen and Squire's (1980) paradigm, there is a single learning experience with a single set of stimulus materials and study instructions. The subject is presented with a series of words and is to make a judgment on each one; the decision involves either how many vowels the word contains or how "likeable" it is. This constitutes the "study" phase for both to-be-tested performances, although the subject's only instructions concern the judgments that are to be made, and no mention is made of a subsequent memory task. Memory is then assessed in two different ways, under two test instruction conditions, but with the same set of test items. The test items are word stems, constituting the initial letters of words, half of which had been presented on the study time list for that subject and half of which had not been presented previously to that subject, and vice versa for another subject. For example, one subject's study list will include the word *motel*, but not the word *cycle*, and the opposite will be the case for the other subject; but at test, both subjects will see the stems *mot*__ and *cyc*__.

Under stem completion instructions, the subject is to complete the stem with the first word that comes to mind. Each stem can be completed to form several different words. The measure of memory is the increased likelihood of completing a stem to form one of the recently studied words for stems of words that had been on the study list—that is, in the example above, a higher probability of completing *mot*__ to *motel* than of *cyc*_ to *cycle* for the first subject, and vice versa for the second subject. The processing requirements include visual pattern analysis, letter and word form analysis, and (word) speech production, in order to generate legal word completions. The memory requirements involve memory retrieval of (preexperimental) word knowledge, with which to compare the presented word stems, as well as some aspect of memory for (or increased fluency, activation, or accessibility of) recently presented words from the study list that would make those items more likely to be generated at test. These requirements differ in various ways from those at study, which include letter analysis and processing of word form and word meaning, so as to enable decisions about the number of vowels in and the likeability of any given study list word. They also include incidental encoding of the words.

Under cued recall instructions, the subject is to complete each word stem with a word from the study list. That is, the stems are to be treated as cues for recalling particular words from the list. The measure of memory is the number of study list words generated in response to the recall cues. The processing requirements include visual pattern and word form analysis and (word) speech production, in order to compare the presented word stems with words retrieved from memory so as to correctly generate words that were on the study list and that match the stem cue. The memory requirements include memory retrieval of recently presented words. In addition, the major competing theories under consideration here would also include conscious recollection of the study episode, memory for relations among the various items presented during study and the other cues that were part of the study event, representational flexibility, and conceptual and attributional processing, so that words from the specific list of words presented in the study phase of the experiment can be correctly elicited by the stem cues.

Just as in the other condition, the test time requirements differ in various ways from those at study, which, as was described above, include letter analysis and processing of word form and word meaning, so as to enable decisions about the number of vowels in and the likeability of any given study list word. They also include incidental encoding of the words.

An inspection of Table 3 and a comparison with the earlier tables makes clear that this paradigm does reduce the number of dimensions on which the dissociated performances differ, moving us in the right direction. Graf et al.'s (1984) study improves over Cohen and Squire's (1980) study in that the type of stimuli and the measures obtained are now equivalent across the instruction conditions. But just as clearly, the dissociated conditions differ not only in their memory demands, but on other dimensions as well. These differences are imposed by the distinct test instructions, which necessarily entail different processing and memory requirements, as is illustrated in Table 3. Thus, despite the methodological improvements over Cohen and Squire's study, Graf et al.'s work did not isolate the memory dimension, which is critical to distinguishing a multiple memory systems account from a unitary system (or processing) view. Accordingly, various alternative explanations of the dissociation that emphasize those other differences can be offered.

For example, for both this experiment and Cohen and Squire (1980), it is possible to argue that it is the difference in processing demands at test time elicited by the different test instruction conditions that is the critical element for understanding the performance dissociations. Thus, processing-based views, in which only a single memory system is postulated, can be maintained as an alternative to multiple memory systems accounts of these particular findings by arguing that amnesic patients have a deficit in conceptual, attributional, or conscious processing. It is worth noting here that, with the dissociation across instruction conditions approach, it is especially difficult to distinguish between the processing view and the particular variant of a multiple memory systems view embodied in the explicit–implicit memory distinction. The explicit–implicit memory distinction is the most process oriented of the multiple memory systems accounts. Its crucial assertion is that the memory systems differ fundamentally in the extent to which they support conscious recollection or conscious awareness of some prior learning episode and that tasks that require the ability to consciously recollect are impaired in amnesia. Tasks that would test this view with the dissociation across instruction conditions approach necessarily involve a comparison between pairs of conditions that require versus do not require the particular mode of processing used in remembering consciously, which in turn necessarily leaves both memory requirements and processing requirements as dimensions of difference between the dissociated performances.

Moreover, the limitations of evidence from this dissociation approach are apparent even if we choose to interpret the evidence wholly within a multiple memory systems framework. Our analysis makes clear that one cannot use the examples of neuropsychological dissociation evidence considered above to adjudicate between the declarative–procedural memory account and the explicit–implicit memory account. As long as the different instructional sets used to dissociate performance emphasize explicit (direct) versus implicit (indirect) testing of memory, as is the case in the examples here, the conscious component of explicit memory is confounded with the relational component of declarative memory, as has been described above.

Limitations and Solutions

The foregoing considerations illustrate weaknesses in the existing neuropsychological dissociation approaches that prevent current findings in the literature, taken in isolation, from definitively ruling out alternative formulations of the organization of memory. However, identifying limitations in the existing approaches to neuropsychological dissociation evidence should not be confused with an indictment against the multiple memory systems view. That is, the issues raised here cast doubt on the power of existing empirical approaches to adequately test the theoretical claims or, more accurately, to adjudicate among competing theories; the limitations considered here are not about the substance of the theoretical claims. This leaves the question, How can we garner the kind of evidence needed to decide among the theories? Two solutions are available: to not consider the neuropsychological dissociation evidence in isolation but, rather, to always bring to bear evidence from other converging lines or to develop a more powerful neuropsychological dissociation approach that avoids the critical weaknesses identified with the existing approaches discussed above. These will be discussed in turn.

The first of these two suggestions is the converging methods approach that has been widely adopted in cognitive neuroscience. As was indicated earlier, claims about multiple memory systems in general and about our multiple memory systems theory in particular have, from the beginning, taken evidence from and endeavored to provide an account not only of human neuropsychological dissociations, but also of human functional imaging data and findings from both lesion and electrophysiological recording studies of animals. We have explicated the relevant findings in detail elsewhere (Cohen & Eichenbaum, 1993; Eichenbaum & Cohen, 2001) and will not recount them here. But the fact of the matter is that there are data from other converging cognitive neuroscience lines of evidence that existing processing views just do not explain and that, taken together with the neuropsychological dissociation evidence, provide a way to choose among the potential theories discussed above.

Consider, for example, the various neuroimaging findings of hippocampal activation during incidental encoding of words, faces, or pictures and the correlation between that encoding time activity and success in subsequent memory tasks (Brewer, Zhao, Desmond, Glover, & Gabrieli, 1998; Kelley et al., 1998; Kirchoff, Wagner, Maril, & Stern, 2000; Martin, Wiggs, & Weisberg, 1997; Stern et al., 1996; Wagner et al., 1998). In these studies, there was no requirement for conceptual or attributional processing and no need to consciously recollect some previous learning experience, because brain activity was assessed not at test time but at encoding time. One might argue that conscious recollection is part of what subjects do in the course of encoding, but some of the successful demonstrations of hippocampal activation at encoding have involved studies in which nonfamous faces or unfamiliar scenes were used as the stimuli, for which subjects had no previous experience to recollect (see the review in Cohen et al., 1999).

Or consider the well-established findings that single neurons in the hippocampi of freely behaving rats fire preferentially to particular conjunctions of cues—that is, the relations among various objects, locations, and task-relevant behaviors while the animals navigate through their environment (see the review by Eichenbaum, 2000). During the course of whatever processing the animal is doing, different hippocampal neurons take on different firing preferences, each firing preferentially to one or another specific combination of and relations among the constituent elements of the environment. This apparent mapping of the spatial and other relations in the environment by the set of hippocampal neurons is well handled by a theory that attributes a special role to the hippocampus in the formation and use of (declarative) memory for relations but has no obvious explanation in processing accounts that posit conceptual, attributional, or, especially, conscious processing as the role of the hippocampus. Nor does it find an explanation in the multiple memory systems account that claims a selective role of the hippocampus in explicit memory; it is difficult to see how the tasks that elicit such hippocampal neuron activity in these animals could be said to require conscious recollection of previous episodes. This criticism is true of the animal studies in general, in which one is hard pressed to show that the memory tasks on which animals with hippocampal lesions fail are exclusively those for which normal animals use conscious recollection.

Accordingly, it seems that the limitations of the neuropsychological dissociation evidence can be overcome by making use of these other lines of evidence to successfully constrain the theories we are considering. Here, as elsewhere, science is well served by bringing to bear as much evidence as possible. Rarely is there the single critical experiment capable of resolving all debates in a given field; rather, multiple findings are used to constrain the problem space of possible solutions. But a reasonable goal would be to expect each *line* of evidence to be strong enough to be taken in isolation and, of particular relevance here, to seek neuropsychological dissociation evidence that does not suffer from the limitations discussed above.

This brings us to our second suggestion—namely, to develop a more powerful neuropsychological dissociation approach that avoids the critical weaknesses that have prevented us from successfully ruling out alternative accounts, without appealing to other converging lines of evidence. One such dissociation approach is outlined and illustrated in the next section. Regardless of whether one is considering the particular theories under discussion here or other theories and whether the domain is memory or some other cognitive ability, an approach to neuropsychological dissociation evidence that brings us closer to being able to isolate a single dimension of difference would be an important advance.

TOWARD A MORE POWERFUL CLASS OF NEUROPSYCHOLOGICAL DISSOCIATION EVIDENCE

We have argued that the limitations of existing classes of neuropsychological dissociation evidence arise from the failure to successfully minimize the dimensions of difference between the dissociated performances. The ideal approach would permit isolation of memory requirements as the single critical dimension of difference between conditions showing performance dissociations in amnesia. We now describe a *dissociation within condition* approach, suggesting that it has the greatest potential for targeting differences in memory representation requirements to the exclusion of other differences and, thereby, for providing more definitive tests of multiple memory systems claims.

Dissociation Within Condition

This strategy involves testing with a single set of materials on a single task with a single set of instructions and deriving measures sensitive to (or revealing of) different forms of memory simultaneously, thereby holding constant everything except the memory requirements. The logic here is as follows: (1) There are multiple memory systems; (2) one of the memory systems depends critically on the hippocampal system (and/or other) structures that are damaged in amnesia, and this memory system is selectively compromised in amnesia; (3) the different memory systems are always processing in their own modes, at the same time, for the same materials; (4) we can devise measures sensitive selectively to the operation of each of the separate systems; (5) normal subjects should show evidence of the operation of the separate systems, assessed simultaneously; and (6) amnesics should show evidence of intact operation only of those memory systems that work independently of the hippocampal system.

This approach has been applied to the issue of preserved versus impaired memory performances in amnesia in a recent series of studies in which subjects were presented with a set of scenes under a single instructional set and their eye movements were monitored while they viewed the scenes (Ryan, Althoff, Whitlow, & Cohen, 2000). We found that different aspects of eye movement behavior, collected simultaneously, revealed different aspects of memory for subjects' prior viewing history with the scenes. One set of eye movement measures was sensitive to previous exposure to (i.e., repetition of) scenes, providing an index of memory for items (here, whole scenes), whereas another set of eye movement measures was sensitive to manipulations of the relations among elements of those previously viewed scenes, providing an index of memory for relations. We found that amnesic patients showed the effects of repetition just as did normal control subjects but failed to show the normal effects of manipulation of relations. Given that there was a single class of materials, a single set of instructions, and a single class of (eye movement) measures collected at the same time, this evidence of dissociation within condition makes a particularly compelling case that amnesia is a deficit in, and the hippocampal system is specialized for, a particular aspect or form of memory.

First, we will describe the paradigm and results in a little more detail. We then will explicate the way in which it constitutes an application of the dissociation within condition approach and show how it manages to avoid the limitations of the previous dissociation approaches.

In this work, the subject sees a series of images of real-world scenes, some presented only once during the experiment (novel scenes), some presented in the same form once in each of the three blocks of the experiment (repeated scenes), and some presented once each in the first two blocks and then presented in manipulated form in the final, critical block (manipulated scenes). Manipulated scenes involve a modification of the relations among the scene elements, including deletions, additions, or left–right (or right–left) shifts of one of the objects from the original form of the scene. Any given scene is viewed by the subject in only one form (novel, repeated, or manipulated) but is viewed equally often in the different forms across subjects. Thus, the physically identical scenes that are viewed as manipulated by one subject are viewed as unmanipulated (novel or repeated) by other subjects.

The subject's task is to answer a question about the relations among the depicted elements for each scene displayed on the monitor (e.g., *are there kittens behind the boy?*). The instructions make no mention of a subsequent memory test or of the possibility of manipulations of the scenes. Eye movements are monitored throughout viewing. Note that there is no eye movement response required of the subject; it is incidental to the subject's task. There is no distinction to be drawn between study and test phases, because the same task, the same type of stimulus materials, and the same instructions are used throughout the experiment. The measure of memory is provided by differences in eye movement patterns elicited to physically identical scenes as a function of differences in their viewing histories.

From the eye movements recorded continuously, we derive two classes of measures, obtained simultaneously. One set of measures compares eye movements elicited to previously viewed scenes versus the very same scenes when they are novel. Differences in viewing scenes when they are novel versus repeated constitute a *repetition effect*, reflecting item memory for (previous exposure to or repetition of) the scenes. The other set of measures compares eye movements elicited to manipulated scenes versus the (very same) scenes when they are repeated in the same unmanipulated form throughout the experiment. Differences in viewing scenes when they are manipulated versus repeated unmanipulated and, particularly, increased viewing directed to the very region of the manipulation in manipulated scenes (e.g., greater viewing directed to the now empty region of a scene where a kitten had been in previous viewings of that scene, as compared with viewing of that same region when it had always been empty) constitute a *relational manipulation effect*, reflecting memory for relations among the constituent elements of scenes. Scenes with these different types of viewing histories (novel, repeated unmanipulated, and manipulated) are intermixed.

The findings were that normal control subjects showed both types of eye movement effects. They showed memory for items: There was significantly greater sampling of the scene by the eyes (higher number of fixations within the fixed viewing period) and significantly more regions of the scene sampled by the eyes when the scene was novel than when it was repeated. And they showed memory for relations: There was significantly greater viewing directed to the very region of manipulation (higher proportion of total fixations and higher proportion of total viewing time) when the scene was manipulated than when it was repeated. The latter effect occurred whether or not the subjects were consciously aware that a manipulation had occurred; that is, it occurred even for scenes that the subjects could not tell had been manipulated. But amnesic patients showed only the repetition effect, which was of the same magnitude as

Table 4
Dissociated Performances Using the Dissociation Within Condition Approach in Ryan, Althoff, Whitlow, and Cohen (2000)

Dimension	Measure 1: Repetition Effect	Measure 2: Manipulation Effect
Type of stimuli	images of real-world scenes	images of real-world scenes
Obtained measures	patterns of eye movements	patterns of eye movements
Study–test match	yes	yes
Methods/instructions	answer yes/no orienting question: (*Are there kittens behind the boy?*)	answer yes/no orienting question: (*Are there kittens behind the boy?*)
Processing requirements	visual object and scene perception processing of spatial relations	visual object and scene perception processing of spatial relations
Memory requirements	knowledge retrieval of objects and scenes **memory for items (scenes)**	knowledge retrieval of objects and scenes **memory for relations**

Note—Dimensions of difference between dissociated performances appear in bold.

that seen in the normal control subjects; none of the amnesic patients showed a relational manipulation effect.

The logic of the *dissociation within condition* approach and how it is implemented in Ryan et al. (2000) are illustrated in Table 4, in which that work is considered with regard to our seven dimensions of difference.

Looking at the two columns in Table 4, we see not a comparison of two different tasks or of two test instruction conditions but of two simultaneously obtained measures in a single condition of a single task with a single set of stimulus materials under a single set of test instructions—thus, a dissociation within condition. The processing requirements for both of the dissociated performances include visual object and scene perception and processing of spatial relations, in order to correctly answer the orienting questions. The memory requirements for both of the dissociated performances include memory retrieval of preexperimental knowledge about visual objects and scenes, to help in answering the orienting questions. The only difference emerges in the memory representation requirements for showing the repetition effect, which requires memory for the previous occurrence of scenes, versus those for showing the relational manipulation effect, which requires memory for relations among the constituent elements of scenes.

The findings of dissociation—with impairment in amnesia on measures of memory for relations but sparing on simultaneously collected measures of memory for repetition of items—when subjects are performing within a single processing mode illustrate the power of the dissociation within condition approach. Pointing to the special status of memory for relations, they provide strong support for the multiple memory systems view. Moreover, as we will see next, the alternative formulations under consideration here do not provide a means for accounting for these data.

The dissociation reported in Ryan et al. (2000) emerges between two simultaneously obtained measures in a single condition of a single task with a single set of stimulus materials under a single set of test instructions. For each stimulus in the list, subjects make a decision about the relations present in the scene, with all information required for that decision in full view. Thus, subjects are engaged in just a single mode of processing throughout the experiment, and the dissociation emerges as a function of the previous viewing history with these stimuli. There are no processing mode differences here to be confounded with the differences in memory requirements that could be used to explain how amnesic patients show a normal repetition effect but no relational manipulation effect.

One could conceivably take a narrower view of processing differences and argue that the different stimulus types (novel, repeated unmanipulated, and manipulated) invoke different processing modes on a trial-by-trial basis. But this is not persuasive for three reasons. First, note that the data showing the two eye movement effects are for physically identical stimuli. For example, for the relational manipulation effect, the finding of increased viewing being directed to the (*now* empty) region of a manipulated scene where there had previously been a kitten involves a comparison with the amount of viewing of the same scene when there had never been a kitten in that (*always* empty) location. Hence, any difference in viewing of the empty region is elicited not by the stimulus itself but by the comparison of the stimulus with a memory representation of its previous occurrence. Given that every trial can be conceived of as involving a comparison of the stimulus with memory representations of the previously presented scenes, there is no obvious processing mode distinction to be drawn among trials. But it is essential that the subject have memory for the relations among the constituent elements of the earlier presented scenes in order for the eyes to be attracted to the now empty region.

Second, note that the relational manipulation effect occurs whether or not the subjects are aware that there has been a manipulation. That is, the effect is seen just as well for scenes that the subjects claim have *not* been manipulated. Thus, one cannot argue that the subjects identify the manipulated stimuli as a special class of stimuli and then engage in a different mode of processing that manifests itself in a different pattern of eye movements.

Third, with regard to the failure of amnesic patients to show this effect, one cannot argue that the particular kind of eye movement pattern elicited by manipulated scenes reflects a certain mode of relational processing that they simply cannot perform. In follow-up studies (Ryan & Cohen, in press), we have been able to show that amnesic patients exhibit the normal effect of increased viewing being directed at the critical region of change in manipulated scenes in a short-delay variant of the original paradigm; they show the deficit only when there are enough intervening items and a long enough delay to tax long-term memory. And it is only the relational manipulation effect that they fail to show at long delays; amnesic patients show an intact repetition effect even at long delays. Taken together, these results show that there is a deficit only in the measure that is sensitive to the comparison of the current stimulus with long-term memory representations of the relations among the elements of previously presented scenes. This set of findings is not accommodated by processing accounts. Rather, it is the memory representation requirements—specifically, long-term relational (declarative) memory—that produce the dissociation.

Ryan et al.'s (2000) findings also succeed in disambiguating among competing multiple memory systems accounts. The task and instructions used here assessed memory implicitly (indirectly). The subjects answered a question about the relations among the depicted elements for each scene on the screen without any reference to a memory task; there were no instructions either to study the scenes for a later test or to refer back to any previous occasions. The eye movements used to assess memory, monitored throughout viewing, were incidental to the subjects' actual task. Furthermore, the relational manipulation effect, which was found to be selectively impaired in amnesia, did not depend in any way on explicit remembering or conscious recollection; it occurred (in normal control subjects) whether or not the subjects were consciously aware of the manipulations. This is critical, providing the means to pit the declarative–procedural memory distinction against the explicit–implicit memory distinction. Because memory is assessed implicitly (indirectly), the explicit–implicit account, holding that the hippocampal system specifically mediates explicit memory, must predict that the relational manipulation effect would be *preserved* along with the repetition effect; that is, they should share the same fate. However, the declarative–procedural memory distinction, holding that the hippocampal system specifically mediates memory for relations, predicts that amnesic patients would be *impaired* selectively. The findings that amnesic patients fail selectively to show the relational manipulation effect while, nonetheless, exhibiting the repetition effect normally, despite both effects being assessed implicitly (indirectly), provide strong support for the view that the hippocampal system is tied to memory for relations and not to explicit memory.

It should be noted that additional support for this conclusion comes from Chun and Phelps (1999), who reported the failure of amnesic patients to show contextual cuing, a form of implicit perceptual learning of the repeated configurations of targets and background contexts. In this visual search task, subjects were to identify a rotated *T* among a set of distractor *L*s presented at various locations and orientations. In a subset of the trials, the locations of the target and the distractors remained constant, thus providing a repeated spatial context or spatial relations that could be used to guide search performance. In normal subjects, such trials elicited a decrease in search time, as compared with novel trials, even though the task assessed memory implicitly (indirectly) and the subjects were unable to distinguish explicitly the trials with repeated contexts from novel trials; amnesic patients failed to show this relational effect (but see Manns & Squire, 2001).

Contrasting the Different Classes of Dissociation Evidence

Why is it that whereas various competing theories can all provide an account of earlier neuropsychological dissociation evidence, they cannot provide an account of this class of evidence? Let us examine these accounts with respect to the different neuropsychological dissociation approaches. Processing views can be maintained in findings of dissociation across tasks, because the two tasks inevitably end up engendering quite different modes of processing. As we have seen, in the dissociations observed between motor skill learning and recognition memory, subjects are confronted with fundamentally different cognitive challenges at two different test occasions—they are instructed to perform different operations with different classes of stimuli—and their performance is assessed in fundamentally different ways (see Table 1). These differences can elicit differences in mode of processing that are as compelling as the differences in memory requirements. Likewise, processing views can be maintained in findings of dissociation across instruction conditions, because the different instructions given at different times necessarily invoke different modes of processing, even for the same test materials (see Table 3). For example, as we saw in stem completion versus cued recall (Graf et al., 1984), the instructions at test time purposely directed subjects to perform different processing tasks that differed with regard to whether or not they encouraged conscious recollection. Thus, the differences in memory requirements are confounded with difference in processing requirements. These processing requirements may all arise from a single system of memory. By comparing across conditions that differ with respect to processing requirements, the argument remains that the dissociation in performance may arise either from a single or from multiple systems of memory. That is, the dissociation may occur across processes that are each part of a single system, or the dissociation may persist in types of processing that are unique to separate memory systems.

But the dissociation within condition approach avoids different tasks and different instruction conditions. More generally, its power comes from its ability to reduce the dimensions of difference among the dissociated performances. As can be seen in Table 5, the dissociation within

Table 5
Dimensions of Difference Between Dissociated Performances That Remain in Each Dissociation Approach

Dimension of Difference	Dissociation Across Tasks	Dissociation Across Instruction Conditions	Dissociation Within Condition
Time of administration	√	√	
Type of stimuli	√		
Obtained measures	√		
Study–test match	√		
Methodology and instructions	√	√	
Processing requirements	√	√	
Memory requirements	√	√	√

condition approach has the potential to isolate a single critical dimension of difference, permitting us to entertain targeting memory representation requirements selectively.

Precedents and Other Examples of the Dissociation Within Condition Approach

Ryan et al.'s (2000) work, discussed above, was expressly designed as an implementation of the dissociation within condition approach, although the explication of the logic of the approach and the evaluation of its potential for addressing critical claims about multiple memory systems are done for the first time in the present paper. There are, however, two precedents for the approach within the amnesia literature on preserved versus impaired memory of which we are aware. The first is the mirror-reading study of Cohen and Squire (1980), discussed earlier. In addition to the dissociation it offered between intact perceptual (visual pattern analysis) skill learning and impaired recognition memory—a dissociation across instruction conditions—the study also included a within-condition comparison. Within the mirror-reading component of the study, some of the trials involved novel word triplets, seen only once during the study, and some were repeated word triplets, seen many times throughout the study; these trial types were intermixed. Enhancement of reading speed across novel triplets provided a measure of generalized skill learning; amnesic patients proved to be fully intact on this measure. An additional increment in speed for the repeated triplets, as compared with novel triplets, was observed. But the results were mixed. Amnesic patients showed an advantage for repeated triplets over novel triplets, but less than that shown by normal control subjects. As was indicated in Cohen (1984), this is likely due to that element of performance being supported by a combination of two distinct phenomena: repetition priming, producing enhanced speed of reading of each of the often repeated words, and consciously aware (i.e., explicit) declarative memory for relations among the words within each triplet, producing the ability to generate the second and third words of a triplet upon reading the initial word of the triplet without having to complete the process of reading. To the extent that repetition priming is intact in amnesia, one would expect to see enhanced performance for repeated triplets over novel triplets; but to the extent that memory for relations among the words within triplets is impaired in amnesia, one would expect failure to show the full advantage for repeated triplets that normal subjects show. Accordingly, although on our present analysis the Cohen and Squire study included a within-condition comparison, the results did not produce the full dissociation of normal performance on one measure and failure on the other, simultaneously obtained measure that would signal the separate, simultaneous operation of hippocampal and nonhippocampal systems, respectively.

The second study is the one by Chun and Phelps (1999), discussed at the end of the preceding section. The design of this perceptual-learning experiment is much like that of Cohen and Squire (1980), with novel trials and often repeated trials intermixed throughout the study. Enhancement of search speed across novel trials provided a measure of generalized skill learning, whereas any additional increment in performance for the repeated trials, as compared with the novel trials, provided the measure of memory for relations (here, the spatial contextual relations between targets and distractors). As we have seen, amnesic patients failed to show any improvement in performance for the repeated trials; they also showed generalized skill learning, manifested as increasingly faster search across novel trials. However, performance on the novel trials was not specifically compared between amnesic patients and control subjects, so it is not clear whether skill learning was fully preserved in amnesia here. Thus, the results did not quite produce the full dissociation of normal performance on one measure and failure on the other, simultaneously obtained measure that would demonstrate the separate, simultaneous operation of hippocampal and nonhippocampal systems, respectively. Nonetheless, this and the previous study have the within-condition comparison that is fully realized in Ryan et al. (2000), and they provide data strongly supportive of the same conclusion.

In work on long-term versus short-term or working memory, there is one well-known study of amnesic patients that ostensibly makes use of a dissociation within condition strategy. Baddeley and Warrington (1970) looked at performance of amnesic patients on immediate free recall. In normal subjects, performance is sensitive to the serial position of items in the study list: The initial items in the study list are relatively well recalled, as are the terminal items in the list, as compared with those items that appeared in the middle portion of the study list. The advantage for the early items is called the primacy effect, and the advantage for the final items is called the recency effect. Baddeley and Warrington found that amnesic patients showed the recency effect but had a reduced primacy effect. Attributing the recency effect to short-term or working memory and the primacy effect to long-term memory, these authors took these data as supporting a fundamental distinction between short-term and long-term memory stores. It is not clear that the primacy effect and the recency effect can be mapped directly and completely onto long-term and short-term memory; nor is it clear that subjects are using the same strategies and processes in recalling items that were just presented and were just being rehearsed and still have sensory representations available, as compared with recalling items from the very beginning of the list. Nonetheless, the logic being used here—that there are multiple systems making separate contributions to performance on the single task being performed—is very much in the dissociation within condition spirit.

There is also a parallel example of the dissociation within condition approach from a different domain of neuropsychology that provides compelling evidence concerning the question of whether there are functionally distinct systems for recognition of faces versus other (nonface) visual objects. Investigators have addressed this nearly exclusively by using the standard dissociation across tasks approach. There are many reports of face agnosia—a deficit in identifying people by their faces—despite intact recognition of nonface visual objects, and there are some recent demonstrations of (nonface) visual object agnosia with no deficit of face recognition. But this issue is complicated by the fact that faces and nonface stimuli differ in many regards, including the physical nature of the stimuli, the amount of expertise with the stimuli, the degree to which items need to be specifically individuated to support performance, and so forth. Yet, in the course of a set of 19 experiments with a patient with (nonface) visual object agnosia, Moscovitch, Winocur, and Behrmann (1997) offered two experiments that, by using a dissociation within condition sensibility, provide a different angle on the issue.

Presented with a set of paintings (by such artists as Arcimbaldo, Biblico, and Terra) of faces whose component features were fruits, vegetables, and/or other objects, normal subjects were simultaneously aware of both the faces and the objects, but patient C.K. was not; he had no problem seeing the faces but was rarely able to detect that the faces were made up of objects or were peculiar in any way. In the other experiment of interest here, subjects viewed the painting "The Faces in the Forest," showing a scene involving trees, rocks, streams, and other natural objects. But the scene was composed in such a way that, by careful configuration of these natural objects, it was possible to see a set of faces of various sizes in various places in the forest. Normal subjects found it difficult to see the faces, and it took them a long time to discover them among the trees, rocks, and so forth of which they were composed; they had no trouble at all identifying the nonface objects. Patient C.K., by contrast, had little problem perceiving the faces, discovering them more rapidly than did the normal subjects, but had great difficulty in appreciating the nonface objects.

What makes this work particularly compelling is its ability to give a sense of face and object processing operating simultaneously under normal circumstances, but not in this patient with brain insult, thus realizing one of the critical premises and strengths of the dissociation within condition approach. In doing so, these findings provide particularly compelling evidence for a dissociation between face processing and (nonface) visual object processing, however those systems are conceived.

Extensions of the Dissociation Within Condition Approach

Dissociation evidence is used throughout cognitive neuroscience; not just within neuropsychology. Accordingly, it is not the only method for which our analysis of different classes of dissociation evidence is relevant. The comparisons across conditions or across trials that are an essential part of functional imaging and psychophysiological studies raise the very same issues as those considered in this article for neuropsychological dissociations. Indeed, the logic of the dissociation within condition approach seems ideal for functional imaging and psychophysiological work. The approach is based on the idea that, for the domain of memory, various systems are always processing in their own modes, at the same time, and for the same materials and that the ideal research strategy is to derive measures sensitive selectively to the operation of each of the separate systems. Any technique that permits monitoring of the participation of multiple brain regions/systems from trial to trial throughout the experiment can make use of the dissociation within condition approach. Thus, for example, fMRI or ERP evidence of changes in the extent to which different systems are actively engaged, while sampling them continuously and simultaneously during a single condition of a single task with a single class of stimuli differing only on the dimension being tested (specifically, previous viewing history), can provide dissociation within condition evidence of the separate, simultaneous operation of different memory systems.

Taken altogether, if researchers use converging lines of evidence and are armed with well-reasoned ideas and well-motivated experiments, the dissociation within condition approach outlined here is capable of providing a particularly powerful tool for testing claims about the organization of memory (and other cognitive capacities) in the brain. Applied to the issue of preserved versus impaired memory performances in amnesia, this approach permits disambiguation among competing theories, providing strong support for the multiple memory systems view that distinguishes between declarative (relational) and procedural memory. Its application to other neuropsychological data and to other cognitive neuroscience data holds great promise.

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NOTE

1. Regarding the description, above, of the processing and memory requirements of the task, it is neither possible nor necessary to offer a full analysis or complete listing here. Clearly, to fully understand and model performance on this task or the others to be considered in this paper, a more complete account would be in order. However, for the purposes here of considering the ability of each of the three classes of dissociation evidence to isolate a single critical dimension on which the dissociated performances differ, only a general description of the major requirements will prove necessary.

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