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Not one versus many, but zero versus any: structure and function in the context of the multiple memory systems debate

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PRELUDE

Imagine the following five scenarios. Each begins with a person, let's call him John, who has purchased a new house and, before going to bed on his first night there, hangs his car keys on a nail in the kitchen closet. That following morning his wife asks 'where are the car keys, John?'. In the first scenario, John replies 'they're in the kitchen closet', while in the second he says, 'they're hanging on that nail in the kitchen'. In the third scenario, John says, 'I don't remember, but check that nail in the kitchen closet'. In the fourth scenario, John says, 'I don't remember where they are', but then immediately walks over to the kitchen closet, retracing his steps of the previous evening, and finds the keys. Finally, in a fifth scenario, John doesn't say anything but simply points to the kitchen closet.

All of these scenarios reflect pretty run-of-the-mill stuff, the kinds of things that happen to us every day. What makes them interesting is that all of John's various responses, as well as numerous others not considered, could easily have arisen from the exact same encoded event. The question is: what kind of memory system mediates John's various responses?

The act of hanging the keys on that first night was a novel event for John, something that had happened only once in his life. This might lead one to believe that, upon hearing his wife's question, John experienced an episodic memory of hanging the keys the previous evening. This possibility is consistent with John's reply in the first two scenarios, but notice that his answer is not exactly the same. In the first case he refers to the closet, while in the second he refers to the nail. Do we need to postulate different episodic memories in the two cases?

In contrast to the first two, the third scenario ('I don't remember, but check that nail') does not seem consistent with an episodic memory interpretation. Here, John does not exhibit an episodic recollection of key placement, but only a vague knowledge (or *knowing*) of where the keys might be. In this case, therefore, John's response seems most consistent with the operation of semantic memory. But note that both the first and second scenarios are also consistent with a semantic memory

interpretation, as there is nothing in what he says to indicates a vivid episodic recollection. This interpretive difficulty is a bit troublesome but, ignoring minor details, perhaps we could at least be sure that in all three cases John had some form of *declarative* (propositional) memory of the keys' location. Or could we?

In scenario four, John does indeed utter a declaration ('I don't know'), but it suggests no memory for the keys' location. Yet, despite the lack of evidence for declarative memory, by 'retracing his steps' he walks directly to where the keys were hung the previous evening. In this case, therefore, based on a series of motor movements nearly identical with those executed the previous evening, we might say that a procedural memory mediated John's finding of the keys.

Scenario five, where John simply points to the closet, also lends itself to a procedural interpretation. But imagine that, upon seeing him point, his wife says, 'how do you know they're in the closet?', to which John replies, 'because I distinctly remembering putting them there last night. . . I remember the smell of mildew when I opened the closet'. Here, then, we would have verbal evidence that John did in fact have an episodic memory of the keys' location. Would we now want to say that, upon hearing the original inquiry as to the keys' location, John retrieved an episodic memory that then *directed* the motor system to raise his arm and point?

Finally, imagine a slight twist to our scenario. Instead of keys, John hangs a heavy vacuum cleaner on the nail in the kitchen closet. The next morning his wife asks, 'John, do you think that the nail in the kitchen closet is strong enough to hold an ironing board?', to which John answers 'yes', confidently and without hesitation. What memory system is mediating John's response? Is it that John first experiences an episodic memory of hanging the vacuum cleaner, and then uses this memory as a basis for reasoning about the strength of the nail? Or perhaps in originally hanging the vacuum cleaner on the nail, John acquired the semantic fact of the nail's strength. What if John correctly answers the strength-of-the-nail question, but moments later exhibits no memory for hanging the vacuum cleaner; or claims no declarative memory for its location but walks over to the closet, thus exhibiting procedural memory? Can procedural memories form the basis of propositional (declarative) reasoning?

The above examples were designed to raise a few questions about the notion of memory systems. Most importantly, how does a systems theorist unambiguously identify a particular memory as being in one system or another (episodic or semantic, declarative or procedural)? What are the rules by which an event gets encoded *into* any particular system? Is it based on the content of the to-be-remembered information; whether it is verbal or motoric; the state of the rememberer? And when is a measure of performance (e.g. talking, pointing, walking) taken as indicative of, say, episodic memory as opposed to procedural memory? More generally, what is the relation between proposed memory systems and other aspects of cognition such as reasoning and acting? Before answering these questions, we suggest that memory researchers step back and ask an even broader question: does the theoretical machinery underlying the multiple systems approach clarify or obscure our understanding of memory?

INTRODUCTION

One of the most important developments in modern cognitive psychology has been the realization that past experience can affect subsequent performance in a multitude of different ways. In addition to traditional expressions of memory such as recall and recognition, people also show effects of prior experience that are unaccompanied by conscious recollection of the past, and these effects may manifest themselves as changes in perception, categorization, reasoning, or motor behaviour. A major issue concerns the most appropriate way of characterizing and explaining such variety, with two general perspectives defining the theoretical landscape. The most popular view is that the various expressions of memory reflect the operation of multiple, relatively independent memory systems. The alternative 'processing' view does not postulate multiple systems, but rather views mnemonic variety as reflecting the different ways in which task demands and processing goals can alter how prior experience gets expressed in subsequent performance.

Proper understanding of the current debate between the 'multiple system' and 'processing' approaches to memory requires an appreciation of their underlying assumptions. Insight into these assumptions is revealed by examining the historical legacies of the two frameworks, legacies which can be traced to the beginnings of psychology as a science. During those formative years, two opposing metatheoretical approaches dominated conceptions of the mind. One approach, structuralism, advocated studying the contents of the mind; complex mental abilities such as perception and memory were viewed as separate phenomena, to be understood by decomposing and analysing their constituent elements. An opposing view, functionalism, rejected this 'mental chemistry', arguing that the various faculties of mind (perception, memory, reasoning) operate in an integrated fashion to bring about adaptive, goal-directed thought and behaviour; thus, rather than analysing the structure and content of mental acts (what they *are*), functionalists emphasized the role that such acts play in an organism's response to changing environmental demands (what they *do*).

In the context of modern theories of human memory, structuralism is represented by the multiple memory systems approach. In this approach, one postulates a multitude of distinct memory representations, and the systems in which these representations are stored. Memory, then, is the process of activating the representations stored in a particular system. Once activated, the representations are able to influence a person's performance with the nature of that influence being dependent on the kind of information 'contained in' the representation. Thus, for the systems approach, memory is explained by reference to structural concepts—specifically, memory systems (the 'architecture' of memory) and memory representations (the fundamental components from which these large-scale systems are built).

In contrast, modern processing approaches exemplify a more functional orientation to the study of memory. For these approaches, little is gained in talking about underlying memory representations or the systems in which they are stored,

because memory is not something to be found *in* those representations and systems. Rather, memory emerges in the interaction between a person with a prior history of experiences, and the environmental situations (e.g. the memory tasks) in which those prior experiences can be identified as influencing performance. Here, then, the dominant metaphor is one of process rather than structure.

Of course, these are caricatures of current approaches to memory. Process theorists regularly talk in terms of representations, mental attributes, and the like, while systems theorists are obviously concerned with functional uses of memory. However, we believe there are important insights to be gained from psychology's initial attempt to wrestle with mental structure and function, insights that have wide-ranging implications for the current debate over multiple memory systems. We shall say more later about the historical antecedents of current processing approaches, but for the moment we wish to focus on the lineage of structuralism in the multiple systems approach to memory.

The legacy of structuralism in multiple systems theory

Perhaps the clearest rendition of the structuralist's program was provided by Titchener (1898). In particular, Titchener drew an analogy between structuralism in psychology and morphology in biology, and saw the structural approach as providing a kind of morphology of mind: 'The primary aim of the experimental psychologist has been to analyze the structure of the mind. . . . His task is a vivisection, but a vivisection which shall yield structural results.' (p.450). Moreover, this morphological approach was viewed as necessarily primary to the analysis of psychological processes advocated by the functionalists. Just as the biological study of a physiological process is predicated on an understanding of its underlying morphology, so too psychological processes and functions had to reflect the operation of some underlying parts, and it was a structural analysis that was required to discover and describe these parts: 'In a word, the historical conditions of psychology rendered it inevitable that, when the time came for the transformation from philosophy to science, problems should be formulated, explicitly or implicitly, as static rather than dynamic, structural rather than functional' (Titchener 1898, p.453).

A strikingly similar metatheory underlies current systems approaches to the study of memory. Thus, advocates of this approach are adamant that 'some sort of systematic classification of memory is fundamental to our theoretical understanding of mnemonic processes' (Schacter and Tulving 1994*b*, p.2) and is required to 'guide functional research on learning and memory' (Tulving 1985*b*, p.72). The claim, then, is that understanding the structure or 'morphology of memory' is a prerequisite to understanding mnemonic processes and functions, just as understanding the morphology of a bird's wing is necessary for understanding its ability to fly.

The main argument of this chapter is that this strategy, although logical and sound in biology, is seriously flawed in the psychological study of memory.

Interestingly, the major flaw can be traced to a fundamental *difference* between the structuralism advocated by Titchener and that advocated by modern systems theorists, a difference we spell out more clearly below. First, however, we provide a brief description of the more popular memory systems proposed in the literature, and a general critique of those proposals.

THE MEMORY SYSTEMS OF 199X

There are a number of different proposals regarding human long-term memory systems. Most of them, however, derive from two early dichotomies; first, between declarative and procedural memory (Cohen 1984; Cohen and Squire 1980) and second, between episodic and semantic memory (Tulving 1972, 1983). In general, declarative memory ('knowing that') is defined as memory for *facts and events* that can be consciously accessed and verbalized. Procedural memory ('knowing how') is memory for *cognitive or motor skills* that cannot be consciously accessed or verbalized. Episodic and semantic memory, although sometimes treated as distinct systems (e.g. Tulving 1983), can also be viewed as subclasses of declarative memory (see Schacter and Tulving 1994*b*; Squire 1994); both are viewed as propositional in the sense of having a truth value and being expressible in words or statements. Episodic memory is memory for specific autobiographical events. Semantic memory is closely tied to language and involves memory (or 'knowledge') of facts, ideas, and concepts.

Two other dimensions that appear critical in the classification of memory are those of consciousness (or awareness) and intent, dimensions captured in the distinction between explicit and implicit memory (see Schacter 1987; Roediger and McDermott 1993). Explicit memories are both conscious, in the sense that the person is aware of remembering prior events, and intentional, in the sense that the person in some sense wants, or voluntarily intends, to retrieve them. In contrast, implicit memories are unconscious, in the sense that the person is unaware of retrieving or otherwise being influenced by prior events, and their retrieval is thought to occur involuntarily or without intent (see Jacoby 1984; Jacoby and Witherspoon 1982). Some researchers (e.g. Squire 1994) view the distinction between explicit and implicit memory as co-extensive with that between declarative and procedural memory, thus implying that explicit, but not implicit, memories can be expressed verbally. Moreover, explicit memories are considered to be *cognitive*, concerned with 'information' or 'symbolic knowledge', whereas implicit memories are *non-cognitive*, concerned with 'stimulus–response bonds' or 'response probabilities' (see Petri and Mishkin 1994).† It is not clear whether implicit and explicit memory are supposed to be treated as memory systems *per se*, or simply as descriptive terms that are indicative of separate systems (see Ratcliff and McKoon 1996).

Procedural memory, also referred to as 'non-declarative memory', has recently been subdivided into a number of other systems (see Schacter and Tulving 1994*b*; Squire 1987, 1994). These include (1) skills and habits, (2) simple associative learning or conditioning, (3) non-associative forms of learning such as habituation and sensitization, and (4) the perceptual representation systems, a collection of pre-semantic subsystems used in the perception of objects and words. The latter system is simply called 'priming' by Squire (1994).

Finally, in addition to the more general systems described above, a number of more content-specific memory systems have also been proposed, or at least hinted at. For example, Schacter (1989) (see also Moscovitch 1989, 1992), proposed a number of distinct 'knowledge modules' that seem likely candidates for being memory systems, including the lexical, conceptual, facial, spatial, and self modules. Given that each of these domains reflect 'overlearned or unitized information', additional systems of this kind could also be postulated, such as the music and mathematics systems. Moreover, given that memory modules may be assembled through experience (Moscovitch 1989), systems specific to particular areas of expertise may also be possible; experts in fields such as radiology, entomology, and cosmology, for example, may be expected to have x-ray, insect, and stellar memory systems, respectively.

CRITICAL ANALYSIS OF THE MULTIPLE SYSTEMS PROJECT

The systems described above reflect a concerted attempt to provide a comprehensive morphology of memory, a theoretical classification of the different ways in which prior experience may affect subsequent thought and behaviour. In this section, we discuss some of the difficulties for these classification schemes. Central to our analysis is consideration of the criteria that have been proposed for identifying memory systems. Although proposed criteria undergo almost constant modification‡, three general criteria seem to recur in the literature, so we assume that

† The connection between the explicit/implicit distinction and that between declarative and non-declarative memory is potentially problematic both with regards to their verbalizability and in terms of what is thought to be stored in the memory trace or system. First, in terms of verbalizability, it is often unclear whether researchers are referring to the processes underlying particular forms of memory, or the mnemonic 'products' of those processes. If it is the underlying processes that are viewed as central, then nether implicit or explicit memory seem declarative as people can provide little or no verbal description of the processes underlying either type of memory. If, alternatively, it is the mnemonic product (i.e. what 'comes to mind') that is most important, then both forms of memory seem declarative (verbally describable), at least in situations in which words, signs, pictures, objects, or other language-related stimuli are retrieved (as if often the case in studies of implicit memory).

A second problem concerns the issue of what is stored 'in' an implicit or explicit memory. Although it is intuitively appealing to say that explicit ('cognitive') memory is concerned with *information*, whereas implicit ('non-cognitive') memory reflects stimulus–response (SR) connections (strengths, biases, or response tendencies), it is unclear what this information/SR-connection difference is supposed to correspond to in the memory trace. Stated as a question, what difference in the brain should one expect to see between an explicit/cognitive memory and an implicit/non-cognitive memory such that 'information' could be discerned in the former case but not the latter?

‡ In presenting the case 'for the possible heuristic usefulness of a taxonomic distinction between semantic and episodic memory', Tulving (1972) enumerated four major differences between these two

these form the fundamental core of the multiple systems proposal. These criteria are (1) that memory systems can be functionally dissociated, (2) that each system stores a different kind of information, and (3) that each system has a distinct neural implementation. Evidence for any one of these criteria is usually sufficient to suggest the possibility of a memory system; in general, however, confident postulation of a system requires that all three criteria be met.

In exploring these criteria, our analysis appeals to two issues that have recently become central in the study of memory: the relation between tests and processes, and the relation of memory to other aspects of cognition such as perception, reasoning, and action. Consideration of these issues sets the stage for further analysis of the relation between current system-based approaches to memory and earlier (Titchenerian) approaches to mind.

Functional dissociations and the process-pure problem

Functional dissociations are one of most important criteria for the postulation of memory systems. A functional dissociation occurs when an experimental manipulation produces different effects on two or more tests of memory. For example, variations in encoding—attending to the meaningful versus perceptual aspects of a word—have been shown to have a large influence on explicit tests such as recall and recognition, but little or no effect on implicit tests such as perceptual identification or stem completion (e.g. Jacoby and Dallas 1981; Graf *et al.* 1982). Similarly, amnesic patients show deficits on explicit/declarative tests of recall and recognition, but not on implicit/procedural tests such as mirror-reading (e.g. Cohen and Squire 1980). These results have been taken as strong evidence for the existence of separate memory systems.

A major problem with the functional dissociation criterion is that dissociations are known to occur between tasks that supposedly tap the same memory system (Blaxton 1989; Dunn and Kirsner 1989; Hayman and Tulving 1989; Hintzman 1990; McKoon *et al.* 1986; Ratcliff and McKoon 1996; Witherspoon and Moscovitch 1989). For example, using normal subjects, Blaxton (1989) showed a dissociation between two tasks thought to tap episodic memory (semantic cued recall and graphemic cued recall) and between two tasks thought to tap semantic memory (word fragment completion and answering general-knowledge questions). Dissociations between various procedural memory tests as a function of neurological dysfunction have also been identified (see Moscovitch *et al.* 1993).

How are such findings handled by multiple systems theory? One strategy is to simply postulate new systems for the dissociated tasks; for example, rather than reflecting the operation of semantic memory (Tulving 1983) performance on word fragment completion is now thought to reflect the operation of a perceptual representation (Tulving and Schacter 1990) or priming (Squire 1994) system.

A second way to explain apparent within-system dissociations is to note that tasks are not pure with regard to the mnemonic processes or systems they access. That is, rather than selectively measuring a single kind of memory, it is now widely agreed that most, if not all, memory tasks engage multiple forms of memory. This is known as the 'process-pure' problem (see Jacoby 1991) but it could as easily be called the 'system-pure' problem. Thus, the episodic system may contribute to both semantic and graphemic cued recall, but these tasks may also reflect contributions from other systems; semantic cued recall, for example, may reflect contributions from semantic memory, while graphemic cued recall may draw on the word-form subsystem of the perceptual representation system.

There is a serious problem, however, in appealing to the process- (or system-) impurity of memory tests if one's goal is to use functional dissociations to discover and verify the existence of proposed memory systems. What is crucial is not that two *tasks* differ in their information-processing requirements; this is known by definition (they are, after all, *different* tasks). Rather, the researcher is interested in evidence that the hypothetical *systems* proposed to mediate performance on those tasks are fundamentally different with respect to their *mnemonic*-processing requirements. The problem, then, is the following: if test performance reflects the operation of multiple mnemonic systems, how can one be sure that distinctions made at the task level (i.e. on the basis of dissociations) accurately reflect the underlying structure of memory? In general, researchers postulating multiple memory system are cognizant of this problem and thus advocate 'converging dissociations . . . of different kinds, observed with different tasks, in different populations, and using different techniques' (Schacter and Tulving 1994*b*, p.18). Unfortunately, converging dissociations, rather than solving the process-pure problem, may simply exacerbate it if the nature of the impurity is consistent across a particular method of testing, or is inherent to the kinds of mnemonic content being contrasted.

To illustrate, consider a recent study by Glisky *et al.* (1995). These researchers were interested in the difference between item memory and source memory, and the possibility that these two forms of memory reflect the operation of different brain systems. To investigate these issues, Glisky *et al.* used neuropsychological test performance to separate elderly subjects into 'high frontal' or 'low frontal'

kinds of memory: (1) the nature of the stored information (basically, 'facts' versus 'events'); (2) autobiographic versus cognitive reference; (3) conditions of retrieval; and (4) vulnerability to interference. In Tulving (1983), episodic and semantic memory were no longer useful heuristic categories but were regarded as distinct 'functional systems' with 28 diagnostic features. Also, these two systems were to be distinguished from a third, procedural, system of memory. In 1984, Tulving identified five major criteria for distinguishing between memory systems: (1) their functions and the kinds of information they process; (2) their laws of operation; (3) their basis in the brain; (4) their phylogenetic and ontogenetic development; and (5) their format for representing information. A possible sixth criterion proposed in this period (Tulving 1985*a*) concerned the different kinds of consciousness associated with each memory system. More recently, three 'broad criteria' have been proposed for identifying different memory systems: class inclusion operations, properties in relation to other systems, and convergent dissociations (see Schacter and Tulving (1994*b*) for an explanation). In one way or another, these recent additions include the three 'general criteria' discussed in this chapter.

Squire (e.g. 1987) has been less explicit about criteria; however, in 1994 he notes that 'forms of memory are different in terms of what kind of learning occurs in each, what is stored as knowledge, and what brain systems are involved' (Squire 1994, p.215), thus enumerating the three criteria we examine here. Other criteria, proposed in the animal literature for example (Nadel 1992), have included length of storage time and computational differences. The latter notion is similar to Sherry and Schacter's (1987) notion of 'incompatibility' and is discussed in more detail below.

groups, and (in a separate analysis) into 'high temporal' and 'low temporal' groups. All subjects were then exposed to a list of sentences, half spoken in a male voice, the other half in a female voice. Subsequent testing revealed an impressive double dissociation between item memory (recognition of previously presented sentences) and source memory (recognition of the voice in which the sentences had been spoken). In particular, the 'high frontal' group exhibited better source memory than the 'low frontal' group, but the two groups showed equivalent item memory; conversely, the 'high temporal' group showed better item memory than the 'low temporal' group, but the two groups did not differ in their ability to discriminate source.

Such data would seem to constitute promising evidence for separate memory systems, an item-based system mediated by the temporal lobes, and a source-based system mediated by the frontal lobes. Indeed, by concluding that 'memory for the content and for the context [source] of an event may be functionally dissociable and may rely on different parts of the brain' (Glisky *et al.*, p.229) they invoke two of the main criteria used to postulate memory systems, functional dissociation and different underlying neurology. Moreover, this claim was noted to gain additional credibility by the existence of other, *converging* studies showing that individuals with frontal dysfunction often are impaired on tests of source memory (e.g. Craik *et al.* 1990; Janowsky *et al.* 1989; Schacter *et al.* 1984).

The problem with this interpretation concerns the fundamentally different processing demands made by the item and source tests. In particular, the item test used by Glisky *et al.* involved presentation of two sentences, one that had been previously presented in the experiment, another that had not been presented in the experiment or, possibly, at any other time in the subject's prior history. In contrast, the source test involved two presentations of the same previously presented sentence in each of two voices, *both of which had been heard at study*. Thus, despite the fact that '[t]he form of the source memory test was identical to the item memory tests' (i.e. both were two-alternative forced choice), the stimuli used and discriminations required were actually quite different.

Rather than tapping distinct systems, then, an alternative explanation is that the item and source tests simply differed in the *specificity* of the mnemonic judgment they required. Stated in 'processing' terms, performance on the item memory test may have been largely mediated by familiarity (an automatic form of memory), while performance on the source test required conscious recollection of the sentence–voice configuration. If one makes the further assumption that more fine-grained ('configural') distinctions recruit controlled processes dependent on frontal-lobe structures (e.g. Rudy and Sutherland 1992; Shallice 1988), then the apparent 'double dissociation' between item and source, rather than reflecting the operation of distinct systems, is more appropriately seen as a consequence of the way in which the two tests required a different balance of mnemonic automaticity and control.

Regardless of the accuracy of this account of Glisky *et al.*'s item/source dissociation, the general point is that the relation between test performance and hypothetical underlying memory systems (or processes) can be quite complex.† Few researchers would argue with the claim that modern research on memory is just beginning to unravel the complex arrangement of processes that underlie memory performance; and that even relatively simple tasks, such as recognition of isolated words or sentences, involves a complex combination of processes and processing relationships. An obvious implication of this fact is that currently proposed memory systems are based on test performance that reflects different combinations of mnemonic processes or systems; that is, they are based on data from process *impure* tests. The impurity of available memory tests, relative to the presumed discrete nature of proposed memory systems, undermines the use of task dissociations to cleanly identify memory systems.

Wider implications of process-impurity

The process-pure problem extends beyond the interpretation of specific tasks and may well be the Achilles' heel of the multiple systems approach. By definition, any particular act of memory draws on more than one (ostensibly defined) system. The most obvious example of this is the reliance of episodic memory on semantic memory. When we remember a specific autobiographical event, we understand its meaning. Episodic events are always interpreted in relation to other facts we know about the world. Memory is never purely episodic.

The problem extends beyond episodic and semantic memory. Motor and cognitive skills are classified as procedural (Schacter and Tulving 1994*b*) or non-declarative (Squire 1994), but the concept of skill is equally applicable to declarative knowledge. Witness our descriptions of mathematicians, philosophers, and politicians (to name a few) who have acquired 'skill with language' or 'skill in the manipulation of concepts'. And as shown in our 'key' example that started this chapter, single episodes (episodic memories?) regularly mediate motoric acts such as pointing or walking. On a memory systems account, examples such as these require the postulation of complex, but rarely specified, communication routes between systems (e.g. the episodic system directing the procedural system) in addition to the systems themselves.

Moreover, the mixture of declarative and procedural memory is not restricted to just the skill and habit system. 'Simple associative learning' is held to be non-declarative, a position that seems reasonable when the discussion is restricted to sensory-affective forms of classical conditioning. However, a large literature shows that classical conditioning operates in the declarative domain. For instance, conditioned responding to *words* has been shown using both salivation and GSR as the conditioned response (Razran 1939; Riess 1940) (see also Phillips 1958; Raskin 1969). Importantly, stimulus generalization in these paradigms has been shown to

† Additional evidence for such complexity is provided by Jacoby *et al.* (1993) who showed that apparent null effects of an experimental manipulation on implicit test performance (i.e. reading versus solving anagrams), can be produced by differential contributions of controlled and automatic uses of memory that offset one another in overall performance (see also Toth *et al.* 1994).

be greater for synonyms (i.e. 'urn' to 'vase') than homonyms ('urn' to 'earn'). Such results place 'simple' conditioning squarely in the declarative/semantic domain.

Conversely, if non-declarative memory systems are implicit (unconscious and unintentional), and thus independent of explicit/declarative systems, then it seems difficult to explain the modulation of simple (non-declarative?) conditioning as a function of verbal instructions and intentions to learn (e.g. Hilgard and Humphreys 1938; Hill 1967; Nicholls and Kimble 1964). These findings constitute direct evidence that lower-level ('implicit') forms of memory are penetrable by higher-level ('explicit') processes.

Of course, it is always possible for the multiple systems theorist to appeal to the impurity of their paradigms. That is, observed responses in conditioning experiments may reflect influences from higher-level systems that are nevertheless independent of the lower-level systems the conditioning paradigms were designed to index. However, such arguments beg the question of which results can be taken as contaminated and which as pure, as all paradigms seem equally suspect.

Perhaps because of problems like these, Tulving (1984, 1985*a*) proposed a 'monohierarchical arrangement' of memory systems such that episodic memory is dependent on semantic memory which, in turn, is dependent on procedural memory. Ironically, the monohierarchical conceptualization simply formalizes the problem of using task dissociations to identify discrete systems and, however implicitly, acknowledges that multiple systems theories are not open to empirical confirmation or falsification (see McKoon *et al.* 1986; Ratcliff and McKoon 1996). In addition, the monohierarchical concept entails the implication that similar basic mechanisms, both psychological and neurological, are at work in all forms of memory, a position with which we agree and explore more fully below.

The problems that provoked Tulving's monohierarchical arrangement go far beyond the inextricable coaction of different forms of memory, as it is never purely 'memory' that is being assessed in memory tasks but a host of other, supportive abilities such as perception, comprehension, and reasoning. Abilities such as these set the context for mnemonic processing in such an way as to form an integral part of the very definition of memory (Bransford *et al.* 1977). Thus arises another difficult issue for the multiple systems approach: The degree to which memory systems can be considered separate from other aspects of cognition.

Systems defined by contents: the artificial separation of memory, perception, reason, and action

In describing his original reasons for making a distinction between semantic and episodic memory, Tulving (1984) nicely captures an important, but under-appreciated problem posed by the postulation of multiple memory systems. Specifically, he noted that researchers such as Rumelhart *et al.* (1972), Kintsch (1972), and Collins and Quillian (1972) 'were concerned with what I thought were the processes involved in the understanding of language, whereas they suggested that they were studying memory in a broader sense than had been used in the past. . . . I thought

that the extension of the concept of memory to the comprehension of language, question answering, making of inferences, and other such cognitive skills was inappropriate' (Tulving 1984, p.223).

Of course, history shows that Tulving was actually of two minds about this issue. What he apparently found inappropriate was the extension of traditional definitions of memory—in terms of conscious, explicit recollection—to the domains of language, question answering, etc. Yet his solution to this problem was, in fact, to extend the concept of memory, *in the form of a semantic memory system*, into these very domains. From our perspective, however, memory permeates every form of cognitive processing from perception to language to reasoning to action. Thus, just as it seems inappropriate to extend traditional notions of memory into the domain of language, so it seems inappropriate to extend the concept of memory, *in the form of memory systems*, to every aspect of cognitive processing that shows sensitivity to prior experience. Stated simply, postulation of 'separate' or 'independent' memory systems erects artificial boundaries between memory and other aspects of cognition that should eventually be incorporated into a more comprehensive theory of thought and behaviour.

The problem appears in sharp relief when considering the second criterion for the postulation of memory systems, the notion that different systems store different kinds of contents or forms of information.† As noted above, one distinction between kinds of information is that between declarative knowledge (facts and events) and procedural/non-declarative knowledge (cognitive and motor skills). Also noted was the possibility that more specific kinds of mnemonic contents, such as faces or music, may also qualify for memory system status. Consistent with the modularity-of-mind hypothesis (Fodor 1983), Sherry and Schacter (1987) argued that specialization for one kind of content may make a system unable to process another kind of content, an idea referred to as 'functional incompatibility'. For example, it might be argued that a system specifically devoted to the processing and storage of faces would be unable to process and store music.

A potentially serious problem with the different-contents/incompatibility criterion is that it confounds incompatibility of memory function with incompatibility of other psychological functions such as perception. That is, it might be the case that the neural machinery devoted to the perception of faces is incompatible with that required for the perception of music, yet the principles of memory could be the same. Sherry and Schacter were aware of this problem and thus argued that postulation of a distinct memory system or 'memory module' necessitates that it have 'its own acquisition, retention, and retrieval processes and that the rules of

† The different-contents criterion has always been a staple of distinguishing between systems (see footnote to p.237). Its role in more recent formulations, however, is somewhat unclear. In particular, under the 'properties and relations' criterion, Schacter and Tulving (1994*b*) state that 'The properties of any system include rules of operation, *kind of information*, and neural substrates' (p.16; emphasis added). However, under the 'class-inclusion' criterion we are told that 'An intact memory system enables one to perform a very large number of tasks of a particular class or category, *regardless of the informational contents of the tasks*' (p.15; emphasis added). We can only assume that 'kind of information' and 'informational contents' mean something different to Schacter and Tulving.

operation of these processes differ across modules' (Sherry and Schacter 1987, p.440). This is one of the stricter criteria for postulation of a memory system, but it is still problematic because it assumes a separation between the neural and psychological mechanisms underlying memory, and those underlying other aspects of processing. If, alternatively, memory and other forms of processing (e.g. perception, action) share underlying mechanisms, it may be difficult, if not impossible, to ever show mnemonic incompatibility between different mental contents.

An analogy with the distinction between implicit and explicit memory may help make this idea clear. A major advance in determining whether performance on a task reflects implicit (unintentional) or explicit (intentional) memory involved keeping retrieval cues constant and varying only the test instructions, a strategy known as the retrieval intentionality criterion (Schacter *et al.* 1989). The intentionality criterion was important because dissociations produced with different retrieval cues (e.g. faces versus music) can logically reflect not differences in consciousness, intentionality, or underlying principles of memory, but less interesting differences associated with the information-processing requirements of the retrieval cues themselves (Dunn and Kirsner, 1989); for example, that we *see* faces but *hear* music. On the basis of this criterion, then, a direct comparison of memory mechanisms for different content domains, *keeping all other information-processing demands constant*, is impossible.

Note that this is a logical problem rather than an empirical one, and stems directly from treating memory as an independent mental act separate from other cognitive functions such as perceiving, reasoning, and acting. This compartmentalization of function is a throwback to the faculty psychology of Gall and, more generally, to the structuralist enterprise of analysing the mind into separable components. And although it is often claimed that modern research on the brain has revitalized these ideas in the form of Fodorian modularity, it is worth noting that modern brain science can also been seen as providing the opposite lesson—that there are no hard and fast distinctions between perception, memory, reasoning, and action (see, e.g., Deacon 1989; Milner and Goodale 1995; Mesulam 1990).

Commenting on the proliferation of memory systems, Nadel (1992) makes this point concisely: 'The view that processing and memory storage occur in the same circuits. . . emerged from the neurobiological literature, largely because it is hard to imagine how in the nervous system these activities could be kept entirely separate from one another. One might almost argue that we have gone too far in this regard—everything the nervous system does could be construed as "memory-like" in some sense, as just about every form of activity in the nervous system leaves some relatively nontransient trace behind' (Nadel 1992, p.180). Indeed, we would count ourselves among those who feel that multiple system theorists have 'gone too far', treating almost every aspect of cognition (e.g. learning, language, object perception) as a distinct kind of memory system. As noted by Dennett (1991), 'the very idea that there are important theoretical divisions between such presumed subsystems as "long-term memory" and "reasoning" (or "planning") is more an artifact of the divide-and-conquer strategy then anything found in nature' (Dennett 1991, p.39).

The point, of course, is not to abandon the divide-and-conquer strategy, but rather to be vigilant against reifying *in* nature (i.e. in the mind or brain) heuristic divisions made in the interest of clarity or scientific understanding. As discussed in the next section, one must also guard against viewing the divided-and-conquered parts as recently discovered, alternative versions of the whole.

Lower-forms of learning as separate systems?

What is the difference between learning and memory? Most textbooks describe learning as the process of *acquiring* information about the world whereas memory is the storage and subsequent expression of that leaning. If we accept this definition, then characterization of different forms of learning as separate memory systems seems inappropriate; learning is a component of memory, not a qualitatively different form of memory. Moreover, even if we take learning to incorporate both acquisition and subsequent expression, it is not at all clear that lower (non-declarative) forms of learning operate independently of higher (declarative) forms (see pp.241–2).

'Simple associative learning' is now commonly described as one of the many memory systems, as are the non-associative processes of habituation and sensitization (e.g. Squire 1987, 1994). This expansion of the definition of memory to include 'lower' forms of learning plays an interesting *rhetorical* role in the multiple systems debate because their 'discovery' by memory theorists produces a relatively large increase in the number of putative long-term memory systems. Yet most neurobiologists would agree that these phenomena are ubiquitous in the nervous system, cutting across numerous content domains as well as both perceptual and motor systems. They are also likely to play a role in perceptual priming, as well as other rapid motor and sensorimotor adaptations, thus making it difficult to see how they can be considered as 'separate' memory systems.

On the basis of evidence that the cellular mechanisms underlying classical conditioning are an extension of those underlying sensitization, Hawkins and Kandel (1984) (see also Lynch and Granger 1992) have suggested that higher forms of learning may reflect combinations of the neurobiological mechanisms underlying basic habituation and sensitization. In particular, they suggest that 'whereas single neurons may possess only a few fundamental types of plasticity which are used in all forms of learning, combining the neurons in large numbers with specific synaptic connections (as occurs for example in the mammalian cortex) may produce the much more subtle and varied processes required for more advanced types of learning' (Hawkins and Kandel 1984, p.380).

Such observations are fascinating and could have widespread implications for our understanding of both the neural and cognitive bases of memory. In particular, they suggest the possibility that lower (procedural/non-declarative) forms of learning may be on a continuum with, and thus partially underlie, higher 'cognitive' forms of memory including explicit/episodic recollection. Of course, this is not to deny the differences that certainly emerge from the combined operation of basic neural mechanisms, or from the operation of large-scale neural collectives. But a continuum of learning and memory is consistent with the idea that memory tasks, although dissociable, also have numerous shared components (e.g. Humphreys *et al.* 1989; Moscovitch 1992; Ratcliff and McKoon 1996). Conceptualization of different forms of learning and memory as independent from one another, residing in isolated systems, draws attention away from such commonalties, and thus undermines the possibility of finding unifying principles of memory. As discussed more fully in the next section, we believe that multiple system theorists may be confusing dissociable memory *tasks* with ontologically 'real' memory systems.

Memory systems: a psychological theory or a taxonomy of tasks?

It is often unclear whether the postulation of multiple memory systems is to be taken as a formal theory, a taxonomic classification of memory, or simply an intuitive description. Thus, writing in 1986 about the episodic/semantic distinction, Tulving stated that 'what had been a "potentially useful" heuristic in 1972 has now become a full-fledged hypothesis, or theory, of the basic nature of memory' (Tulving 1986, p.307). Yet, in the same paper he writes that '[t]he idea of differentiable episodic and semantic systems, in its most rudimentary form, is simply a hunch . . .' (Tulving 1986, p.308). Most recent work seems to emphasize the classificatory nature of the multiple systems approach (e.g. Schacter and Tulving 1994*b*, p.26). But what exactly is being classified?

Tulving (1985*b*) provided an insightful discussion of the classification problem in the study of learning and memory, focusing on the conceptual problems involved in defining the fundamental unit of analysis for the field. In particular, he noted that 'Systematic biology . . . differs from systematic learning and memory in many ways. One of the more conspicuous differences is the fact that there is little difficulty in determining the to-be-classified things in biology: They are concrete things that occupy space, that have boundaries, and that have perceptually identifiable and objectively measurable characteristics. In learning and memory, it is not necessarily clear what the objects of classification are or what they should be' (Tulving 1985*b*, p.77).

Identifying the fundamental unit of analysis for the study of learning and memory is indeed central if one's goal is to offer a taxonomy of memory tasks and, ultimately, of underlying memory structures. Tulving (1985*b*) explored the possibility that *tasks* may be the appropriate unit of analysis for memory, but this approach was quickly dismissed given the multiple ways in which tasks can be performed, and the way a particular response may reflect very different processes (recall our discussion of the process-pure problem, and our examples of 'John' at the beginning of the chapter). Tulving's solution to this problem was to draw an analogy with the biological concept of species and suggests that, instead of specific tasks, classes of tasks may be a more appropriate unit of analysis in learning and memory. And, indeed, this seems to be the strategy adopted by multiple system theorists, as examination of their classification schemes reveal them to essentially

be lists of the various tasks and paradigms that have been used to study the effects of prior experience.†

But if a single task is inappropriate as the unit of analysis in a study of memory, is a class of tasks any better? In both cases we are still left with the fundamental difficulty that, unlike biological organisms, neither the covert processes that determine test performance, nor the memory structures to be inferred from that performance, have any 'perceptually identifiable characteristics'. Indeed, as described in the next section, the only observable 'units' in memory are functional relations, but functional relations provide a poor basis for structural classification.

The central problem facing the multiple systems project: can you build psychological structures using only functional relations?

Multiple system theorists are faced with a fundamental problem: their goal is to provide a theory of observed memory performance based on underlying systems/structures, but they have no means for identifying or isolating the 'units of analysis' that would unambiguously identify those systems. To understand the problem, let us return to our analogy between current multiple systems approaches to memory and earlier structural approaches to mind. Recall that, as is true for the multiple systems theorist, structural psychologists such as Titchener believed that a 'morphological' analysis of mind was a prerequisite to understanding its processes and functions. Importantly, however, there is a critical methodological difference between Titchener's structuralism and the renovated structuralism advocated by current system theorists. In particular, structuralists such as Titchener believed they were in possession of a scientific methodology that would allow them to *directly* observe the structure that necessarily underlies mental experience. That method was introspection. Irrespective of its shortcomings, introspection held out the possibility of directly 'looking' at the structure of mind in the much the same way that one might visually inspect the structure (morphology) of a bird's wing.

However, because the method of introspection has become unacceptable in experimental psychology, largely because of its subjectivity, the analogy between morphological analysis in biology and structural analysis in psychology has lost its meaning. That is, elimination of introspection as a viable method in psychology also removes any means of directly observing the structure of the mind, and thus of hypothetical memory systems. Of course, what has taken the place of introspection is the analysis of something more objective and directly observable, but which is necessarily *functional*, namely task performance.

† An important exception to this is the more functionally oriented multiple-entry, modular memory (MEM) system advanced by Johnson (1983). Critically, MEM is concerned with processing requirements *among* tasks, rather than distinctions *between* tasks as a function of their content (see Johnson and Hirst 1993; Johnson and Chalfonte 1994). Thus, unlike many other multiple systems theories (e.g. Schacter and Tulving 1994*b*; Squire 1994) the subsystems in MEM are not assumed to be coextensive with particular memory tasks.

The point is this: multiple systems approaches to memory are attempting to describe the underlying structure of memory. However, that structure cannot be directly observed but can only be inferred on the basis of task performance. Task performance, however, is not structural, but rather reflects the functional relationship between prior experience and subsequent task demands. But this leads to a fundamental circularity because if mental structures (i.e. memory systems) are being inferred though a functional task analysis, how can these structures then be used to explain performance on those very same tasks?

As a concrete example of this circularity, consider semantic-cued recall and graphemic-cued recall, discussed earlier in the context of the process-pure problem. Both tests were/are ostensibly episodic as they both probe memory for a specific prior event. Yet, as shown by Blaxton (1989) these two tasks respond very differently to experimental manipulations. Specifically, semantic-cued recall shows a positive generation effect (i.e. self-generated items are better remembered than read items) while graphemic-cued recall shows the opposite relation (read greater than generate). Results such as these have led multiple system theorists to view graphemic-cued recall as tapping a perceptual memory system, and semantic-cued recall as tapping semantic memory (Tulving and Schacter 1990). Thus, classification of these memory tests is entirely based on functional relations; that is, in terms of the pattern of results they exhibit. They are not defined *a priori* as episodic, but rather functionally, in terms of their relation to experimental variables. No structure (system) has been 'discovered' by these observations, and to explain the results by appeal to such hypothetical structures confuses more than clarifies our understanding of the observed functional relations.

In the light of these arguments, it is worth considering Sherry and Schacter's (1987) claim that multiple systems theorists need to consider more thoroughly the functions of the systems they propose. Sherry and Schacter recognized the need for 'a well-specified set of criteria' for determining functional incompatibility between memory tests, but went on to acknowledge that such criteria cannot currently be specified because 'the necessary information concerning the operation of memory is unavailable' (Sherry and Schacter 1987, p.449). What information is required? Sherry and Schacter state: 'To provide a convincing analysis of functional incompatibility, it would be necessary to possess (a) an understanding of the demands of a particular memory problem, (b) a description of the *architecture* of the hypothesized system that allegedly handles the problem, and (c) a description of the properties of some other hypothetical system that allegedly cannot handle the problem' (Sherry and Schacter 1987, p.449, emphasis added). Our analysis suggests that such a program could never be realized because it is impossible to obtain 'a description of the architecture of a hypothesized system' independently of 'the demands of a particular memory problem'.†

† Sherry and Schacter do provide two examples of functionally incompatibility, one concerning dual visual systems in flying insects, the other concerning dual blood supply systems in the wings of bats. What is most notable about these biological examples is that both are predicated on a morphological analysis of observable anatomical characteristics.

Perhaps it is the tacit recognition of this conundrum that has spurred the feverish activity and rhetoric of the system theorist about the importance of neuroscience to the study of memory. Thus, one increasingly hears that 'brain systems' provide the best explanation of memory, or sees the terms 'brain systems' and 'memory systems' used synonymously. One might go so far as to say that this trend reflects the realization on the part of multiple system theorists that they lack the psychological grounding for the memory structures (the 'architectures') they have built. That is, knowing at some level that their postulated memory structures can never be truly observed or verified, they appeal to the more substantive and objectively observable structures found in the brain.

Memory and brain

The third major criterion for the postulation of memory systems is that they are based on the operation of different brain systems. For instance, Squire (1994) describes different 'forms' of memory, and then notes how these 'multiple memories' are most consistent with a 'brain-systems' view. Similarly, Schacter and Tulving (1994*b*, p.13) state that different memory systems reflect 'different neural substrates (neural structures and mechanisms)'.

The brain systems manoeuvre is often taken as the most scientifically compelling criterion for the postulation of multiple memory systems, but for all of its technological appeal, it may well be the most obfuscating of the three criteria. Examination of the literature reveals very few clear statements about exactly what is meant by the terms 'brain system' or 'neural mechanism'. For example, is the hippocampus a 'brain system' and is it the same thing as the episodic or declarative memory system? Exactly what are the necessary and sufficient structures that define the 'medial-temporal lobe memory system'? And is it just the neural structures or do we also include in this brain system neural *processes* and other 'non-neural' components (e.g. glial cells, blood flow, hormonal influences, etc.)? And what of 'neural mechanism'? If we were to discover that all long-term memory in the brain is mediated by a similar form of long-term potentiation (Lynch and Granger 1992), or that all learning reflects variations on the basic neural processes of habituation and sensitization (Hawkins and Kandel 1984), would this mean that there is a single memory system? In short, serious evaluation of the brain systems criterion requires a precision in theoretical definition that is currently lacking in both psychology and neurology.

Even if the lack of precision were ignored, however, and the relationship between 'memory systems' and 'brain systems' was assumed to be isomorphic, available functional neuroimaging evidence does not bear out the tidy compartmentalization of memory systems implied by current system classifications. That is, rather than seeing a circumscribed Episodic Memory System being activated for all episodic memory tasks, or a Semantic Memory System underlying performance on all semantic tasks, instead what one observes are highly distributed and often overlapping patterns of activations that suggest numerous components, both shared and distinct, among tasks. That is, the picture one gets is much more compatible with a processing, or a components-of-processing view (Witherspoon and Moscovitch 1989), in which various neural processes are recruited or assembled for the task at hand (see Mesulam 1990). Two recent studies bare out this point.

Cabeza *et al.* (1997) used PET to directly compared the neural activity underlying recall and recognition. Versions of each task were specifically designed to be matched in terms of visual input, verbal output, and cognitive effort, thus raising the possibility that a core episodic system might be identified. However, although there were overlapping areas of activation (right prefrontal and anterior cingulate), the two tasks also produced very distinct patterns of activations. In particular, whereas recognition produced higher levels of activation than did recall in the inferior parietal cortex, recall resulted in significantly greater activation in the anterior cingulate, globus pallidus, thalamus, and cerebellum. This would seem to provide direct evidence that, although both tasks are thought to tap the same episodic/declarative memory system, they are nevertheless mediated by different neural networks (i.e. distinct 'brain systems' or 'neural mechanisms').† Thus, the Cabeza study provides little evidence for a core system underlying episodic memory.

Even more dramatic evidence of the variable relation between memory performance and brain activation is shown in a PET study by Jennings *et al.* (1997). These researchers attempted to determine if the neural activation underlying a *single* semantic task would be the same across different modes of responding (vocal versus mouse-clicks versus silent thought). In separate scans, subjects used each response mode to make yes/no decisions to visually presented words in either a semantic task (living/non-living) or a non-semantic task (does the word contain the letter 'a'). Within a particular response mode, activations from the non-semantic (letter) task were subtracted from those in the semantic task, and the patterns were compared across response mode. As in Cabeza *et al.* (1997), there was some shared activation across the three response modes. More striking, however, was that each response mode produced a unique pattern of activation such that 'different areas of the brain were recruited for semantic processing depending on how participants organized their response'. Indeed, analyses of the neural interaction between processing task and response mode showed that specific regions exhibiting *increased* activation for one response mode, often showed *decreased* activation for another response mode.

Jennings *et al.* (1997) justifiably used their data to impugn the additivity assumption underlying the widely employed subtraction technique in neuroimaging studies. However, given that this technique has apparently been successful in the identification of language and perceptual processes (e.g. Peterson *et al.* 1988), we suggest that Jennings *et al.*'s results may be essentially correct: there is no single locus for semantic memory in the brain. Rather, semantic memory is a psychological-level description of a class of *tasks* (or environmental challenges) that *interact* with the brain in different ways. No doubt these different ways have some things in common but, ontologically, there is no one core commonality that could be called 'the semantic memory system', and that corresponds in a one-to-one fashion with a particular system in the brain.

† The Cabeza study would thus seem to satisfy one of the main criteria for postulation of separate memory systems, distinct neural implementation. It is worth noting that the two other main criteria—functional dissociation and different contents—also seem to have been met as it is widely known that recall and recognition can be dissociated as a function of frequency in the language; and the two tests appear to require memory for different kinds of information (recall requiring memory for a specific target event, recognition requiring memory for the context in which a target event occurred). Based on these criteria, then, recall and recognition would appear to be based on separate memory systems.

Our point in discussing these two studies is not to suggest that they are not useful. On the contrary, both are very interesting, well designed studies that tell us much about the neural systems underlying different kinds of memory performance. However, we question the ability of such studies to ever provide the kind of evidence that would prove the existence of memory systems. Indeed, we are unclear as to what form such evidence would take. The studies by Cabeza and Jennings may be important in telling us about the 'brain systems' associated with memory performance, but they do not, and could not, identify *memory* systems.

Lesion data have also been championed as providing direct support for a multiple systems view of memory. A full explication of the uses and inherent problems of inferring psychological function from lesion data is beyond the scope of this chapter. We restrict ourselves here to two points. First, there is little agreement on how best to characterize the deficits seen in amnesia and other neuropsychological syndromes. Thus, whether they show deficits in episodic memory, declarative memory, context memory, configural memory, or some other, as yet little understood, form of memory is a completely open question. We therefore think it premature to claim that patient data prove the existence of multiple memory systems.

The second point is simply to note the danger, described by both philosophers (e.g. Malcolm 1977) and neuropsychologists (e.g. Luria 1973), of treating psychological functions such as memory as isomorphic with brain structures. Psychology is not neurology. More specifically, psychological functions such as episodic memory are not isomorphic with neurological structures such as the hippocampus, just as the function of respiration is not isomorphic with the lungs but rather involves dynamic relations between the lungs, diaphragm, chest muscles, etc., as well as the gaseous environment in which respiration occurs.

Data from patients with brain damage, and neural activation studies, while certainly important for understanding the neurological substrates of memory, cannot adjudicate the multiple memory systems debate. In our view, understanding the psychological basis of memory is a prerequisite to understanding its neurological basis. The issue is one of levels of analysis (between brain and cognition/behaviour); and of what one means by the term 'memory'. If one views memory as equivalent to an underlying (neural) representation, then brain data do indeed become the Rosetta stone for understanding memory. If, in contrast, one views memory as a psychological phenomenon, something that reflects the interaction between a person with a prior history of experience and a task environment in which that history is relevant, then brain data, while interesting and important, cannot fully explain memory. To 'locate' memory in the brain is to miss the larger (functional) set of factors, external to the brain, by which memory is meaningfully defined.

A recent PET study by Schacter and colleagues (Schacter *et al.* 1996) illustrates this contrast. They were interested in the neuroanatomical correlates of illusory ('false') memories induced by asking people to recognize a visually presented word that was not studied, but which was semantically related to other, aurally presented study words (see Deese 1959; Roediger and McDermott 1995). Results showed increased blood flow in the left medial-temporal lobe for both true and false memories, but true memories exhibited additional activation in left temporoparietal cortex, a region that has been associated with phonological memory. Most relevant here is Schacter *et al.*'s account of their data; in particular, they state that their findings 'raise the possibility that illusory recollections of false targets seem authentic *because* they are accompanied by medial temporal lobe activity that is usually linked with veridical conscious recollection' (Schacter *et al.* 1996, p.271; emphasis added). The implication is that people assess veridicality by reference to which of their brain areas are currently activated. This is to be contrasted with explanations that appeal to the psychological properties of the false memory paradigm; for example, that non-presented words seem authentic because they are strong semantic associates to studied words. We don't question the fact that such-and-such brain areas were indeed activated by the various tasks, but wonder whether assigning causal efficacy to these areas provides a complete account of the false memory phenomenon. On our view, a complete account of false memory will have to make reference to the psychological properties of the initial event and the conditions under which it is later tested.†

Brain data are fascinating. There is no question that damage to the brain can cause specific memory impairments. It is also true that performance of different memory tasks activates different neural structures and pathways as measured by PET, fMRI, and other neurophysiological techniques. However, interpreting these findings as evidence for memory systems requires more than just the observation that performance of different memory tasks depends on, or differentially activates, distinct neural structures. The real question concerns how brain activity relates to memory as a psychological phenomenon, an issue that goes far beyond the multiple memory systems debate. As disappointing as it may be at the close of the decade of the brain, we still do not possess principled arguments necessary to equate brain stuff with the concepts of psychology, and psychology as an experimental science will suffer if it is dazzled by 'mind/brain' rhetoric and technology into thinking otherwise.

† Indeed, on further scrutiny the data presented by Schacter *et al.* (1996) raise troubling questions about the relationship between the neural activity and behavioural phenomenon, and thus may have deepened, rather than clarified, the false memory phenomenon. In particular, given that the brain responded differentially to true and false items, the data of Schacter *et al.* (1996) apparently demonstrate that the brain does not show false memory! If nothing else, this would seem to be a striking example of a reductionistic analysis losing the phenomenon it was attempting to explain.

INTERIM SUMMARY

In the sections above, we have described some of the more difficult theoretical problems that face any multiple systems approach to memory. One of these problems is the fact that memory tasks are not pure with regard to the processes or systems they index. As shown by our discussion of Glisky *et al.* (1995), the process-impurity of memory tests can easily lead to the postulation of unnecessary memory systems. A second problem concerns the relation between memory and other aspects of cognition. Memory is not an isolated form of cognition, separate from other aspects of processing such as perception, reasoning, and action, but is rather embedded in those processes. Memory for prior events alters how we perceive, reason, and act; conversely, any instance of perception, reasoning, or action results in a modification of the brain (i.e. results in the creation of 'memory'), and there is good reason to believe that these modifications occur in the very same structures that mediate those other ('non-mnemonic') processes. The interrelation of memory and other aspects of processing undercuts the strategy of identifying 'separate' memory systems, and makes it impossible to ever truly evaluate the different-contents criterion.

A similar problem concerns the treatment of different forms of learning as distinct memory systems. Not only is learning in a different conceptual class from memory (i.e. by definition 'learning' is acquisition whereas 'memory' is storage and retrieval), but there is evidence that learning is a ubiquitous property of the brain. Many of the available neural activation studies also seem inconsistent with a multiple systems interpretation. Moreover, key terms in the neural implementation criterion, such as 'brain system' and 'neural mechanisms', are only vaguely defined; and when specific neural mechanisms are precisely identified (e.g. Hawkins and Kandel 1984), the evidence seems to support commonalities among forms of memory rather than differences.

In our view, all of these problems stem from a subtle, but fundamental, problem in the metatheory underlying the systems approach to memory. In particular, distinctions between memory systems are not based on a direct 'morphological' analysis of the structure of memory; rather, such distinctions are necessarily derived from a functional, task-based analysis. Tasks are specific environments which challenge the organism in a variety of different ways; memory systems are thus defined by their *function* within such environments. But this leads to a fundamental circularity in the explanation of memory: structures (memory systems) are inferred from functional (task-specific) uses of memory, but are then used to explain the very effects observed on those tasks. Moreover, in the absence of any hope of directly observing a psychological 'memory system', system theorists appeal to 'brain systems' as their explanation for memory phenomena.

Is there any way out of this circularity and wanton reductionism?

A neofunctional alternative to the question of memory

In describing an alternative to the multiple systems approach to memory, we ask readers to remind themselves of exactly what it is we are trying to explain. The central question faced by memory researchers is not 'how many memory systems are there' or even whether there are such things as memory systems. Rather, what needs to be explained, at least in the context of this debate, is the remarkable variety with which past experience influences subsequent thought and behaviour.

The multiple systems approach offers a dense theoretical armament for addressing this variety. Indeed, there is a sense in which the theoretical machinery of the multiple systems approach is as complex as the phenomena it is trying to explain; due, perhaps, to its tendency to enumerate a mixed list of tasks, paradigms, and phenomena. But even if it contains a descriptive kernel of truth, we believe that it is in many ways premature. It is certainly not uncontroversial and one may imagine an outside observer wondering whether the science of memory has reached the level of sophistication where so much of our time and effort is spent trying to establish the number and characteristics of hypothetical memory systems, or even debating their reality. That outside observer, having some basic training in the natural sciences, might also inquire into the goal of our theoretical debates: 'What are the fundamental empirical regularities of memory that your theories are trying to explain?'.

If you were to describe the most important principle discovered about memory in the last 100 years, what would it be? The question is a sobering one, for although one could point to numerous empirical generalizations—such as the level-of-processing effect, the Tulving–Weisman function, or the differential sensitivity of certain tests to prior perceptual or conceptual processing—few such generalizations have been shown to be invariant across situations. That is, for each empirical regularity that is announced, one can invariably devise a situation for which this regularity does not hold. In many ways, it is this non-uniformity, the lack of even one uncontroversial empirical law, that makes the study of memory less than a mature scientific endeavour.

Yet there is one principle that is relatively invariant, or at least general enough on which to base an empirical investigation of memory, namely, the principle of transfer-appropriate processing (Morris *et al.* 1977). Although this principle has been expressed in different ways by different authors—for example, as 'memory for operations' (Kolers 1976) or 'encoding specificity' (Tulving 1983)—each of these concepts expresses a central uniformity about memory: past events influence subsequent performance to the extent that cognitive activities occurring at retrieval are similar to those that occurred at encoding. In our view, this is one of the most important principles ever to be articulated about memory and thus we see it as the starting point for explaining the mnemonic variety that drives this debate. We also see it as a fundamentally *functional* principle as it embodies the notion that, whatever memory is (system, process, or, perhaps, disposition), it will have to be explained in terms of the relation or interaction between what a person was *doing* when an event was first experienced and what they are *doing* when that event subsequently exerts its influence.

The reference to activity in the preceding paragraph (i.e. memory as *doing*) is not unintentional. As described below, we view memory as an active process rather than a static representation. Nevertheless, we hesitate to rely too heavily on 'process' as the central theoretical construct in our account of memory because, in many ways, mnemonic processes are as metaphorical as the memory systems with which they are often contrasted. The label 'processing approach' is popular because of the success of the distinction between data-driven and conceptually driven processing in explaining dissociations among implicit and explicit tests (Jacoby 1983*a*; Roediger and Blaxton 1987); and because of evidence that the means of acquiring information (i.e. the specific operations performed) effectively define the memory acquired (Kolers 1976; Kolers and Roediger 1984). As shown by the popularity of these ideas, the process metaphor is certainly a useful one, and one that we rely on in our own research as well as in many of the passages below. But we believe that what most advocates of the 'processing view' have in mind when describing memory is more akin to the concept of *function* than it is to process.

To understand our point of view, consider the following basic definitions of function and process provided by Brent (1984): 'The concept of function focuses attention on changes in the relationship between a structure and its external context. The concept of process, on the other hand, focuses on changes in the internal relationships among the parts of the structure itself. A functional analysis thus views structural activity macroscopically, in terms of the broader context in which it is embedded. A process-oriented-analysis, on the other hand, views that same activity microscopically, as a causally integrated sequence of acts by the constituents of the structure' (Brent 1984, pp.18–19).

Thus, on Brent's definitions, the alternative to a multiple system approach is better captured by *function* than by process. A true process-based analysis would necessarily assume some underlying parts, such as mental representations, upon which the processes operate. Although beyond the scope of this chapter, we have reservations about the need to postulate mental representations to account for memory phenomena (see Van Gelder 1997; Verela *et al.* 1991).† Regardless, we believe that many of the theorists who use the process metaphor actually intend a concept more in line with function; namely, a macroscopic relationship between a holistic organism (e.g. a person) and its environment. Although 'memory process'

† Of course, another interesting interpretation of Brent's definitions is that to fully understand memory, the (microscopic) structures and processes that will need to be described are in fact neural. This may indeed be true but it would make an even stronger case for a *functional*, rather than structural, account of psychological abilities such as memory. That is, on this account, concepts of memory, perception, etc. would effectively refer to functional (macroscopic) relations between a person and their external context, with these functions (at least partially) realized by structural changes in internal (i.e. neural) relationships. But such a conceptualization even more strongly undermines the notion of memory systems *qua* psychological structures.

may serve a useful purpose in describing that relationship, like 'memory system' its explanatory role should be recognized as predominantly metaphorical and thus subsidiary to more concretely described functional relations. Indeed, even the data-driven/conceptually driven distinction can be viewed as drawing its explanatory power, not by reference to any specific 'process', but rather through the functional relations that obtain between particular test cues (e.g. a dictionary definition versus a briefly flashed word) and observed performance (e.g. the presence or absence of a levels-of-processing effect). It is for these reasons that we describe our alternative to multiple systems as functionalist (or 'neofunctionalist') rather than as a 'processing' approach.

Researchers who we would describe as functionalists tend to be rather eclectic, emphasizing similarities amongst diverse forms and tests of memory (e.g. Jacoby 1983*b*; Humphreys *et al.* 1989) while at the same time showing the striking variety with which a particular form of memory may subsequently influence thought and behaviour (e.g. Bransford *et al.* 1977; Jacoby 1988; Whittlesea 1993). Given this eclectic orientation, it is not as easy to group functional approaches (i.e. theorists or particular theoretical ideas) under a single banner as it is for multiple system approaches (Schacter and Tulving 1994*a*). Nevertheless, in the final sections of this chapter, we lay out what we see as the central tenets of a modern functional approach to memory. We believe that, taken together, these tenets provide a more promising and flexible approach to understanding of memory than does an approach based on the questionable doctrine of psychological structuralism.

Memory is an activity

'The fact that mental contents are evanescent and fleeting marks them off in an important way from the relatively permanent elements of anatomy. No matter how much we talk of the preservation of psychological dispositions, nor how many metaphors we may summon to characterize the storage of ideas in some hypothetical deposit chamber of memory, the obstinate fact remains that when we are not experiencing a sensation or idea it is, strictly speaking, non-existent' (Angell 1906, as quoted in Herrnstein and Boring 1965, p.502).

This quote, by a leader of the functionalist school, captures what was one of the central complaints against structural approaches to mind such as that advocated by Titchener, and also summarizes what we see as a major problem with present system-based approaches to memory. In particular, both are predicated on the notion that mental events, including memories, are to be treated as concrete entities instantiated in a mental or neural representation.

A very different orientation is to view memory as an activity. Here, memory is not a concrete thing (as is, for example, a brain structure) but is rather a transaction between a person and what we might call a retrieval environment. As Craik (1985) put it, 'the memory trace is perhaps not a specific structure located at some point (or even diffusely) within the central nervous system, but is rather an altered potential of the system to carry out certain mental activities provided that the context, task, goals, mental set, etc. present at the time of initial learning are also reinstated, either "driven" by external stimulation or reconstructed internally by the rememberer. By this account, remembering is essentially a form of perceiving.' Moreover, '[j]ust as it is not very sensible or meaningful to talk about the percept as a function of mental activity only (rather, it is by nature an interaction between stimulus information and specific "mental skills" of the perceiver), so it does not seem too useful to regard memory as a function of the mind alone' (Craik 1985, p.200).

The view of memory as activity has two major implications, outlined in the following two tenets.

Memory is not 'stored'

In structural (multiple systems) approaches, memory consists of concrete entities (representations) and the storage places (systems) in which they are kept. For the structuralist, then, memories exists (have ontological reality) when not in use. For the functionalist, in contrast, memory is a potential, disposition, or capacity for interacting with the environment in particular ways, or for achieving certain states of awareness that are similar to earlier states (see, for example, Ben-Zeev 1986).

Critically, to view memory as a potential or capacity, one necessarily gives up the metaphor of 'storing' memories. Memory is not something stored 'in' the person or even 'in' the brain, any more than music is stored in the radio, or walking stored in the legs. In each case (memory, music, and locomotion), the system under investigation has the potential to achieve certain states, or exhibit particular actions, when relevant conditions are met, but these states or actions do not reside in the system. Like walking, memory is a dynamic event that exists only in its operation. Extending the quote of Angell above, one could say that when we are not experiencing (e.g. recollecting) a prior event, or otherwise being ('implicitly') influenced by that event, memory is, 'strictly speaking, non-existent'.

Describing memory as an activity, and thus as something which is not stored, seems to befuddle many people. How can one speak of memory without first postulating the prior, independent existence of the thing remembered? Indeed, such questions arise even among those who grant that memory is an activity rather than a concrete entity. As noted by Malcolm (1977), even when trying to explain a 'memory-act' or 'memory-process', there follows a strong tendency to inquire about the *content* of this act or process: 'It is as if we thought of the memory-act or memory-process as being a *container* (something like a box); and then we ask, What is *in* this container? What are its contents?' (Malcolm 1977, p.35). We suggest that such questions stem from both ingrained folk psychology (see Roediger 1980) and the structuralist assumptions, embodied in system-based approaches, critiqued above. We also suggest that part of the solution to this problem involves the relocation of memory from something that exists 'in' the person or brain to something that obtains in the interaction between the person (and their brain) and the environment in which acts of memory occur.

Memory is an interaction between a person and a retrieval environment

A second major implication of the memory-as-activity view is that memory cannot be defined outside of the retrieval environment (i.e. the context) in which prior experience influences current performance. This definition of memory is similar to the definition of attentional automaticity put forth by Neumann (1984). Neumann argued that, rather than being an absolute property of a particular process, automaticity is better viewed as an emergent property of task performance, reflecting the coupling of input parameters (specified in the sensory array) with the skills of the performer. Similarly, mnemonic processes may best be defined in terms of how a current disposition, enabled by past experience, gets coupled to a retrieval environment such that prior experience becomes manifest.

When we say that memory reflects an interaction between a person and a retrieval environment, we mean quite literally that memory cannot be discussed in the abstract, outside of the context of retrieval cues and, as argued below, the goals of the rememberer. Recall our first two scenarios involving John's response to his wife's inquiry about the location of their car keys. In first scenario, John tells his wife to the look 'in the kitchen closet' to find the keys, while in the other he tells her to 'look on the nail'. In both cases, the initial event of John hanging the keys was the same, but his answer is different depending on how he (tacitly) interprets the question. In our example, this interpretation involved John's knowledge of his wife's prior experiences in their new house, whether they were of the kitchen closet or of the nail. There is no way we can describe John's memory outside of the context of the question he is asked. His memory does not exist as a fixed snapshot of the prior event that is later retrieved *in toto* and adapted to the current circumstance. Rather, the current circumstance determines how the prior event manifests itself in performance and, indeed, in subjective experience (see Kelley and Jacoby 1990; Whittlesea 1993). In this sense, then, the current circumstance is as much part of the memory as is the past event.

Memory is context specific

If memory reflects an interaction between the person and the retrieval environment, then one should expect to find a high degree of contextual specificity in the expression of memory. This contrasts with the structuralists' assumption, echoed in current multiple systems theories, that events can be represented abstractly, stripped of their episodic/contextual details.

What evidence is there for such contextual specificity? Some of the earliest evidence was uncovered in the initial research on what is now called 'implicit memory'. For example, studies of visual word identification (Jacoby and Dallas 1981; Kirsner and Smith 1974; Winnick and Daniel, 1970) showed that performance was highly dependent on the details of prior presentation, such as the modality in which words were initially presented. These results strongly contrasted with existing models of word recognition which suggested that word recognition was based on abstract representations that did not preserve the episodic details of initial processing. Evidence for contextual specificity led to changes in existing models of word recognition, including the postulation of modality-specific representations; and, more generally, to a revision and expansion of system-based explanations of priming. In particular, performance on word identification, instead of reflecting semantic memory as had previously been argued (Tulving 1983), was subsequently viewed as a form of procedural memory (Tulving and Schacter 1990). Even these adjustments, however, seem incapable of capturing the range of contextual effects shown, for example, in the sensitivity of word identification to changes in type font or case (e.g. Jacoby and Hayman 1987); in the sensitivity of re-reading to the original orientation of text (e.g. Kolers 1976); or the sensitivity of lexical decision to the conceptual biasing effects of preceding words (e.g. Masson and Freedman 1990).

As a further example of the degree to which memory can exhibit contextual specificity, consider experiments by Hayman and Tulving (1989) examining the 'hyperspecific' nature of priming on the implicit word fragment completion test. Subjects were first shown a list of study words (e.g. MOSQUITO) and then were given two successive fragment completion tests. Critically, the fragments presented on the two successive tests were either identical (e.g. –O–Q—TO on both tests) or were 'complementary' such that the two cues had little or no overlap (–O–Q—TO and M–S–UI–O). The critical results concerned the stochastic relations (degree of dependence) between performance on the two successive tests. In particular, when the same fragment was used, performance on the tests was found to be highly related (i.e. performance on one test predicted performance on the other). In contrast, when complementary fragments were employed, the two tests showed no significant relation (i.e. performance of the two tests was independent of one another). Witherspoon and Moscovitch (1989) also showed stochastic independence between successive measures of retention but their experiments employed demonstrably different tests (fragment completion and perceptual identification). Hayman and Tulving showed that such independence was also possible between different versions of the *same* test, and thus presumably tapping the same memory system.

Hayman and Tulving took their results to implicate the existence of a 'traceless QM (quasi-memory) system', a notion that was later incorporated into the word-form subsystem of the PRS (perceptual representation system). Such labels are fine, but what the reader should take away from these experiments is neither the labels nor the 'discovery' of a new system, but rather the phenomenon. That is, what is timely about Hayman and Tulving's elegant experiments is not the QM system (which was abandoned, or at best renamed, a year later), but the high degree of context specificity that can be elicited by subtle changes in retrieval cues.

Much of the research showing context-specific transfer has been limited to the perceptual domain. However, more recent research suggests that a similar level of specificity can be found on conceptual/semantic tests. Cabeza (1994), for example, has shown a double dissociation between two conceptual implicit tests (category–exemplar production and free association) as a function of the type of orienting task performed at encoding (categorical classification versus associative production). Similar results have been reported by other researchers (McDermott and Roediger 1996; Vaidya *et al.* 1997; Woltz 1996). We believe that such experiments are only the tip of the iceberg, and that further demonstrations in the semantic domain will eventually be as common as the forms of contextual specificity observed in recall and recognition (e.g. Morris *et al.* 1977; Tulving and Thompson 1973).

Although we view context specificity as a key assumption underlying functional approaches to memory, it is clear that memory is not completely context bound. To take again our example of John, although his 'memory' changes dramatically depending on the retrieval cues in which the prior (key-hanging) experience becomes manifest, there are a multitude of different questions he could be asked (or retrieval tests he could perform) that would all show memory for the keys' location. Given such generalization, how can one maintain that memory is context specific?

A detailed answer to this question is beyond the scope of this chapter but we hasten to add that, rather then being fundamentally problematic, the apparent lack of situational specificity becomes one of the most interesting, important, and difficult aspects of memory research, and leads to an emphasis on *transfer*, how activity in one situation is repeated, or acts as a source of influence in subsequent, but necessarily different situations. Critical here is appreciation of the fact that *no events ever truly recur*, so in fact all memory (transfer) is a case of generalization. Rather than abandoning the focus on context specificity, then, a functional approach recommends close examination of the activities performed during the initial event, as well as the retrieval demands made when that event exerts its influence (e.g. Whittlesea *et al.* 1994).

Memory is relative to (and thus defined by) task demands and goals

The context specificity of memory can be viewed as the primary factor underlying the observed variety with which prior events influence subsequent performance. It therefore leads to a program of research where, instead of the characteristics of hypothetical memory systems, the nature of retrieval environments (instructions, cues, task demands) become of central importance (e.g. Humphreys *et al.* 1989). In addition to an emphasis on the objective characteristics of retrieval environments, however, a functionalist approach also places a heavy emphasis on the goals of the subject in performing a task. This point can be appreciated by noting that dissociations arise even when a subject is given identical retrieval cues on two separate tests (e.g. Graf *et al.* 1982). The fact that such dissociations can be obtained suggests the need to consider not only the different retrieval environments in which prior experience may influence performance, but also how a subject conceptualizes that environment, and what they are trying to achieve within it. In the case of explicit and implicit memory, the determining goal appears to be whether the subject responds to test cues with or without reference to a specific prior event.

The findings of Morris *et al.* (1977) (see also Stein 1978) in the explicit domain can also be viewed as dependent on the goals of subjects. In particular, whether

explicit memory-test performance was enhanced by semantic orientation at study (attention to meaning), or non-semantic orientation (attention to phonemic qualities), depended on the whether the subject's goal was to establish a meaningful (semantic-based) relationship between current and prior words, or whether the relationship to be established was phonemic (rhyme-based). These results and others are consistent with the claim that the goals of test performance can have a dramatic effect on whether a test stimulus acts as a conceptually driven or data-driven cue (see Toth and Reingold 1996).

Thus the approach we are suggesting is one in which both the prior event (the 'to-be-remembered' event) and the retrieval environment are analysed relative to the goals of the subject. This perspective is not unlike that advocated by Logan (1988) in his instance theory of automaticity: 'Each encounter with a stimulus is assumed to be represented as a processing episode, which consists of the goal the subject was trying to obtain, the stimulus encountered in pursuit of the goal, the interpretation given to the stimulus with respect to the goal, and the response made to the stimulus' (Logan 1988, p.495). This theory, which is supported by an impressive array of empirical findings, expresses our position that subject-determined goals and interpretations play a central role in determining what gets 'into' and 'out of' memory.

There is no principled distinction between memory and other aspects of cognition

Emphasis on the goals and purposes of processing leads, in our view, to a very different conceptualization of the relation between memory and other cognitive abilities than that implicated in the systems approach. As discussed earlier, memory permeates all cognitive activity, a claim borne out both in behavioural data and in the study of the brain. This leads to difficulties with views that postulate strong distinctions between memory and other cognitive activities such as perception, attention, reason, and action. Rather than analysing discrete stages in information processing, a functional orientation is more concerned with how these ostensibly separate abilities act in an integrated fashion to allow adaptive responding to environmental circumstances. Dewey's (1896) classic 'Reflex Arc' paper makes this point in his example of a child reaching for the flame of a candle. Dewey suggested that analysing the situation into sensation, perception, and motor action, either from a contents of consciousness view or from a stimulus–response view, obliterated the central psychological phenomenon of the relationship between the organism and its environment. The adaptive *coordination* of sensation, perception, and action is lost in an analysis of each of those faculties as discrete, separable stages.

A similar obliteration of phenomena occurs when isolated memory systems are charged with explaining mnemonic phenomena that are only slightly more complex than the typical isolated-word experiment. Consider a study of memory and problem solving by Adams *et al.* (1988). Subjects were exposed to acquisition sentences that could be used to solve word puzzles presented later in a test phase. An example of a test-phase problem is the following: 'Uriah Fuller, the famous Israeli superpsychic can tell you the score of any baseball game before it starts. What's his secret?'. The important manipulation involved the type of acquisition sentences subjects were exposed to at encoding. Some subjects were presented with *fact-based* sentences, such as 'Before it starts, the score of any game is 0 to 0'. A second group were given *problem-based* variants of these same facts: 'It is easy to predict the score of any game before it begins . . . the score is 0 to 0'. Despite the fact that both sentences-types communicated essentially the same information, problem-solving performance of these two groups was dramatically different: the problem-based group solved 56% of the test-phase problems, while the fact-based group solved only 36%. Similar results have been reported by Lockhart *et al.* (1988) who also showed that problem-solving performance in the fact-based group was no better than that of a control group not exposed to the acquisition sentences. Moreover, both studies presented strong evidence that the effects were not due to the induction of a general problem-solving set, but were specific to the sentences and problems to which subjects were exposed.

Consider these results in the context of the multiple systems approach. First, it is difficult to specify, in any principled way, the system or systems into which acquisition sentences are being encoded. Both types of sentences appear to have both episodic (autobiographical) and semantic (meaningful) characteristics but, in addition, the problem-based sentences exhibit a condition-action quality, thus implicating a procedural basis. Second, what memory systems would mediate performance when subjects later encounter the test problems? Subjects were not informed of the relationship between acquisition sentences and subsequent test problems, thus qualifying the problem-solving test as implicit. But the data show conclusively that performance is contextually (episodically) specific as to the particular problems presented. Moreover, the very nature of the problem-based sentences, and the nature of their transfer, suggests the operation of procedural (non-declarative) memory; this, despite the fact that the both the acquisition sentences and the test problems are obviously meaning-based (semantic/declarative). Perhaps at retrieval, then, the test puzzles are initially processed for meaning in the semantic system (after, of course, being perceptually processed by the PRS); simultaneously, episodic memories are (implicitly?) retrieved triggering condition-action (skill-based) representations for the problem-based sentences in procedural memory. These representations then interact with representations in semantic memory, allowing the subject to solve the problem.

Compare this tangled account with the more functional explanation provided within the framework of transfer appropriate processing: subjects presented with problem-based acquisition sentences engaged in a set of cognitive activities that overlapped substantially with the types of activities subsequently required to solve the test problems (substantial enough to produce a significant increase in problem-solving ability over control subjects). In contrast, subjects presented with fact-based sentences engaged in cognitive activities that overlapped very little, if at all, with those required by the test problems (as shown by the failure of fact-based

subjects to solve problems above the level shown by control subjects). Exactly what these 'activities' are is currently underspecified, but a functional account at least gives some indication of what aspects of performance to focus on. In particular, the problem-based acquisition sentences involved the initial posing of a problem, followed by presentation of its solution, whereas the fact-based sentences presented a simple fact for verification. Moreover, one can infer that reading specific words had little affect on observed performance because fact- and problem-based sentences showed the same degree of overlap with the test problems.

Additional specification of the relevant activities is provided in a related problem-solving study by Needham and Begg (1991). In the first phase of their experiment, participants were asked to read a series of word problems, each of which contained a description of the relevant solution to the problem posed. One group was asked to examine the solutions and prepare to explain why they were correct, while another group was simply asked to memorize the problems and their solutions. Subsequent tests of the ability to solve analogous problems, or to remember the original problems and solutions, were then administered. Results showed that subjects who were originally instructed to solve the problems exhibited more transfer in solving analogous problems than did the memorization group; in contrast, the memorization group exhibited better memory for the original problems than did the problem-solving group. What is impressive about these results is that both groups were given exactly the same problems at acquisition. Thus, in addition to raising serious difficulties for system-based accounts of problem solving, the Needham and Begg (1991) study also adds further specification to a functional account of memory. It is not simply the posing of a problem-oriented question that determines transfer in problem solving, but whether the goals of initial processing were directed at future meaning-based explanation (i.e. problem solving) versus future reproduction (i.e. memory retrieval).

Experiments such those by Adams *et al.* (1988) and by Needham and Begg (1991) demonstrate the high degree of interdependence between memory and problem solving (reasoning), just as experiments on word or object recognition show the interdependence of memory and perception (e.g. Ratcliff and McKoon 1996). Indeed, the degree of interdependence is so extreme as to make distinctions among these faculties essentially arbitrary. These experiments also lend support to the 'memory for operations' view advocated by Kolers and colleagues (e.g. Kolers and Roediger 1984; Kolers and Perkins 1975). Rather than being a 'focal trace' existing in some static system, Kolers argued that memory is better conceptualized in terms of the mental operations or procedures used in initially interacting with an item or an event. That is, memory is not an abstracted copy or representation of some previous content but is simply the set of operations used in dealing with the event. There is nothing else. Note the parsimony and potential unifying quality of this proposal. Rather than stemming from differences in hypothetical memory systems, variety in the expression of memory arises naturally out the numerous skills or procedures that people have for interacting with their environment.

SUMMARY OF THE FUNCTIONALIST ORIENTATION TO MEMORY

In the sections above, we have tried to briefly identify some of the core assumptions of a functionalist approach to memory, and to give some flavour for that approach by choosing examples that illustrate major assumptions.† To briefly reiterate, we believe that memory is best viewed as a dynamic activity that is not stored in the person or brain, but rather emerges from interaction of the person (and their brain) with the surrounding environment. This view recommends against taking the concept of representation to mean an ontologically 'real' thing existing in either the mind or brain, because to see memory in a representation is to freeze in time and space what is in essence a fluid activity that is spread across both. It is to see rotation 'in' the wheel, or flight 'in' the wing, instead of seeing that rotation and flight are but one function that can be performed by wheels and wings.

By our account, memory is necessarily context specific and part of that context is made up by the goals of the rememberer. The ability of people to transcend context (i.e. generalize)—to remember out of context, or to act in opposition to prior habits—is a central theoretical issue and dovetails with concerns about the nature of similarity, as well as the appropriate interpretation of abstract knowledge. The context-sensitive, goal-directed nature of memory undermines the ability to separate memory into separate, independent memory systems, just as it undermines the ability to view perception, attention, memory, and action, as separate, independent stages of information (or neural) processing. Full appreciation of this latter point necessarily leads to a reconceptualization of the debate that sparked this book: the debate over memory systems is not one versus many, but zero versus any.

CONCLUSIONS

Multiple system structuralists see memory as something you can point to in the brain, or something located in that pernicious category of modern cognitive neuroscience, the 'mind/brain'. In doing so, they 'neuralize' what are, at their heart, psychological and behavioural events and thus participate in a form of neural Cartesianism (see Coulter 1997). For example, Mishkin and Appenzeller (1987, p.80) tell us that 'Ultimately, to be sure, memory is a series of molecular events'.

† Numerous aspects of our functional approach have been left out due to space limitations. These include the distinction between perceptual and conceptual processing, the concept of processing fluency and the general role of heuristics and attributions in memory, and the distinction between controlled and automatic uses of memory. Each of these concepts plays a central role in our view of memory and we hope to spell out their role in a future article. Also needed in a functionalist approach would be specification of the relation between memory as a psychological phenomenon and the operation of the brain (see footnote to p.255). Again, space limitations preclude us from extensive discussion except to note the correspondence between the functional approach recommended here and the 'neural context' approach to brain function advocated by McIntosh (1997).

Similarly, Norman and Schacter (1996, p.232) describe the 'raw material of memory' as 'changes in brain activity'. The problem with these statements is that they are referring to *the neural substrates of memory* not memory *per se*. Memory is something that obtains on laboratory tasks, or between people, or in the minds of the rememberer. No one remembers (or implicitly acts on) biomolecular events, and the raw material of memory is not brain activity but objects and events such as faces, cars, jokes, and baseball games.

In a similar vein, Squire (1994, p.204) states that 'declarative memory refers to a biologically meaningful category of memory dependent on a specific brain system . . .'. What does it mean to say that declarative memory is 'biologically meaningful'? Does this mean that facts and propositions are somehow used to carry out neurobiological functions? Of course not. If anything, declarative memory is a *psychologically* (and socially) meaningful category used to describe a particular kind of knowledge. It is molecular events and brain activity that are biologically meaningful.

Lest we be misunderstood, we believe there *are* important differences between the various forms of memory identified by researchers as constituting memory systems; it seems clear to us, for example, that sensory habituation differs from motor learning which, in turn, differs from memory for autobiographical events. Moreover, these different forms of learning and memory must, at some level, reflect the operation of different brain processes (at least on any monistic–materialist account of mind). Our concern is whether these different forms of learning and memory need to be considered as entirely separate, independent systems, both relative to each other, and relative to other aspects of cognitive processing. Stated differently, although the multiple system theorist's concern with task differences is certainly important to understanding memory, we believe that such differences should be balanced with a understanding of the similarities between tasks. Also, while a memory systems approach does a good job of cordoning off memory as a separate area of inquiry (both psychologically and neurologically), we believe there are important insights to be gained by asking how memory is integrated with other cognitive processes such as perception, attention, reasoning, and goal-directed action.

In their current forms, the structural/neurologically based multiple system approach and the functional/psychologically oriented process approach involve different domains of inquiry, different experimental approaches, and produce different kinds of theories. Which approach is most appropriate to understanding memory? We believe that both can be informative, but some researchers appear compelled to proclaim a rather different answer to this question: given the 'hard' nature of the brain, the backing of biology, and the high-tech armament of neuroscience, they think it is clear that 'a brain-systems view of multiple memories is more consistent with the biological and psychological facts than a processing view' (Squire 1994, p.215) and that '[t]he 'battle' over multiple systems is over, and the multiple-systems view has won' (Tulving, quoted in Roediger 1990, p.376). In the spirit of a lively debate, we close by suggesting that such claims are not only premature, but overly narrow, as they presuppose that by describing the structure of the brain one has explained the function of the mind. In contrast, we view mind and memory as adaptive mental functions that take place in a wider context of environmental demands and subject-determined goals; incorporation of these contextual factors will necessarily form a central part of any complete account of memory and mind. Moreover, proclamations of victory based on the 'brain systems view' incorrectly see the direction of influence in the study of memory as going from brain to mind. In actual fact, the direction of influence has almost always gone the other way. Every interesting 'multiple form of memory' was first identified, and subsequently elucidated, at the psychological/behavioural/functional level and only then were neuroscientists able to probe its neural underpinnings. And so it will always be. The structural/neurological investigators of memory need us functionalists much more than they realize.

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10

Component processes versus systems: is there really an important difference?

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Reading the brief introduction by Foster and Jelicic one learns that each chapter of this book 'concentrates upon the central theoretical question of how long-term memory can best be conceptualized' (p.1). Looking down the author list one will also spot two key names, Roediger and Tulving, and perhaps know that these authors represent the poles of the debate implied in the title of this book. Or do they? Roediger addresses the brief by making a substantive, and by now familiar, attack on the systems approach and, in its place, he advocates the component processing approach. Tulving, however, does not appear to even recognize the debate Roediger refers to. True, he includes a section on process-oriented versus system-oriented accounts of memory but the issues discussed here, centring on a dichotomy between cognitive and neurocognitive approaches to memory, bear no resemblance to the issues raised by those arguing for a process-oriented viewpoint. From then on the idea of multiple systems is, for Tulving, an inescapable conclusion whose progress has simply been hampered by irrational bias against new ideas.

Among the other process-oriented chapters Weldon and Toth and Hunt both make lively, if at times overstated, claims for rejecting the systems approach. Like Roediger these authors base much of their critique around difficulties in deriving sustainable operational definitions of what constitutes a 'system'. In particular much is made of the four criteria devised by Sherry and Schacter (1987) as the basis for defining a memory system. It is therefore a pity that only one contributor purportedly in the structural camp, Mayes, takes on the issues raised by the criteria. As noted above, Tulving pays no attention to these issues and this is also true of McDonald, Ergis, and Winocur in their straightforward localizationist account of memory abilities. Indeed the debate between process and system seems so irrelevant to McDonald *et al.* that they use terminology relating to the two positions interchangeably throughout their contribution. For example, they state 'The concept of multiple memory *systems* in the mammalian brain represents an important advance' (p.67, emphasis added) yet, in the next paragraph, 'we focus on five brain regions . . . that have been reliably identified with learning and memory *processes* (p.67, emphasis added). Later, in their conclusion, 'memory is not a unitary process but one that consists of multiple *components*' (p.94, emphasis added).