A New Theoretical Framework For Explicit and Implicit Memory

Andrew R. Mayes, Patricia A. Gooding & Rob van Eijk
Department of Clinical Neurology
Royal Hallamshire Hospital
University of Sheffield
Glossop Road
Sheffield S10 2
U.K.

a.mayes@sheffield.ac.uk

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Abstract

A framework to explain item-specific implicit and explicit memory is proposed. It explores the mutual implications of four kinds of processing mechanism that are familiar in the literature. The first kind of mechanisms are those related to memory representation which include the kind of storage processes that subserve the maintenance of different types of information in memory. It is argued that there is very little evidence to suggest that fact and event memory require the postulation of algorithmically distinct kinds of storage mechanism. The second mechanism is the enhanced fluency of activation of representation triggered by the encoding of components of those representations that results from the storage changes mediating memory. It is argued that enhanced fluency underlies all item-specific implicit memory and that the same kind of fluency process is probably involved regardless of the type of memory representation fluently activated. The third type of mechanism is the kind of attribution process that is triggered by fluency and gives rise to aware memory feelings as well as specific perceptual and aesthetic feelings The final mechanism is active search, which is an often present feature of explicit memory, and involves the effortful mediation of the frontal lobes. How the interactions between these different mechanisms accounts for item-specific implicit memory, recognition and recall is discussed, as is the framework's relationship with other current views about the mechanisms underlying memory. The best available methods of

measuring enhanced fluency, familiarity, and recollection are reviewed so as to indicate the ways in which the framework may be tested.

1. Introduction

In this paper, we consider the implications of a framework comprising four kinds of mechanism that underlie recall, recognition, and what we refer to as item-specific implicit memory (ISIM). All four mechanisms are familiar in the literature, but the ways in which they may interact have not been fully explored. We argue that use of the framework strongly suggests that a redundancy relationship exists between ISIM and explicit memory in which explicit memory for specific information of any kind does not occur without ISIM (indicated by an enhancement of fluency) occurring for the same information. We discuss the relationship of this four component redundancy framework to current ideas in the literature about these forms of memory and indicate why we think the framework discussed here offers a better way of explaining available data. We then consider the problems associated with the measurement of so-called explicit and implicit memory processes before describing a variety of ways in which hypotheses related to the framework can be tested. Our argument is that there is reasonable support for the four component redundancy framework, and although it is far from proved, it is eminently testable and its adoption would be heuristically beneficial.

2. The Framework

Traditionally, performance on indirect memory tasks in which no reference is made to a study episode or to memory was thought to depend primarily on what will be referred to in this paper as ISIM because it is the subtype of implicit memory (Schacter, 1987) that is item-specific. In contrast, performance on direct memory tasks in which reference is made to a study episode and to memory was thought to depend primarily on what will be referred to in this paper as (item-specific) explicit memory (Schacter, 1987; Roediger, 1990). Examples of typical indirect memory tasks include preference judgements, word stem completion, lexical and object decision, and word and picture naming or categorization (see Graf and Masson, 1993 passim). Examples of direct memory tasks include yes\no and forced-choice recognition, and cued and free recall (see Richardson-Klavehn and Bjork, 1988 for a review). ISIM and explicit memory are the hypothetical memory processes that are postulated to underlie performance on these two kinds of memory task. It is believed that the implicit process(es) lead to unaware memory whereas the explicit process(es) lead to aware memory. Most workers believe that these processes are distinct from each other (Schacter, 1992, 1994; Squire, 1992, 1994).

The theoretical framework that we would like to describe comprises four kinds of process or mechanism: memory representations (see Mayes, 1988 for a discussion); enhanced fluency (see Jacoby and Dallas, 1981); attributions (see Jacoby, Kelley and Dywan, 1989); and active retrieval search (see Gillund and Shiffrin, 1984). These mechanisms, all of which have been discussed to some degree in the literature, can explain how performance is mediated not only on indirect memory tests (usually regarded as primarily sensitive to ISIM), but also on the direct memory tests of recall and recognition (usually regarded as quintessentially explicit memory tasks). We propose that indirect memory test performance usually depends primarily on only ISIM which is typically dependent on one of the four mechanisms, namely enhanced fluency. When the indirect memory test involves a non-memory attribution, ISIM depends on an attribution mechanism as well as enhanced fluency. These mechanisms can operate on different kinds of memory representation depending on the kind of information tapped in the indirect memory task.

We suggest a redundancy model in which explicit memory for specific information always depends on enhanced fluency for the same information triggering memory attribution processes (see Jacoby, Kelley and Dywan, 1989). Explicit memory also often requires an active retrieval search mechanism. As with ISIM, these mechanisms can operate on different kinds of memory representation depending on the kind of information tapped in the task. Recognition always depends on enhanced fluency and attribution operating on one or both of two different kinds of memory representation for items and item-context associations respectively (for example, see Mandler, 1980). Active retrieval mechanisms will often be used to assist the search, but only for memory representations of item-context associations. Recall also always depends on enhanced fluency and attribution, usually with active search mechanisms helping retrieve memory representations for the same kind of item-context associations as are accessed when active retrieval mechanisms are used in recognition. In other words, ISIM and explicit memory differ in that the former is unaware memory whereas the latter is aware memory, but both are mediated by the same two kinds of mechanism (fluency and attribution) that operate on largely common kinds of memory representation. Explicit memory for any kind of information does not occur unless there is ISIM (in the sense of enhanced fluency) for that information.

Memory representations store specific kinds of information and should presumably be defined in terms of what that information is and the way in which it is stored. There is a basic presupposition that memory representations are located in the same neural site as that which was responsible for making the representation in the first place (Rose, 1992; Mayes, 1988). Support for this presupposition can be derived from functional brain imaging studies that have found results consistent with it (see Ungerleider, 1995 for a review). Almost universally, storage is believed to involve structural changes at synapses that affect the ease with which neurons in a neural network can activate each other (for example, see Rose, 1992). Explicit memory and ISIM tap semantic, perceptual and episodic information which is likely to be represented primarily in the neocortex so the synaptic changes should increase the degree to which the neurons representing the separate informational components of the memory are interconnected. So storage probably involves forming stronger links between the neocortical neurons that represent the basic components of the information stored. In this sense, all memory is associative and new memories should depend on strengthening links that either did not previously exist or were weaker. They may also depend on weakening pre-existing links that represent information disruptive of that which needs to be stored.

It is possible that there are different kinds of memory representation corresponding to those kinds of association that are stored in algorithmically distinct ways. For example, it could be that storage of single items (words or faces) in memory depends on associations that are formed between neurons in one neocortical region whereas associations between items and their study context (and perhaps associations between different kinds of items) depend on very different kinds of association formed across distinct neocortical regions (Cohen et al. in press; Curran and Schacter, 1997; Schacter, 1994). For the example to apply it needs to be shown that not only do single item and item-context associations involve storage in different brain sites, but that the storage operations mediated by these brain sites are algorithmically distinct. Storage operations could differ at two main levels: operations within neurons and inter-neuronal re-organization operations. Abel et al. (1995) have argued that explicit and implicit memory (and presumably their subtypes) 'seem to share a common molecular logic for initial consolidation' and, therefore, they probably share storage processes at the intra-neuronal level. If they are correct, this suggests that any algorithmic differences in the storage of different representations must relate to organizational differences at the inter-neuronal level.

That something external, like a face or a film, can be encoded in different ways so that different information is represented in memory is obvious. It is nevertheless not easy to show that the different representations are stored in algorithmically different ways. Whether exactly the same information can be stored twice according to algorithmically distinct principles seems considerably less likely. Even so, it has been argued that ISIM for what might be regarded as inter-item associations is organized differently from explicit memory for the same associations. Whereas explicit memory representations of inter-item associations have been postulated by Cohen et al. (in press) to be componential, they have argued that ISIM representations of the same information are inflexibly merged into a new Gestalt. On this hypothesis, componential representations retain the identities of their components so that the whole representation can be flexibly retrieved from different componential features. In contrast, ISIM representations show the property of hyperspecificity, which means that they can only be accessed when the precise cues encoded during the study phase are presented during retrieval. Flexible memory representations are initially mediated by storage changes in the hippocampus which link to the neocortical regions that represent the component features of each representation. Inflexible memory representations, in contrast, depend on direct neocortical connections being strengthened as soon as the memory is created.

We should stress, however, that the evidence for the same kind of information being stored twice according to different algorithmic principles currently does not exist. One reason for this, highlighted by the notion of memory representation, is that it is far from a trivial problem to determine exactly what information is being retrieved. Performance on different memory tests for the same nominal stimulus may tap retrieval of distinct encoded features of the stimulus or of semantic features that were encoded in association with the stimulus when it was perceived Thus, it is hard to know whether particular instances of ISIM and explicit memory for the same nominal stimulus involve retrieval of exactly the same information.

Enhanced fluency occurs when studied information has its memory representation activated more rapidly, easily and strongly after cues that are components of the representation have been encoded (see Jacoby and Dallas, 1981). Enhancement is relative to the fluency with which the same cues would have activated the representation on a previous occasion. It is often caused by the strengthening of the information's memory representation and this mnemonic enhancement of fluency is postulated to be, in some sense, automatic (Jacoby, 1983; Jacoby and Dallas, 1981; Jacoby and Witherspoon, 1992; Jacoby and Kelley, 1992). However, fluency of reactivation can also be influenced by non-mnemonic factors such as arousal level. For example, if visual cues are presented with various degrees of masking, the masking will strongly influence the ease with which the related representation is reactivated. Reactivation of the representation is triggered by cues that constitute varying degrees of the original information. They may be very partial in the case of stem completion (where the cues correspond to those provided in cued recall) or perhaps total in the case of the cues in a perceptual identification task (where the cues correspond to those used in recognition). The ease with which a memory is reactivated depends not only on the strength of the memory, but also on the degree of match between the encoded cues and the memory representation in accordance with the encoding specificity principle (for example, see Tulving, 1983). It is postulated that subjects have some awareness of the fluency with which representations are activated, but that the fluency feeling is similar regardless of whether it is caused by mnemonic or non-mnemonic factors.

More interestingly, fluency can be increased by subliminal priming with the same item that is then immediately afterwards presented in a normal manner. A plausible explanation of this phenomenon is that the representation is still partially active because in subliminal priming there is a delay of less than a second between prime and normal presentation of the item. Continued activation of the representation is unlikely to explain ISIM at longer delays. There is also evidence against this possibility. Thus, Reinitz and Alexander (1996) have shown that perceptual identification priming of words and pictures depends on reactivating the memory representation at a faster rate from an initial level of activation equivalent to that of unstudied items rather than reactivating it at a normal rate from a partially activated state that has been maintained during the delay. Fluency, therefore, varies when (a) the rate at which a representation is reactivated is increased because its components are linked more strongly in long-term memory, (b) non-mnemonic factors, such as arousal, either increase the speed with which a representation is activated or reduce the processing needed to activate it, or (c) factors, such as subliminal priming, may activate short-term, but not long-term, memory thus reducing the amount of processing needed to reactivate a representation because it is still partially active.

The concept of attribution as it is applied to memory is regarded as involving a rapid, automatic and unconscious inference based on some aspect of enhanced fluency that gives rise to the feeling that the fluently processed representation is a memory. In other words, it gives rise to a feeling of aware memory. Major proponents of this process are Jacoby and his colleagues, who have also done much to develop the notion of enhanced fluency as underlying ISIM (for example, see Jacoby and Kelley, 1992). As we have already indicated and will explain more fully shortly, we propose that attribution underlies all forms of aware or explicit memory (where subjects know they are remembering). Jacoby and his colleagues have focused their work in which they argue for this attributional view of aware memory on the non-specific form of aware memory for items, known as familiarity. Nevertheless, Jacoby, Kelley and Dywan (1989) proposed that even specific and more "analytic" forms of aware memory, such as recollection, rely on attributions of pastness so that there can be illusions of recollection, generated by encouraging subjects to make misattributions.

Few people, including ourselves (until it was pointed out to us!), seem to realize that Jacoby and his colleagues ever believed that all aware memory relies on memory attributions based on enhanced fluency. For example, Squire (1995) seems to believe that Jacoby and his colleagues only believe this view as it is applies to the narrow sense of familiarity (which excludes recollection), and Squire is critical even of this narrower view. There are perhaps two reasons for this. One reason is that the broader view is not developed and was only explicitly stated once and some time ago (Jacoby, Kelley and Dywan, 1989), and, when it was, the term "familiarity" was treated as equivalent to all kinds of aware remembering rather than the non-specific and automatic kind of aware memory, which corresponds both to current usage and the way that Jacoby and his colleagues now use the term (for example, Jacoby, Toth and Yonelinas, 1993). The second reason is that recollection is indeed more analytic than familiarity and usually involves an effortful and active search so that sometimes aware memories are only found after a prolonged search. This seems the very opposite of a fluently reactivated memory as is required by the hypothesis. As this problem has not been addressed and, more recently, Jacoby and his co-workers (for example, Jennings and Jacoby, 1993) have emphasized that recollection is an active, analytic process, his current views are not equated with the idea that recollection involves enhanced fluency for item-context associations and a memory attribution based on this. Most importantly, this idea has not been developed and reconciled with apparently contradictory observations such as the occurrence of recollection sometimes after a prolonged retrieval search. Nor has it been properly tested. So, in this paper, we consider how the idea can be reconciled with available observations and outline some of its predictions and implications so that it can be systematically assessed.

Attributions that are based on enhanced fluency are not just made about memory. They can also be made about perceptual or aesthetic features of more fluently processed information. For example, when spoken sentences are presented against a background of white noise, the white noise is judged to be quieter when the same sentences are repeated than when similar new sentences are presented, presumably because repeated sentences are more fluently activated (Jacoby et al., 1988). Whether attributions are about memory or about perceptual or aesthetic features of items, however, they are believed to be automatic and not to require effortful monitoring. Whether a memory or a perceptual/aesthetic attribution is likely to be made is determined to some degree by whether the context directs the subject's attention to memory or non-memory issues. Thus, when subjects are thinking about making noise judgements, enhanced fluency of processing a spoken sentence in noise will be automatically interpreted as related to the noise level (Jacoby et al., 1988) whereas, when they are thinking about memory, enhanced fluency is more likely to be taken to mean that a spoken sentence is remembered.

The fourth mechanism of the theoretical framework is active search (for example, see Gillund & Shiffrin, 1984 for a discussion of this mechanism). This is typically important in direct memory tests of recognition, cued recall, and, particularly, free recall. In these tasks, subjects are given different degrees and kinds of cueing and then search for further cues that are components of the target memory with the aim of increasing the number of components that they can encode so that eventually they are able to automatically reactivate the entire memory through an automatic fluency mechanism. In essence, subjects engage in a directed search that uses their existing semantic and episodic memory in a problem solving fashion to generate cues that will reactivate the target memory automatically. Active search refers to the effortful processes that may lead to several automatic retrievals in the course of the search before the target memory is retrieved. In our framework, we are proposing that, in the final stage of any memory retrieval, a memory is automatically reactivated through a fluency-based process. This means that active search will usually be combined with a fluency mechanism. Depending on the success of the search, both these processes may be repeatedly used as rememberers approach the state in which they have sufficient cues to reactivate the target memory automatically. It needs to be indicated why the process or processes that make up active search are effortful. Very little is known about the true reasons, but one reason why effort is involved could be that the rememberer has to monitor the products of retrieval and then make a decision about what to search for next and hence, what to encode. Retrieved information is used to direct the selection of cues that are encoded and used for the next automatic retrieval. This must be an effortful process and is probably mediated by the frontal association cortex. The central point that we are making here is that a memory representation can be retrieved using a fluency-based process alone or it can be retrieved through a multistage effortful process or set of processes which interact with an automatic fluency-based retrieval process. The final stage of active search is verifying that what has been retrieved is the desired target memory. This stage of intentional retrieval is probably effortful as it may often involve the directed retrieval of confirmatory information and the use of inference.

In the next section, we discuss in more detail the redundancy relationship account of ISIM and explicit memory that arises naturally from this four process framework, and other views that are current in the literature.

3. What Processes Underlie ISIM and Explicit Memory?

There is a widely held view that ISIM and explicit memory depend on radically different processes is based on either single or double dissociations of the kind that have been reported between performance on direct and indirect memory tests. If the processes underlying the two forms of memory are not only distinct from each other, but also functionally independent (i.e., they operate in parallel), then the appropriate kind of double dissociation must be found. If the processes are distinct, but there is a serial (or redundancy) relationship between them, then the appropriate kind of single dissociation must be found. The only acceptable kind of serial relationship is one in which the processes of ISIM contribute to those of explicit memory, but explicit memory requires the operation of some further and distinct process or processes. If this is the way that ISIM and explicit memory are related to each other, then one should expect to find variables that only affect explicit memory, but not variables that affect only ISIM for the same information.

Double dissociations between indirect and direct memory test performance have often been reported. For example, semantic orienting tasks typically improve direct memory test performance, but often have little or no effect on indirect memory test performance. In contrast, shifts of sensory modality between study and test typically affect performance on indirect memory tests, but not on direct memory tests (see Roediger and McDermott, 1993 for a review). There are, however, two plausible kinds of interpretations for such dissociations. First, they could arise because different kinds of process underlie performance on direct and indirect memory tests. This would apply if performance on the two types of test depended on different kinds of encoding, storage and/or retrieval processes. Second, they could arise because direct and indirect memory tests depend on the retrieval of different kinds of information. They could, of course, arise for both reasons. If, however, it is known that two tasks, performance on which dissociates, depend on the retrieval of different kinds of information, then further evidence is needed to prove that the dissociation reflects the operation of algorithmically different kinds of processes. Memory for different kinds of information may be dealt with by partially distinct brain structures that mediate encoding, storage and retrieval processes that are algorithmically identical (which is more likely if the regions have similar cytoarchitectonics as applies, for example, with different neocortical regions). With the above examples of double dissociations, one can argue that indirect memory test performance was unaffected by semantic encoding at study because it depends on retrieving perceptual information (with tasks such as stem completion) whereas direct memory test performance is very little affected by shifts in sensory modality between study and test because it depends primarily on retrieving semantic information (with tasks such as cued recall). Performance on semantic indirect memory tasks such as category generation almost certainly will be affected by semantic orienting tasks and more perceptual direct memory tasks such as memory tests for the font in which different words have been presented will almost certainly be affected by a shift in sensory modality of presentation from visual to auditory between study and test (Roediger, 1990).

In the previous paragraph, we suggested that double dissociations between performance on direct and indirect memory tasks may arise because performance is primarily driven by explicit memory or ISIM respectively and these two forms of memory are either (1) dependent on algorithmically distinct processes, which almost certainly must be mediated by partially distinct brain regions with somewhat distinct cytoarchitectures, (2) dependent on retrieval of different kinds of information even though both forms of memory are served by processes that operate according to identical algorithms probably mediated by different brain regions with similar cytoarchitectonics, (3) dependent on algorithmically distinct processes and the retrieval of different kinds of information that are probably mediated by distinct brain regions with different cytoarchitectonics. In terms of the framework, we are saying that the kinds of information held by two different memory representations may explain double dissociations between ISIM- and explicit memory-dependent tasks. Some, if not all, of these dissociations do not require the assumption that the two kinds of memory work according to different algorithmic rules.

Are there any dissociations which can be plausibly be ascribed to algorithmic processing differences underlying performance on direct and indirect memory tasks? One can be confident that distinct processes underlie ISIM and explicit memory if there is one process variable that affects only ISIM and one process variable that affects only explicit memory. The problem is how to determine whether or not a variable is selectively affecting a process. Only if one knows that ISIM and explicit memory are for the same information can one easily be sure that process variables are operating. This problem is illustrated by a recent study in which Keane et al. (1995) reported a double dissociation between performance on a word recognition memory test and performance on two verbal indirect memory tasks. Recognition memory was disrupted by medial temporal lobe lesions whereas ISIM was impaired by a lesion that was mainly located in the right occipital lobe. The cytoarchitecture of these two regions is different, but may not be sufficiently distinct to claim with any confidence that they must use radically different memory processing algorithms. Furthermore, many would argue that verbal recognition memory involves retrieval of semantic information, whereas the verbal indirect memory tasks depend on retrieving perceptual information. In other words, the double dissociation could simply reflect the fact that the different memory tasks require the retrieval of distinct kinds of information that are mediated by non-overlapping brain regions. So although amnesics often perform normally on indirect memory tasks, it is a moot point as to whether amnesia disrupts a kind of processing unique to explicit memory or whether it disrupts memory for a kind of information that is normally tapped by explicit memory, but not ISIM (or both of these). Deciding which interpretation of the findings with amnesia is correct will require considerably more evidence.

There are, however, two kinds of dissociations, involving psychological manipulations, which might appear to suggest that algorithmically distinct kinds of processing underlie ISIM and explicit memory. First, subliminal priming at test (Jacoby and Whitehouse, 1989) has been shown to selectively enhance familiarity (Rajaram, 1993), which, as will be discussed shortly, is hypothesized to depend on an implicit memory process that contributes to recognition memory. Jacoby and Whitehouse showed that familiarity was enhanced when the priming presentations were brief so that subjects were largely unaware of them, but with longer presentations, so that subjects were aware of the primes, familiarity was actually inhibited. Whether prime duration or awareness is actually critical has, however, been disputed (Joordens and Merickle, 1992). The critical point to note here, however, is that brief and primarily subliminal priming selectively affects familiarity, which many believe to be driven by ISIM. One explanation of this effect is that the priming boosts the enhanced fluency process that underlies the feeling of familiarity. There is, in fact, some direct evidence that subliminal priming increases the fluency with which items are processed (Whittlesea, 1993; Whittlesea, Jacoby and Girard, 1990). Although it is also possible to interpret the above results in terms of the target item acting as a retrieval cue for the subliminal probe, with this act of retrieval, rather than enhanced fluency, causing the familiarity boost, Whittlesea's (1993) experiments, which make the same point about fluency and familiarity, but do not involve subliminal priming, cannot be so interpreted.

Second, and conversely, work in our laboratory and by others (for example, Jacoby, 1991) has shown that dividing attention at test disrupts recollection, the explicit form of memory hypothesized to underlie recognition memory, but leaves familiarity unaffected. One possible interpretation of this double dissociation is that the ISIM required for familiarity is enhanced by subliminal priming at test, but is unaffected by dividing attention at test because it depends on enhanced fluency and automatic retrieval processes. In contrast, the explicit memory process underlying recollection is not affected by subliminal priming at test, but is disrupted by dividing attention at test, because it does not depend on enhanced fluency, but typically depends on effortful retrieval processes. Retrieval processes that are automatic are prima facie likely to be algorithmically distinct from retrieval processes that are effortful. In other words, the double dissociation produced by using the subliminal priming and divided attention manipulations at test, can be interpreted in terms of process differences between ISIM and explicit memory. Before considering our opposing view that explicit memory shares common processes with ISIM, we need to discuss in more detail the processes underlying ISIM and the dual process theory of recognition.

ISIM always involves enhanced fluency, but it sometimes also involves a non-memory attribution process. Performance on indirect memory tasks indicates the presence of ISIM when subjects process previously encountered items differently from equivalent items that have not been previously encountered. This changed processing probably entails more rapid or fluent processing of previously encountered items. ISIM must, therefore, involve an increased fluency of processing of remembered items where increased fluency means an increase in processing speed. An increase in processing speed may occur automatically in the sense that it may still be apparent when subjects are engaged in another activity at the same time provided control items are processed under the same conditions. The enhancement itself need not involve extra effort, i.e., it will be automatic, even though the basic process (for example, naming a picture) is effortful. If, as the framework suggests, enhanced fluency depends on speeded reactivation from cues of a memory representation that derives from strengthening the storage connections that underlie the representation, it is plausible to postulate that the enhancement will be effortless. If, however, it depends on using memory to focus attention, as is suggested by Reinitz and Alexander (1996), then enhancement may need extra effort, which is contrary to some unpublished evidence discussed later in this paper.

Enhanced fluency is often indicated directly by measures that show repeated items are more rapidly processed (in a variety of ways). It may be indicated less directly by tasks such as stem completion in which previously studied items are generated more often from fragments. There is some unpublished evidence that such target generation is performed more rapidly than baseline generations. For example, Rajaram (personal communication) found that word fragment completion was significantly faster for studied items and that there was a trend in the same direction for word stem completion. These effects might have been greater if only correct rather than all completions for studied items had been analysed. The generative phenomenon itself (as an indication of accuracy) suggests ready reconstruction of the whole of a studied item from a part. Whether increased accuracy of generation is driven by the same process as that driving increased speed of generation remains to be determined. The simplest assumption is that there is one underlying process responsible for both, which may be operationally defined best in terms of reaction time measures, but this remains to be proved.

According to the framework, therefore, ISIM always depends on the set of processes that produce enhanced fluency of activation of a representation from relevant cues because the long-term memory for that representation has been strengthened. If an item is processed more rapidly following a recent study episode, it is plausible to argue that this results from the readier reactivation of the item representation which, in turn, depends on strengthening of the neural links required for its storage. Enhanced fluency is, therefore, evidence of item-specific memory, but by itself it cannot lead to awareness that one is remembering. Even when ISIM involves non-memory attribution processes as well as enhanced fluency, there should be no awareness that the retrieved information is remembered because the enhanced fluency of its activation has been used to make a mistaken inference about perceptual/aesthetic features.

Although enhanced fluency by itself can only lead to unaware memory, Mandler's two process theory of recognition and similar theories imply that if further processes interact with fluency, then aware memory may result (Mandler, 1980, 1991; Jacoby and Kelley, 1992). Such dual process accounts propose that recognition memory is mediated by two kinds of memory process that work independently: familiarity which depends on an implicit process, and recollection which is an explicit process. When an item is judged to be familiar subjects feel that they have encountered it before, but in a context or contexts that they cannot specify. This non-specific memory feeling is hypothesized to arise because they process the item more fluently than they would have done if it had not been recently encountered and this leads them to make an automatic attribution that it must be familiar (for example, see Jacoby, Kelley and Dywan, 1989). In our terms, therefore, familiarity may be viewed as a form of aware memory that depends on enhanced fluency plus an automatic attribution of familiarity. This attribution is an interpretation that makes sense of the increased fluency of processing in the context of a memory situation. In such a context, it is also rationale to think that an item feels familiar (or more familiar than expected) because it has recently been encountered. Other automatic attributions about features of remembered stimuli may be made in different contexts where the focus is on things such as how long stimuli were on a screen (Witherspoon and Allan, 1985; Paller et al., 1991), how aesthetically appealing they were (Bonano and Stillings, 1986;

Zajonc, 1980), or how loud the noise was in which they were embedded (Jacoby et al., 1988). Subliminal priming at test selectively enhances familiarity because it increases the fluency with which primed stimuli are processed. We have evidence that will be discussed briefly later which also suggests that the sensitivity of familiarity attributions is not decreased by dividing attention at test and so presumably both the increase in fluency and the attribution occur automatically.

In contrast, recollection in which subjects are aware that they have encountered an item before within the specific context of the experiment is not enhanced by subliminal priming at test (Rajaram, 1993), but is disrupted by dividing attention during retrieval (Jacoby, 1991; van Eijk, Mayes and Meudell, in preparation). It might be argued that recollection is not influenced by subliminal priming at test because it does not depend on more fluent processing of the remembered information. It is, however, decreased by dividing attention at test because retrieving this information depends on effortful search processes and this is a characteristic of explicit memory in general. A defensible position, derivable from the dual process account of recognition, would, therefore, be that ISIM is a form of memory in which there is always an automatically increased fluency of reactivation of the remembered representation, and in which there is also sometimes an automatic attribution made. Depending on whether this is a memory or a non-memory attribution, therefore, enhanced fluency may lead to either aware (familiarity) or unaware memory. In contrast, recollection is explicit memory, which is essentially an aware form of memory that does not depend on enhanced fluency or memory attributions, and, at least in memory experiments, also depends on effortful search processes. This would seem to provide good prima facie evidence that at least the retrieval algorithms of ISIM and explicit memory are distinct.

We wish to make two related points about this view that ISIM and explicit memory depend on algorithmically distinct processes. The first point is a terminological one. Both familiarity and recollection are aware forms of memory, which might lead one to regard them both as forms of explicit memory. On the other hand, the dual process view of recognition proposes that only familiarity depends on the enhanced fluency and attribution mechanisms of ISIM, which might be regarded as a reason for seeing it as a form of implicit memory. In contrast, recollection, which typically depends on effortful retrieval and, according to the dual process view, does not depend on either enhanced fluency or attribution processes is explicit memory. In this paper, we want to stress that what matters is the nature of the underlying processes that mediate aware and unaware memory for different kinds of information. As we will argue that familiarity and recollection are mediated by at least two common mechanisms: enhanced fluency and memory attribution processes, although these are applied to different kinds of information, we will treat them as different forms of explicit memory. So we suggest explicit memory comprises the hypothetical processes leading to aware memory. In contrast, we have argued that ISIM should be equated with hypothetical processes that lead to unaware memory and comprises enhanced fluency alone or enhanced fluency accompanied by a non-memory attribution (as Jacoby and his colleagues have long argued), operating on several kinds of information that overlap with those tapped by explicit memory. On our account, therefore, both explicit and implicit memory depend on common information and rely on at least two common processes (if different kinds of attribution are treated as variants of one type of process). Unlike multiple memory systems theorists, therefore, we suggest that ISIM and explicit memory depend on the same memory representations. Whether the recollective form of explicit memory essentially relies on active retrieval search is an issue that we will discuss.

The second point relates to a major problem with the process interpretation of the subliminal priming/divided attention double dissociation discussed earlier, and brings us to our preferred interpretation of this dissociation. Familiarity depends on remembering specific items not in association with any specific contextual markers whereas recollection depends on remembering an association between an item and unspecified and probably variable markers of the context in which it was encountered. In other words, familiarity, which the process interpretation hypothesizes to depend on the enhanced fluency of ISIM and a memory attribution based on this, and recollection, which is hypothesized not to depend on these processes, also involve the retrieval of different information. In the terms of Mandler's (1980, 1991) two process theory of recognition, familiarity and recollection involve retrieval from memory representations of individual items and item-context associations respectively. This makes possible a different kind of interpretation of the subliminal priming and divided attention dissociations, found at retrieval. The dissociations could depend at least in part not on process differences between familiarity and recollection, but on the fact that they depend on representations of different kinds of information. For example, subliminal priming could selectively enhance familiarity because it increases the fluency with which item representations, but not item-context representations are activated. Item-context associations may be more fluently activated following subliminal priming with matching associations. One reason for preferring this interpretation to the view that recollection, unlike familiarity, does not depend on enhanced fluency and memory attribution, is that only it provides an explanation for how subjects know that they are recollecting item-context associations. This is the major problem with the view that only ISIM depends on enhanced fluency and is central to this paper.

What is the difference between remembering such an association and imagining one? Just representing the information so that one is aware of it is insufficient because it may be represented with no feeling of memory or with an overwhelmingly strong feeling of memory. We do not believe that this problem is solved by Moscovitch's (1995a) proposal that aware feelings of memory for episodes are created by an extended hippocampal system which acts as a module that receives episodic information of which the subject is conscious. This proposal does not solve the problem because subjects will be similarly conscious of both remembered and imagined episodes so that it remains unexplained how they develop a conscious feeling that the episode is one that they have encountered in the past. It might be thought that the problem could be solved in Moscovitch's terms if every remembered episode were represented not only by an association between the components of the episode and the consciousness of this, but also with the informational tag "you have encountered this episode in the past" of which the rememberer would have to be conscious. However, not only does this view not appear to Moscovitch's, there is also no evidence for it, it is circular, and it seems subjectively implausible. Most significantly of all, the suggested solution does not work, but merely pushes the problem back one stage as there still needs to be a basis for determining whether the new and more complex association is remembered or imagined.

For this reason, we think that recollection must involve representing the item-context association and making an attribution that one is remembering. Most probably, recollection, like familiarity, depends on an attribution, based on the increased fluency of processing representations of item-context associations. This would mean that all aware forms of memory involve attributing an increase in the fluency of processing remembered information to a previous encounter with that information (Jacoby, Kelley and Dywan, 1989; Roediger and McDermott, 1995). Subliminal priming with an item would not be expected to increase the fluency with which an item-context association is processed because it only involves presenting a fragment of the information to be remembered (the item). If there was subliminal priming for a form of item-context association, however, then the view just stated would clearly predict that recollection would be enhanced. Such a priming manipulation might be achieved by presenting words with novel associates at study (for example, "mountain" with "stamp"), and then subliminally priming with both words immediately before presenting the target word ("mountain" in the example) for the memory test. If our account is correct, then subjects will experience feelings of recollection more often for primed associations. This important experiment has not yet been performed.

In summary, we contend that one cannot experience the feeling of aware memory for anything including item-context associations simply on the basis of the properties of the information represented. The feeling has to derive from something other than the information in the representation. As Jacoby has consistently argued for familiarity (for example, Jacoby and Kelley, 1992), it must be based on an automatic inference or attribution of memory connected with non-informational features that relate to the way in which representations are activated. If these features are fluency, clarity, strength and "pop-out" and they are all closely related activational properties, then all aware memories must derive from memory attributions based on the enhanced fluency of activation of the remembered representations. Even if "richness" is a feature that can underlie memory atrributions, it is most plausibly interpreted as the high fluency with which related associations are activated. This redundancy account can be tested by the appropriate subliminal priming study and those who disbelieve it must show convincingly how else memory feelings can arise.

Even if recollection is like familiarity in being an attribution of a previous encounter that is based on an increase in the fluency with which the remembered information is processed, only recollection seems to involve an effortful search process. In a recognition experiment there is, however, a difference between familiarity and recollection. Whereas the to-be-remembered information is fully present for purposes of making a familiarity judgement, which simply involves remembering that an item is old, this is not true for recollection. For recollection, the context has to be retrieved on the basis of encoding the presented item so that a search process may be involved. It could be argued that not only recollection, but also ISIM when it depends on retrieving informarion that has not been encoded, involves an effortful search process. Such forms of generative ISIM are usually believed to be tapped by indirect memory tasks such as stem completion and free association. To our knowledge, no-one has reported using divided attention at test with an indirect memory task that is likely to depend on a generative form of ISIM. If there was no effect on the ISIM measure, then it might be argued that ISIM involves an automatic retrieval process whereas explicit memory involves an effortful retrieval process under the same kind of conditions. Although this would say little about the underlying search process, it would strongly imply that there is some kind of processing difference between ISIM and explicit memory. Interestingly, preliminary results from Downes (personal communication), from Marsh (personal communication), and from Gooding, MacDonald and Mayes (unpublished) indicate that dividing attention at test with card sorting or counting tasks does not disrupt stem completion priming.

It remains unexplained why dividing attention does not affect this form of ISIM whereas it does disrupt the recollective contribution to recall and recognition in experiments. One possibility is that retrieving item-context associations is effortful whereas retrieving items is not. This could be tested by dividing attention whilst testing for ISIM of such associations provided one was confident that the measure of ISIM was pure. In terms of the framework, we suggest the following possible explanation of why recollection in recognition is an effortful activity that is disrupted by dividing attention at test. We propose that enhanced fluency of reactivation of item-context representations (that underlies ISIM) is not affected by dividing attention at test because it is automatic. In contrast, explicit memory for the same kind of information is disrupted by dividing attention at test because recollection not only involves an increase in the fluency of reactivation of the memory representations for item-context associations plus an automatic attribution process, it also typically involves an active search process. It is the active search process that is disrupted by dividing attention at test. The item cue that is encoded in a recognition test may be insufficient to automatically reactivate the item-context association so that the subject has to engage in an active search process. If this active search process results in the encoding of sufficient cues, then the item-context representation emerges fluently and automatically, which spontaneously leads to the attribution of remembering. This explains how enhanced fluency can underlie recollection even when there is a long search process. It is rate of reactivation from the finally encoded cues that matters.

One implication of this account is that sometimes the active search process may not be necessary (or may be less necessary) in which case recollective recognition will not be disrupted (or will be less disrupted) by dividing attention at test. When recollection is intentional, this is more likely to be the case when memory is very strong so that the initial encoding of item information is sufficient to generate the item-context associations through an automatic fluency mechanism alone. When recollection is unintentional, there is no directed search and it is plausible to argue that the retrieval process is effortless, presumably because the rememberer happens to have encoded by chance sufficient cues to reactivate a representation of interest fluently. This argument applies regardless of whether recollection is associated with recognition or recall. If directed search only occurs when retrieval is intentional, this also explains why ISIM depends on automatic retrieval because it does not involve intentional retrieval. If these suggestions are correct, then active search processes are essential for neither implicit nor explicit memory although the ability of explicit memory to locate target information is often critically dependent on directed and effortful search processes whereas ISIM never depends on active search. Similarly, intentional retrieval which determines whether retrieval is likely to be effortful, sometimes accompanies explicit memory, but never ISIM.

Underlying our argument is the view that the fluency mechanism applies to memory representations of not only single items, but also complex associations of the kind that may exist between items and their study context. Nevertheless, it may well be that the storage mechanisms required for complex associations are algorithmically different from those required for single items. A necessary, but insufficient justification for this view would be that different brain mechanisms are involved in storing the two kinds of information. A widely held theory of amnesia is consistent with this minimal requirement. According to this theory, damage to the hippocampal system or any part of the hippocampal-fornix-mammillary body-anterior thalamus-cingulate/retrosplenial cortex circuit, disrupts the ability to store cross-domain associations that relate information that is represented in different cortical regions (for example, see Cohen et al., in press; Murre, in press). This theory contrasts storage of item information, which depends on associations established locally within one cortical region, with storage of any kind of associative information that requires the establishment of links across different cortical regions. The theory makes no distinction between item-context associations and any other kind of item-item association that requires the creation of links across different cortical regions. Research still needs to show convincingly that the brain mechanisms underlying: (1) storage of new cross-region associations (as with item-context links); (2) creation of new within region links (as with a new face), (3) strengthening of already established cross-region links (as with a known face-name link) and (4) strengthening of already established within region links (as with a known word) are different. It is possible that (4) and possibly (3) may differ from (1) and (2), which do not differ from each other. This would be the case if the hippocampal system is vital for all new associations, but not for strengthening old item memories (or perhaps all established memories for associations). Even if the hippocampal cross-regional theory is true, however, it still remains to be shown that cross-regional associations are stored in a qualitatively different way from intra-regional associations.

One prediction that may follow from this theory is that amnesics will be more impaired at free recall than recognition. This might be expected because the theory states that hippocampal circuit lesions selectively disrupt storage of associations, particularly when these comprise components that are represented in different neocortical regions. Free recall primarily depends on the retrieval of associations whereas item recognition depends on either the retrieval of associations or of items. As item storage should be unaffected by hippocampal circuit lesions according to the theory, item recognition memory may be less affected in amnesics as has been reported by Hirst et al. (1986; 1988). However, Haist et al. (1992) failed to find this effect when memory for an unrelated list of words was tested. These results may not be in conflict because Isaac and Mayes (submitted) have found that amnesics (all of whom probably had hippocampal circuit damage) showed accelerated loss of free recall, but not recognition, for stories and semantically related word lists at delays between 15 seconds and ten minutes such that by delays of ten minutes the amnesics were more impaired at free recall than they were at recognition for these materials. In contrast, the amnesics showed a normal rate of loss of free recall as well as of recognition over the same time period for semantically unrelated word lists.

These findings suggest two things. The first is that amnesics with hippocampal circuit damage may have a particular problem not with storing simple associations which are those between single items and their context (as might be required for the free recall of unrelated word lists and item recognition of any kind), but with storing more complex associations which are those that link two or more items to each other and their study context (as might be required for the free recall of stories and semantically related word lists). The precise characterization of these complex associations (for example, whether they must involve associations with study context or merely with three or more "items") remains to be achieved. This modification of the hypothesis implies that hippocampal damage disrupts storage of only some kinds of cross-domain associations". The second point is that most amnesics must also have another deficit because they are equally impaired at recognition and free recall at short delays. This second deficit (the functional nature of which needs to be characterized) may be caused by lesions outside the circuit that leads from the hippocampus to the anterior thalamus and beyond.

As the theory states that hippocampal circuit damage disrupts storage of certain kinds of association, then, in combination with our redundancy model, one should predict that appropriate lesions will impair not only explicit memory for those associations, but also ISIM. This is because ISIM is equivalent to the enhanced fluency of reactivation of the relevant representations that arises because storage has strengthened the critical associative connections. Some support for this view that amnesics will show combined recognition and ISIM deficits for complex associations has been found by Whitlow et al. (1995). They reported that amnesics not only had poor recognition for complex real world scenes, but also did not show the different pattern of eye movements revealed by normal people when some of the components of the scenes were interchanged. It needs to be shown, however, that eye movement patterns reflect ISIM rather than the directed search that may accompany explicit memory.

If one wished to reject the redundancy view and adopted the view, referred to in the last section, that there may be different ISIM and explicit memory representations for exactly the same complex associations, then amnesics should show preserved ISIM for such associations, provided they do not have fairly extensive incidental damage to association neocortex, which is where the hypothesized "independent" ISIM representations should be stored. We think the existence of such distinct ISIM association representations is rather unlikely because not only would their existence require the duplication of memory representations of identical information, but also because the explicit memory representations of complex associations would not show enhanced fluency. This would leave no explanation for how feelings of memory for these complex associations could arise.

Before discussing how the framework can be used to explain free and cued recall processes, we wish to make two points explicitly. First, what has been described so far, primarily in relation to recognition, implicitly relates to episodic memory. But recognition can be of facts as well as of experienced episodes. Episodic recognition depends on retrieving either item or item-context association information on both the dual process view and our view. Recognition of facts (semantic memory), in contrast, involves retrieving either single items or associations between items. One also feels one knows when one is remembering facts. We, therefore, propose that recognition of facts, like episodic recognition, also involves enhanced fluency leading to a memory attribution. The same point should apply to recall of facts. The only difference is that semantic memory, although it may sometimes involve retrieval of context (or situation) information, cannot involve retrieval of experienced contextual information. For example, one can remember the situation in which Kennedy was assassinated as a semantic memory, unless one saw the assassination in which case it would be an episodic memory. The difference is only important if the storage of fact and experienced episode memory representations are organized in fundamentally different ways.

The second point relates to the difference between the dual process account of episodic recognition and our own four component redundancy account. Although our account claims that recollection as well as familiarity involves the overlapping processes of enhanced fluency or activation and memory attribution, these processes are being applied to item and item-context memory representations. The former may be stored within one cortical domain whereas the latter will not be. Whether or not they are stored in algorithmically distinct ways, the strengths of familiarity and recollection could well be stochastically independent of each other just as dual process theorists such as Jacoby (see Jacoby and Kelley, 1992) have proposed. The relationship between the two should ideally be empirically determined, but this issue is discussed further in the next section. Even the four component redundancy view does not propose that familiarity and recollection depend on identical processes, only on similar fluency and attribution processes. In addition, to claiming that active search is used as a frequent facilitator of recollection, but not familiarity, it allows that the underlying storage mechanisms could be distinct. Elaboration and testing of the view depends on being able to measure the processes underlying familiarity and recollection accurately.

What kind of account of free and cued recall of facts and episodes is likely to be suggested by the theoretical framework? Episodic recall typically involves recollection of item-context associations from the initial encoding of context (free recall) or the initial encoding of context and associates or partial features of items (cued recall) whereas recollection in episodic recognition memory involves retrieving context information from encoded item information. What might be regarded as semantic recall or the recall of facts involves a similar process except that the end product of successful recall is not a feeling of recollection, but a feeling of memory for some kind of item-item association. In both cases, however, the rememberer starts with an initial encoding and aims to get to a stage at which sufficient components of the target memory representation are encoded to enable a fluency mechanism to operate and generate the rest of the representation. If fluency operates, then, at the critical stage, the memory will seem to emerge spontaneously (or with authority as Jacoby, Kelley and Dywan, 1989 put it) so that, via the attribution mechanism, a feeling of aware memory will arise, the strength of which will be a function of the degree of fluency enhancement. If, as will typically be the case, the initial encoding is insufficient to trigger the fluency generative mechanism, then the rememberer will engage in active search. This effortful process is a directed search in which the rememberer attempts to encode cues that are components of the target memory representation such that the generative fluency mechanism will be triggered. Active search, like problem solving, is very poorly understood, but is presumably effortful because it depends on a monitoring process that can direct continued search on the basis of feedback from the results of the search to date. In this sense, monitoring must include a number of elements of planning. These effortful processes of active search interact with the generative fluency and memory attribution mechanisms to produce intermediate products of the search as well as the target if the search is eventually successful.

In summary, we are suggesting that successful recall typically involves a sequence of active search (interacting with fluency and attribution mechanisms), which if successful cumulates in the fluent generation of the target item-item or item-context associations and an automatic attribution of aware memory. When memory is very strong or recall is achieved unintentionally, however, the effortful active search stage will be unnecessary because initial encoding can trigger the final stages of generative fluency and attribution directly. In such cases, recall will be minimally affected or even unaffected by dividing attention at test.

The account of recall and recognition that we have given differs from the account that the SAM model of Gillund and Shiffrin (1984) offers. These authors proposed that long-term memory representations comprise relatively unitized, permanent sets of features called images. These representations are retrieved using one of two mechanisms. The first, used only in recognition, involves matching an item-context cue to all memory images and deriving a familiarity value. The second retrieval mechanism is a search process, which can be used for both recall and recognition, and involves sampling memory images so that information is recovered and used for any given task. SAM differs from the four process redundancy model in that: (1) in the redundancy model, familiarity for single items can be derived without using an item-context cue (an item cue is sufficient); (2) the SAM model does not incorporate the enhanced fluency and attribution mechanisms so it fails to explain how aware memory is achieved. For example, although Ratcliff et al. (1995) allow context to influence the matching process so that a familiarity-like process can drive list discrimination and hence apparently produce recollection, enhanced fluency and attribution are not postulated to underlie this recollection. If correct item-context cues can be presented subliminally, then SAM would be able to explain memory effects on old items, but not on new items whereas the redundancy model can explain memory effects on both; (3) related to this point, only the redundancy model explains the relationship between ISIM and explicit memory. The two models are similar, however, in that both propose that a relatively automatic generative mechanism interacts with an effortful evaluative process in retrieving aware memories. According to SAM the generative mechanism of search comprises a sequence of sampling and recovery operations. However, only the redundancy model proposes that this mechanism depends on an enhancement of the activation of remembered representations. Although the search phases are relatively automatic, their evaluation (which may correspond to monitoring as used by us) is presumably not. It is evaluation that presumably directs the search process as does monitoring in our account. To summarize, there are some similarities in how the models propose search is performed, but SAM fails to give a convincing account of how aware memory arises and what ISIM is.

We have suggested that performance on direct tests of memory typically depends on four algorithmically distinct kinds of process: storage of memory representations; enhanced fluency; attribution; and active search. Such tests, therefore, do not provide means of determining the properties of any single process that is equivalent to explicit memory. Minimally, explicit memory depends on fluency and attribution mechanisms operating on a memory representation. In contrast, performance on indirect memory tests used to be thought to depend only on ISIM, which, on our view, is usually mediated by enhanced fluency alone although sometimes it may be mediated by enhanced fluency in conjunction with a non-memory attribution process. Many workers now believe, however, that indirect memory task performance often receives an input from explicit memory processes. If this is true, then task performance will be influenced by further processes and it becomes much harder to identify the properties of fluency and non-memory attribution by examining the effects of different variables on indirect memory tasks.

In terms of our framework, what would explicit memory mediation of indirect memory task performance mean? Performance on the indirect memory test measure, e.g., reaction time or accuracy of response production, would have to result not only from a fluency and possibly a non-memory attribution mechanism, but also from the operation of another mechanism. Fluent processing may often be accompanied by a memory attribution and hence a feeling of aware memory, but this should not matter as attribution will not by itself have any effect on the measure. Explicit memory mediation would only be importantly implicated if subjects used an active search process to aid (or possibly hinder) performance. Active search is a directed process and so should not occur involuntarily. Involuntary recall or recognition occur when there is no active search, but cues that have been encoded anyway are sufficient to trigger the automatic generative fluency and attribution processes. Therefore, the major worry about explicit memory mediation of indirect memory task performance should arise when subjects consistently and deliberately try to modify their performance by using active search. Nevertheless, the borderline between voluntary and involuntary is blurred and subjects may often be unable to stop themselves from undertaking some active search when certain cues are encoded.

If subjects cannot stop themselves from switching on an active search process occasionally, then indirect memory task performance will be to some extent contaminated as a measure of enhanced fluency and attribution processes. It may also be the case that performance depends on accessing a different memory representation than would have been the case if only a fluency mechanism was being used. For example, stem completion tasks if only mediated by a fluency mechanism would tap memory representations of single words, but if active search was also involved memory representations of word-context associations might also be retrieved. It is very important and not at all easy to determine what kind of information is held in the memory representations underlying performance in both indirect and direct memory tasks. However, as active search is effortful and fluency (and attribution) are not, active search can be markedly reduced if not eliminated by dividing attention at test.

The next section considers how purer measures of fluency, item fluency plus memory attribution (familiarity), and recollection may be achieved. Pure measures are important if the properties of these kinds of memory are to identified, and, in the longer run, the properties of the four kinds of memory mechanism are to be specified. In other words, we need pure measures if the four component redundancy framework proposed in this paper is to be systematically tested. Specifically, pure measures of familiarity and recollection are important for assessing the claim of the redundancy account that both depend on enhanced fluency and attribution, and also for determining the idea, consistent with the four component framework that the underlying storage mechanisms for items and item-context associations may be radically different.

4. How Should ISIM, Familiarity and Recollection Be Measured?

If performance on indirect memory tasks may often be driven by active search as well as by ISIM, getting pure measures of ISIM will be a problem to the extent that the influence may be quite considerable and hard to determine. This problem and how to deal with it has become a major focus of interest (for example, see Roediger and McDermott, 1993). To identify the properties of ISIM, it is important to establish the best means to estimate it accurately. As all the ways of doing this depend on assumptions the truth of which is difficult to establish, we believe that the best approach is to use a convergent operations approach. When the results from the different approaches give convergent implications, then one can trust them with some confidence provided (as is the case) they depend on different assumptions. We now consider several such approaches.

First, if, on the basis of available evidence, one assumes that ISIM involves automatic retrieval processes whereas active search is effortful, then dividing attention at test with indirect memory tasks should provide a means of making performance depend much more on ISIM. It is, of course, important to ensure that divided attention is also used when foil items are being processed because the manipulation will probably decrease the efficiency of the cognitive process the increased fluency of which will indicate the presence of ISIM. If the efficiency of the cognitive process is decreased by dividing attention both for target and foil items, then the automatic increase in efficiency of the process that is assumed to result from readier access to the remembered memory representation should be unaffected. Any influence of active search should, in contrast, be largely eliminated. This procedure is subject to one critical proviso. As enhanced fluency is indicated by an increase in the fluency of performing a cognitive operation on remembered information, it is critical that the divided attention manipulation does not block the cognitive operation altogether. For example, if the cognitive operation involves accessing semantics, then it is critical that subjects can still do this in the divided attention condition.

Second, the use of indirect memory tasks where the basic measure is reaction time may also provide fairly pure measures of ISIM provided subjects cannot anticipate what the next item is going to be through the use of active search. The assumption here is that enhanced fluency operates more quickly than active search so that a reduction in reaction time is unlikely to be mediated by intentional and effortful search processes because such mediation would be more likely to slow responding (Mandler, 1980; Mandler and Boeck, 1974; see Graf and Masson, 1993 passim). For example, the speed of lexical decision with single items may give a fairly pure measure of ISIM. However, there are clear limitations to the approach. For example, if one studies word pairs like "Mountain-Tree" or "Mountain-Frum" and at test makes lexical decisions on the items presented one at a time, one may respond faster to "Tree" or "Frum" because one may have enough time to use active search when shown "Mountain" so as to anticipate the associate.

Third, indirect memory tasks may be used in which the likelihood of subjects becoming aware that test items were shown to them during an early study phase is reduced by, for example, increasing the number of foils (Roediger and McDermott, 1993). Debriefing can also be carried out at the end of the test session so that subjects who report having used active search to aid performance, can be excluded from the analysis (e.g. Bowers and Schacter, 1990). This assumes that subjects give accurate reports of their use of active search even when this occurs involuntarily. An alternative approach is to instruct subjects directly not to use active search, which assumes that not only will subjects try to comply with the instruction, but that they can monitor their processing sufficiently tightly so as to prevent active search "breaking out".

A fourth approach to obtaining less contaminated assessment of ISIM that we have considered involves the use of physiological measures. Autonomic measures such as skin conductance have been shown to differentiate target from foil items in a recognition test format even when an item has not been recognized (for example, see Bauer, 1984). Diamond (1992) has also found that subjects can show skin conductance, heart rate and pupil changes to target items that are not recognized, and that such discrimination is much stronger for target items than it is for foils. If autonomic measures are to be capable of providing good measures of ISIM, however, at least two things have to be assumed. First, it has to be assumed that the responses occur automatically and are not influenced in a systematic way by active search and its results. Second, it needs to be assumed that changes in autonomic responses reflect the increased ease of activation of a memory representation. It is unclear how plausible these assumptions are, but they are hard to test so we suggest, as a preliminary step, that the association between autonomic measures of memory and reaction time measures of ISIM should be obtained. If these measures are highly correlated, there would be much better reason for believing that the pattern of autonomic responses will provide pure measures of fluency.

Use of the above approaches may give more accurate estimates of the enhanced fluency which is always involved in mediating ISIM. It is difficult, however, to find ways even for directly measuring the familiarity and recollection components of recognition, let alone the fluency, memory attribution, and active search mechanisms that the redundancy account argues underlies them. Two approaches have been developed to assess the strength of familiarity and recollection underlying recognition performance. The first approach is the remember/know procedure of Tulving (1985) and Gardiner (Gardiner, 1988; Gardiner and Java, 1990, 1991), and the second approach is the process dissociation (PD) procedure, developed by Jacoby (Jacoby, 1991). It has been claimed that the PD procedure can not only give accurate estimates of the strength of both the familiarity and recollection processes that underlie recognition memory according to the dual process theory of Mandler, but also can give accurate estimates of ISIM that is not associated with memory or non-memory attributions.

The remember/know procedure simply requires subjects to recognize items and then to judge whether they remember these items or merely know them. If they remember them, then the subjects should be able to recall some specific details that relate the items to the study context. In other words, they should have aware memory for an item-context association. This is recollection. It is important to note that recollection merely requires a feeling of memory for a representation that links an item to something else that specifies the study context. The something could be any of a wide range of things although most of them are likely to be represented in different cortical regions (domains) from the target item. If subjects know that an item is correct, they are supposed to feel that it is familiar within the context of the experiment. It should be noted that this concept of knowing may produce confusion in undertrained subjects (nearly everyone!). Familiarity means that one feels that an item has been encountered somewhere before, but cannot specify the context in which it was encountered. Although subjects may automatically infer that an item is surprisingly familiar because it was encountered in a recently experienced context, they may be confused by the expression "familiar within the context of the experiment". This confusion may sometimes lead them, when an item is not unusually familiar, to make know responses on the basis of weak recollection unless the tendency has been trained out (which it never has been).

Even if the instructions did not cause this kind of problem, there would be little point in making independent estimates of familiarity and recollection if remember and know are merely memory responses made at different confidence levels on a unidimensional memory space as has been argued by Donaldson (1996). According to standard signal detection theory, it cannot be true that remember responses differ from know responses solely in requiring a stricter criterion if estimates of memory sensitivity derived from overall recognition hits and false alarms are greater than those derived from remember hits and false alarms. Actually, if the variance for recognition of old items is larger than that for foils as has been shown by Ratcliff et al. (1992), then estimates based on overall recognition should be less than those based on remember responses on the unidimensional view. By analysing the results of several remember/know experiments, we have found that sometimes memory estimated from recognition scores was significantly greater than memory estimated from remember scores (van Eijk, Mayes and

Meudell, submitted). Minimally, this suggests that familiarity and recollection depend on retrieving different kinds of information such that recollection sensitivity is sometimes less than that for the combined operation of familiarity and recollection. Although Donaldson (1996) has argued in favour of a unidimensional memory space in part because he generally found that memory sensitivity estimates were similar whether based on recognition or remember responses, this not only ignores the exceptions, but is a weak argument. It is weak because a null finding is consistent with both the unidimensional view and the view that familiarity and recollection differ not just with respect to confidence level.

In order to estimate the strength of familiarity, it is necessary to assume a relationship between familiarity and recollection. Statistically, there are an infinite number of possible relationships. The extremes are: total exclusivity in which the two kinds of memory can never co-occur; redundancy in the most plausible form of which familiarity can occur alone, but recollection can never appear without familiarity being present; and independence in which an item is just as likely to be familiar whether or not it is recollected (Jacoby, Toth and Yonelinas, 1993; Jones, 1987). The nature of the statistical relationship will depend on two things. The first is the functional relationship between the two kinds of memory (i.e., mutual inhibition, a serial relationship in which recollection is built on familiarity, or non-interactive functional independence) and the second is the extent to which the factors that cause most variability in daily memory affect recollection and familiarity in the same direction. For example, certain kinds of study may strengthen item and item-context memory representations to a similar extent.

Although it seems likely that familiarity and recollection depend on different brain processes, this may be because they involve retrieving different information from memory rather than because they are algorithmically distinct. At present, the view that they are algorithmically distinct depends mainly on the evidence that only intentional recollection is disrupted by dividing attention at test. We believe that it is safest merely to assume that familiarity and recollection depend on independent processes in distinct brain systems even if these processes are qualitatively similar. It is less plausible to assume that an inhibitory relationship exists so that familiarity and recollection cannot co-occur because this implies that as recollection becomes perfect, familiarity (and presumably ISIM) approaches zero. Equally, it is less plausible that familiarity is a necessary condition for recollection because it is very improbable that all recollected items (rather than item-context associations) are processed more fluently than foils. So we assume functional independence. Stochastic independence will not be found, however, when the factors that have the greatest effects on memory variability in normal life influence familiarity and recollection in the same direction. We will assume, nevertheless, as do Jacoby and his colleagues (Jacoby, 1991), that recollection and familiarity are close to being stochastically independent. Fortunately, we have shown with a simulation that even when the stochastic independence assumption is violated to a moderate degree, it is still possible to interpret dissociations in which a variable affects only recollection (see van Eijk, Mayes and Meudell, submitted), and dissociations in which a variable affects only familiarity are totally uninfluenced by how close the independence assumption is to the truth.

In its original form, the PD procedure involves two conditions, inclusion and exclusion (Jacoby, 1991; Jennings and Jacoby, 1993). In the inclusion condition, subjects are asked to respond if they have either recollection for an item or ISIM (or familiarity) so that their score is based on the number of items for which there is explicit memory, ISIM, or both. In the exclusion condition, subjects are asked only to respond to items for which they have ISIM (or familiarity), but not recollection. If one is right in assuming that ISIM (or familiarity) and recollection are functionally and stochastically independent of each other, then Jacoby argues one can obtain accurate estimates of ISIM (or familiarity) and recollection from the inclusion and exclusion scores by solving a simple simultaneous equation. Recollection is equal to the difference between the inclusion and exclusion scores, and implicit memory (or familiarity) is calculated by assuming that the proportion of implicitly remembered or familiar items is the same for recollected items as it is for the unrecollected items that make up the exclusion score.

Jacoby and his colleagues (e.g. Jacoby et al. 1993) believe that one can use this PD procedure to gain estimates of ISIM and familiarity in tasks like the generative indirect memory tasks (illustrated by stem completion and free association priming) and also with two recognition paradigms. The first of the recognition paradigms involves subjects studying two lists of items (Jacoby, 1991). Then, at test, in the inclusion condition they are asked to respond whenever they remember any item from the study phase. In the exclusion condition, they are asked only to respond to items if these are familiar, but are not recollected as coming from a specified list. The second kind of task is derived from the false fame paradigm (Jennings and Jacoby, 1993). Subjects study a list of unknown names or faces. Then, at test, in the inclusion condition, subjects are asked to respond to items either if they recollect them from the study phase or they think they seem famous (familiar). In the exclusion condition, subjects are told that studied items were unknown and are asked only to respond to items if they seem famous (familiar), which if subjects are following the instructions, implies that they do not recollect the items from the study phase. At test, both the inclusion and exclusion conditions include unknown names or faces that were presented in the study phase, new unknown names or faces, and new genuinely famous items. In principle, any variant of this task merely needs to include items at test that have familiarity because they have appeared in contexts other than the study one.

In our view, the PD procedure cannot validly be used to estimate ISIM in generative indirect memory tasks like stem completion. The reason for this is that during the exclusion condition, subjects are likely to reject items which they have generated using the fluency mechanism (i.e., ISIM) when they recognize them, but, in the inclusion condition, they only accept items that are either generated using the fluency mechanism or are recalled (recollected). This means that subjects use recognition for the exclusion condition, but recall for the inclusion condition. If, as is very probable, recognition is stronger than recall, the value of explicit memory will be greater during exclusion than inclusion. There will, therefore, be too many unknowns to solve unless instructions are devised that lead to subjects either only using recall during the exclusion as well as the inclusion condition or only recognition in the inclusion as well as the exclusion condition (see van Eijk, Mayes and Meudell, submitted). Also, one must be confident of the success of such instructions in situations where the expected pattern of results is uncertain.

A similar problem arises when the PD procedure is used with the two list recognition paradigm. This is because for inclusion, subjects merely have to recollect that an item was encountered during study, but for exclusion, they have to recollect in which list it was encountered. There is considerable evidence that it is easier to recollect that an item occurred in a study phase regardless of list than to recollect the list in which the item appeared (van Eijk et al., submitted). As an illustration of this point, it is very likely easier to recollect that you were presented a word in some format or other yesterday than that you were presented a specific word yesterday morning as opposed to yesterday afternoon, that it is was presented visually in capital letters as opposed to in lower case, and that it was in a group of words that were names of animate objects as opposed to being the names of a mixed set of objects.

This criticism does not apply to uses of the PD procedure with variants of the false fame paradigm. Here, subjects only score when they recollect that an item came from the study phase in the inclusion condition and fail to recollect this in the exclusion condition. It also seems unlikely that subjects will confuse recollecting an item from the study phase with recollecting it because it was a famous person's name. In other words, exclusion condition scores are unlikely to be more than minimally distorted by subjects confusing recollection from the study phase with recollection of something about a famous item that is unrelated to the study phase. Confusion should be minimal because the types of information whose retrieval supports these two kinds of recollection are clearly distinct.

In its original form, the PD procedure as applied to the false fame kind of paradigm suffers from two deficiencies. The first of these is implicit in the above paragraph. In order to calculate familiarity and recollection using the procedure, it has to be assumed that the sensitivities and response biases of the two memory measures are the same in the inclusion and exclusion conditions (the equivalence assumption). Unfortunately, this is unlikely to be the case on many occasions so that estimates are likely to be very distorted because there will be four unknowns and not two as is assumed.

The second deficiency is that the procedure does not compensate adequately for false alarms. Although originally, Jacoby and his colleagues did not correct at all for false alarms (Jacoby, 1991; Jennings and Jacoby. 1993), they now do correct for familiarity false alarms using signal detection theory (Yonelinas and Jacoby, 1995; Yonelinas, 1994). But they do not correct for recollection false alarms. The data cited in van Eijk et al (submitted) is inconsistent with threshold models of recollection which assume that recollection false alarms are all guesses, but is consistent with signal detection theory (SDT). We, therefore, believe these false alarms should be corrected for using SDT just as with familiarity false alarms (see van Eijk et al., submitted). According to SDT there is no qualitative difference between the memory feelings associated with true memories for old items and false memories for new items. Support for this postulate is provided by the occurrence of remember false alarms in the remember/know procedure. When subjects make such false alarms it seems to them that they are genuinely recollecting rather than guessing. This strongly suggests that it is appropriate to correct using SDT. In terms of the theoretical framework of this paper and the attributionist ideas of Jacoby, Kelley and Dywan (1989), false recollection feelings will arise whenever a memory attribution is based on enhanced fluency of processing a representation of an item-context association, and the enhanced fluency has been caused by a non-mnemonic factor, or, at least, a mnemonic factor unrelated to the falsely recollected item-context association for which no memory representation exists. False recollection is discussed in the next section.

To address these two deficiencies, we have modified the PD procedure (in a way similar to that described by Richardson-Klavehn et al. (1996) so that there is only one condition from which the inclusion and exclusion scores can be calculated, which prevents the equivalence assumption being violated. At test, subjects are told that the studied items were non-famous and shown studied non-famous items, new non-famous items, and new famous items. They are asked to judge of each item whether it is (1) studied and non-famous, (2) famous (the interest is, of course, in the studied non-famous items judged to be famous because they feel familiar, but are not recollected from the study episode), (3) new and non-famous. The inclusion score is the sum of (1) and (2) and the exclusion score is (2).

In order to calculate familiarity and recollection, we correct for false alarms by using multidimensional SDT. We have used the modified PD procedure with the false fame paradigm in three experiments. In the first, we found that subliminal priming enhanced familiarity, but had no effect on recollection. In the second, we found that dividing attention at test reduced recollection, but had no effect on familiarity. In the third experiment, which we ran in two versions: one with unknown names and one with unknown faces, we found that amnesics showed an impairment of both familiarity and recollection, although their familiarity deficit was less severe. Our estimates were based on the assumption that the two forms of memory are stochastically independent of each other. The simulation we have done (Van Eijk et al., submitted), referred to earlier , shows that moderate violations of this assumption are likely to cause only slight distortion of the above results.

Our finding of apparently impaired familiarity in amnesics is intriguing, and it is not unique as. Knowlton and Squire (1995) have also reported amnesics showed impaired familiarity as assessed with the remember/know procedure. Three obvious interpretations are possible. The first is that the patients do not use familiarity in the same way as normal people, and employ it to infer that items were encountered in the test phase of the false fame paradigm whereas normal people only say this if they feel genuine recollection for an item. If patients are doing this, then subliminal priming should appear to boost their recollection as well as their familiarity. Were this to be found in amnesics and not in their control subjects, we would have to conclude that we have systematically underestimated our amnesics' familiarity so that they may have no deficit. We plan to run this subliminal priming study with our patients. The second possibility is that the patients show normal fluency enhancement, but do not use this to make familiarity attributions because they are able to recollect so little of the past that the attribution makes no sense to them. The third possibility is that the amnesics show impaired familiarity because they do not show normal increases in fluency for repeated items of the kind used in our experiment. We also plan to test these last two possibilities.

Three more points should be made about the PD procedure. The first point relates to whether it provides a more accurate means of estimating familiarity and recollection than the remember/know procedure. We compared the two procedures using a modified version of the remember/know procedure in which, at test, subjects were asked whether they remembered something specific about names or faces from the study episode, whether they felt an item was familiar within the context of the experiment, or whether they did not remember it. Recollection and familiarity were then estimated from the scores using the independence assumption and SDT to correct for false alarms (see Van Eijk et al., submitted). We found that dividing attention at test affected estimates of familiarity as much as estimates of recollection, and that estimates of familiarity correlated with estimates of recollection. We interpret this to show that estimates of familiarity derived from the remember/know procedure are contaminated with recollection. This interpretation is consistent with findings of a study by Perfect et al. (1996, which found that subjects reported a limited amount of recollected detail with a proportion of the items to which they gave a know response. In other words, some know responses are based on familiarity alone, some are based on weak recollection, and some are based on both familiarity and weak recollection.

Is it possible to counter our interpretation by arguing that there are two kinds of familiarity with different properties, one of which is tapped by the PD procedure and one by the remember/know procedure? This has been argued by Richardson-Klavehn et al. (1996) and it is also argued by those who believe that know responses are based on semantic memory, which, unlike item familiarity, presumably depends on the familiarity of relevant associations rather than of items (Tulving, 1985; Knowlton and Squire, 1995). Such arguments are unlikely to be right because there is no known form of memory which is boosted by subliminal item priming at test and reduced by dividing attention at test as occurs with know responses that are made in standard recognition situations where subjects have to identify whether items appeared in a particular study context.

Also, we have shown in unpublished work that there is one kind of situation in which know responses are not boosted by subliminal priming at test, which indicates that sometimes know responses are boosted by subliminal priming and sometimes not. We ran a variant of the modified PD procedure in which subjects were asked to make remember or know responses to non-famous names that they recollected as coming from the study list. The subjects made a significant number of know responses (even when know false alarms were corrected for). Nevertheless, although know responses have been shown by Rajaram (1993) to be selectively influenced by subliminal priming in a standard recognition task, in this variant of the PD procedure we found priming to have no effect on the number of items judged to have come from the study list. In other words, know responses in the above form of the PD procedure were not affected by subliminal priming. Almost certainly, therefore, two influences produce know responses. One influence is the kind of familiarity measured by the PD procedure, and the other is weak recollection. as shown by Perfect et al. (1996). Both of these contribute to know responding in standard recognition tasks whereas only weak recollection contributed to know responding in our variant of the modified PD procedure. It may be that a modification of the remember/know procedure in which subjects are heavily trained not to give know responses if they are weakly recollecting, would result in this procedure measuring familiarity like the PD procedure. This remains to be tried.

The second point relates to the assumption of stochastic independence that underlies the estimates of familiarity made by the procedure (estimates of recollection are not affected by the relationship between the familiarity and recollection processes). The nature of the statistical relationship between familiarity and recollection also has implications for our model. Although the four component redundancy framework does not need to specify the statistical relationship between the processes underlying familiarity and recollection, the nature of this relationship is relevant to one kind of development of the framework. Thus, the storage processes underlying representations of items and item-context associations are more likely to be algorithmically distinct if familiarity and recollection are stochastically independent.

It may be possible to determine what the relationship is indirectly by measuring item fluency for recollected and unrecollected memories. In applications of the PD procedure to paradigms like the false fame paradigm, whether item fluency has increased can be measured by using appropriate reaction time-dependent measures of fluency both at study and at test. This will enable the statistical relationship between fluency and recollection to be worked out and by extension the relationship between familiarity and recollection. One problem with this approach is that it is unclear whether familiarity depends on perceptual fluency, conceptual fluency or both so it may be important to measure both kinds of fluency. An alternative and more direct procedure for determining the statistical relationship between familiarity and recollection that we are currently trying, involves getting subjects to make rapid ratings of how familiar studied items are, and then make untimed ratings of how strong the feeling of recollection is for them. The rationale for this procedure is evidence that feelings of familiarity are generated more rapidly than feelings of recollection (Hintzman and Curran, 1994). If the statistical relationship between familiarity and recollection can be established, then it will be possible both to make appropriate adjustments to the PD equations and to gain some insight into whether item and item-context storage mechanisms are similar or very distinct.

The third point concerns the degree to which normal people use familiarity to contribute to performance in standard recognition tasks. Almost certainly, extent of the contribution will vary depending on the kind of recognition task involved. At one extreme, fluency-based familiarity may be used, but would be unable to make an above chance contribution to performance. This would be in recognition tasks where subjects are asked to recognize in which of two contexts an item appeared when care has been taken to ensure that items from the two contexts have identical levels of familiarity. For example, two lists of words might be presented in distinct spatial locations and recognition of whether or not the items had been presented in a specific study location be tested in a third location. In such tasks, familiarity should make no contribution to recognition performance. At the opposite extreme, if subjects are merely asked whether an item has ever been encountered by them, then familiarity provides them all the information they need to make a correct response. In such tasks, familiarity is likely to make a considerable contribution as its presence directly answers the recognition question being asked. Even so, recollection may also make a moderate contribution depending on the strategy that subjects select. Semantic memory tasks are formally of this kind because subjects may be asked whether they remember that a particular fact is true. Familiarity for the fact is sufficient to answer such questions, but success will probably be increased if subjects also use recollection to identify any specific contexts in which they encountered the fact.

Most recognition tasks, however, fall between these two extremes. Subjects are asked whether they recognize items from a specific context, but usually items from that context are likely to be more familiar than foil items. Familiarity does not directly answer the recognition question and is used inferentially in such tasks. It is likely that this will lead subjects to place less reliance on familiarity (and perhaps be more cautious) than when they are merely asked whether they have ever encountered an item before. Some might dispute that familiarity is used at all in recognizing items from specific study contexts. There is, however, direct evidence that subjects do use it in making episodic recognition judgements. In the Perfect et al. (1996) study, subjects reported a proportion of know responses with their correct recognitions and for some of these responses they were unable to remember any associations with the study phase whatsoever. In other words, the subjects' memory feelings seem to be of non-specific familiarity of the kind that has been shown to be enhanced by subliminal priming both in the remember/know and PD procedures. This means that the subjects' recognition scores must have been better as a result of the contribution from their feelings of familiarity.

It seems likely that subjects can modulate their use of familiarity depending on the extent to which there is a clear familiarity distinction between target and foil items in a recognition test. Application of the PD procedure to the false fame paradigm suggests that when the appropriate instructions are used, subjects can be prevented from using familiarity altogether in making recognition judgements about whether items appeared in a particular context. By implication, the instructions give subjects the impression that if an item is not recollected as coming from the study list and is familiar, this is because it is famous. It is possible to check that subjects adopt this strategy by using subliminal priming and it is clear that the instructions lead normal young people not to use feelings of familiarity to identify that items appeared in the study phase (see van Eijk, Mayes and Meudell, submitted). As discussed above, it remains to be proved that amnesics and older normal people do so as well. In terms of our framework, the implication seems to be that subjects have some degree of control over whether they use aware memory for item or item-context associations in making recognition judgements.

The procedures discussed in this section may have some problems, but they offer the promise of obtaining reasonably accurate estimates of ISIM, familiarity and recollection. By combining the modified PD procedure with a reaction time measure of item fluency or by using a procedure in which subjects make a paced familiarity rating followed by an unpaced recollection rating, it may be possible to measure memory attribution as it applies to familiarity and to determine its major characteristics. Good measurement procedures are vital for testing and developing the four component redundancy framework. The final section considers some further developments of the framework and some of the predictions it makes.

5. Further Elaboration of the Four Component Redundancy Framework and Its Predictions

We have adopted the view, apparent in the early work of Jacoby and his associates (for example, Jacoby and Dallas, 1981) that ISIM always depends on the increased speed, ease and strength of activation of representations which results from increases in the strength of the connections that link the components of the memory whether it is of a single item or involves an associated collection of items. It remains unresolved whether there are any circumstances where continued activation of the memory representation makes any contribution to enhanced fluency except at very short delays as in the case of subliminal priming. Much more importantly for our framework's account of explicit or aware memory, it also needs to be determined whether different ways of measuring ISIM for the same kind of memory representation basically measure the same underlying variable. This should be the case if increases in the strength of neuronal connections underlying the storage of a representation are the primary causes of increases in the speed, and ease, and strength with which the representation is reactivated from its componential cues. For example, if "accurate" stem completion reflects greater ease of reactivation, then it should be the case, but still needs to be shown convincingly that such completions are made more rapidly than "inaccurate" or foil completions. Interestingly, ease of target generation and speed of generation seem to be correlated in another indirect generative memory task. This task involves presenting homonyms paired with context words that are related to one of the homonym's meanings (for example, "bank" with "money") and later asking subjects to give the first definition of the homonyms that comes to mind. Enhanced fluency is shown by the increased tendency to define the homonyms so as to accord with the semantic bias provided by the context word. Priestley (personal communication) has found that this greater ease of generative reactivation of the semantic memory representation is accompanied by an increase in the speed with which "accurate" definitions are made.

It seems to be possible to detect changes in the fluency with which a representation is reactivated as a result of learning experience with techniques such as positron emission tomography (PET) and functional Magnetic Resonance Imaging (fMRI) that indirectly monitor the levels of neural activity in different brain regions. There is, however, no a priori expectation about what kind of change should be found although it should be found in the neural system responsible for representing the relevant information. In fact, decreases in neural activity have been indirectly indicated much more often than increases. For example, Martin et al. (1995) used fMRI to demonstrate that showing line drawings for a second time in a silent naming task led to reduction in activity in the ventral occipitotemporal area. They argued that this reduced activity reflected the increased efficiency with which subjects were able to process repeated line drawings of objects. In contrast, Chen et al. (1995) (see also, Schacter, Reiman et al., 1995), using PET, reported that subjects showed increased activation in the region of the inferior temporal and fusiform gyri when they studied drawings of possible objects for the second time. Nevertheless, the vast majority of studies have found that there is reduced activation when cognitive processing is repeated when items are presented for a second time. We suspect that exceptions relate more to the fact that neuroimaging is still in a fairly early stage of development than to enhanced fluency being a multifaceted process. Observed reductions also seem to occur in regions where the repeated information is likely to be represented, not only when it is perceptual, but also when it is semantic. Thus, Demb et al. (1995) found that not only are semantic judgements made faster on words when the judgement is made a second time, but fMRI showed reduced activation in the left inferior prefrontal cortex. This reduced activation may be specific to semantic representations because it is not found in this region for non-semantic judgements even though these are also made faster when words are re-presented. In other words, representing semantic information activates the left inferior prefrontal cortex and increased fluency of representing this information reduces the level of the activation.

PET and fMRI should prove to be particularly valuable in locating where memory representations are and this may help identify what kinds of information are held in these representations. In contrast, event-related potential (ERP) recordings in humans and single unit recordings in animals should help identify the temporal properties of the memory activations and help determine whether there is an association between the speed of activation and the strength of activation (perhaps indicated by the peak average level of neuronal activity in the neural system where the memory representation is believed to be held). The potential of ERP work in this area has been shown by Paller (1994), who found bilateral ERP changes from electrodes placed over the posterior cortex in a lexical priming task. Therefore, ERP and neuroimaging techniques may provide indirect measures of the speed, ease, and strength of memory representation activation. It should be noted that behavioural measures of fluency are also indirect measures of the fluency of reactivation of memory representations. For example, speeded lexical decision times for studied words are not identical with the faster activation of the word memory. Indeed, Ostergaard (1992) has argued that the contribution of memory to performance in such tasks may be small with unrelated factors making a greater contribution. Even so, the behavioural measures most closely related to the underlying theoretical concept are probably increases in the speed, strength, and accuracy of generation of the representation itself from partial cues.

The redundancy framework predicts that normal people should show ISIM for all those kinds of information, including item-context associations, for which explicit memory exists. This prediction is also made by theorists such as Jacoby and Roediger. But much more work needs to be done to demonstrate that people show enhanced fluency for complex information such as item-context associations. Complete absence of ISIM for item-context associations would refute the redundancy model and, in our view, a convincing demonstration of ISIM for this kind of association still needs to be made. It certainly appears to be absent in some paradigms using "local" context (Mori and Graf, 1996). There is one qualification to the above prediction that should be made, however. With individual memories, the association between enhanced fluency and aware memory may be difficult to demonstrate. This is because explicit memory is often intentional and probably then involves active search the aim of which is to find cues that will lead to reactivation of the target representation with enhanced fluency. The cues that are spontaneously and initially encoded in such cases will not show enhanced fluency of activation of the target representation. All our position requires is that if the right cues are encoded, then enhanced fluency of reactivation of the relevant representation should be shown when it is explicitly remembered. This modified prediction about individual aware memories will only be easy to test when aware memory occurs without the need for active search.

We wish to suggest that the strength of feelings of memory are a direct function of the degree of enhancement of fluency reactivation of the memory representation from cues that are encoded at some stage in the retrieval process. If other things are equal, then the greater the increase in fluency the stronger the feeling of memory. This means that the attribution process, which is probably automatic, must somehow be able to monitor fluency changes and trigger feelings of memory on the basis of them. The strength of the feeling of memory will be used by the rememberer to make a decision about whether they are remembering. Such decisions can probably be modelled by SDT. Fluency may be used, however, to make attributions about things other than memory. Thus, when the instructional set is changed, fluency can also be used to make attributions about the perceptual and aesthetic properties of the things that have more fluently processed representations. This suggests that the kind of attribution made is a function of context. So aware memory for a representation may fail to occur even when the representation is activated with enhanced fluency at some stage of active search if a person does not relate what they are doing to memory, but to something else like making perceptual judgements.

There may be another difference between aesthetic/perceptual attributions and memory attributions that is illustrated by a well-known experiment of Kunst-Wilson and Zajonc (1979). These workers found that subliminal presentation of polygons led to an increase in the positivity of aesthetic attributions that subjects made about them, but did not produce above chance memory attributions. One possible reason for this was that the subjects had no recollection of the study episode about which they were being asked to make the attributions. Such general recollective awareness is probably an essential condition for making memory attributions whether these lead to feelings of recollection or familiarity. In contrast, perceptual/aesthetic attributions should not depend on having general recollective awareness of the study episode.

Even if all the necessary conditions required for making a memory attribution apply, we still have to suppose that the brain is able to monitor small changes in fluency with considerable precision. This requirement of the four component redundancy account of aware memory may seem unlikely to be met because the fluency baseline is likely to fluctuate considerably over time as it will be strongly influenced by non-mnemonic factors. The evidence from subliminal priming, nevertheless, strongly suggests that the brain can monitor fluency with precision relative to a baseline that probably fluctuates. Future work needs to determine just how much the fluency baseline does fluctuate and to identify precisely which features of fluency relate most closely to memory attribution. For example, it may be that the feature of fluency of which we are most directly aware is the strength with which memory representations are reactivated, but that this feature correlates with speed of reactivation. Central to our view is the idea that one or more non-informational feature of any activated representation produces a noticeable effect that provides the basis for an automatic inference. The result is a feeling of memory. The non-informational feature is in our view very likely to relate closely to enhanced fluency. Nevertheless, future work must identify precisely what features of the activation of memory representations people become aware of so that they can make memory attributions.

The redundancy account proposes that all aware memory whether it is for items, item-item or item-context associations results from the processes described above. We have accepted that episodic recognition can be supported by aware memory of items and/or item-context associations, and have suggested that episodic recall primarily involves aware memory for item-context associations. As we have already discussed, the information in these two kinds of memory representation is different and it is possible that their storage is organized in a different way. We wish now to consider what the framework implies about the relationship between semantic and episodic memory.

If familiarity is defined as a feeling of memory that is not specific to any personally experienced study context, then there should be forms of familiarity in which a feeling of memory occurs for item-item associations. There is, in fact, direct evidence that enhanced fluency, or at least a correlate of fluency, can lead to false judgements that certain statements are true, a form of semantic memory that clearly involves item-item associations (Begg, Anas, and Farinacci, 1992). This illusion of semantic memory provides direct support for the view that semantic memory typically involves enhanced fluency for factual information which leads to a memory attribution of familiarity for the fact (or item-item associate).

By definition, recollection is the only kind of memory feeling that directly supports episodic memory because it relates to personally experienced item-context associations. Semantic memory, in contrast, is memory for facts. This definition is perhaps not as clear as it first seems because facts might relate to single items, as well as item-item associations, and item-context associations which do not contain personally experienced information about the context (for example, Knowlton and Squire, 1995). Perhaps to clarify this difference, semantic memory could be said sometimes to draw on item-situation representations. Fluency-based familiarity for item-item associations is sufficient to support memory for facts such as "Canada is north of Spain" or "That picture is of J.F. Kennedy the assassinated President". For facts such as "I had muesli for breakfast on February 28th 1996 at my home around 8.30 a.m. or so I'm told!" only familiarity for item-situation associations (however vague these are) will be sufficient to support memory optimally.

As with recollection, familiarity for factual associations may sometimes be achieved via enhanced fluency and a memory attribution alone, but it will often also require active retrieval search as does recollection. It is hard to see how familiarity for item-situation associations differs from aware memory of item-context associations at the retrieval stage. In other words, episodic memory and semantic memory for item-situation associations should be based on memory representations for similar associations and, in both cases, aware memory is the product of the same fluency and attribution processes and often of the same active search process. The most likely way in which they may differ is with respect to how item-situation (or item-item) and item-context associations are stored. The dependence of episodic memory on personal experience may also mean that the information stored is subtly different, and so is much more likely to involve cross-region associations that link components represented in different neocortical regions. If, as we considered earlier, such associations are stored differently from within domain (or region) associations, then episodic memory at least sometimes would have an algorithmically distinct storage mechanism from semantic memory.

The above argument depends on two assumptions: that episodic memory depends more on forming cross-region associations than does semantic memory, and such associations are stored differently. Both assumptions can be questioned. Many semantic memories involve multimodal representations and there is no good evidence that amnesics with relatively selective hippocampal lesions are more impaired at acquiring new episodic memories compared to new semantic memories. Even if the argument is valid, it only implies that episodic storage differs from the storage of some kinds of semantic information. The only way that occurs to us of arguing for a stronger distinction depends on proposing that there is something special about item-context associations. Experienced context typically does not receive focal attention so the item-context association may be stored in a different way from that used for storing item-item or item-situation associations where all components of the association receive focal attention. This is the basis for the view that amnesics have a selective failure in the ability to form item-context associations (Mayes et al., 1985). As we argue below, however, evidence that amnesia even affects the strengthening of item associations differently from the storage of any kind of new association is currently very weak.

In their study which showed amnesics to have impaired know as well as remember responding in episodic recognition, Knowlton and Squire (1995) argued that whereas the semantic memory (which they believe underlies know responses) primarily depends on structures like the medial temporal lobe that are damaged in amnesia, recollection involves not only these structures, but also frontal regions that are responsible for retrieving contextual associations. This position conflicts with what we have just argued and warrants several comments. First, in terms of the framework used here, Knowlton and Squire's account can be reinterpreted as saying that this kind of semantic memory does not involve active retrieval search whereas recollection does. This is contrary to general experience and also to our results with the remember/know procedure that were reported in the last section. Item-item semantic memory almost certainly involves active search although whether it requires as much active search as recollection will depend on, among other things, the complexity of the associations retrieved. There is evidence that the retrieval of semantic memory involves activation of right as well as left frontal cortical regions, and when retrieval is made hard can involve as much right frontal cortex activation as does recollection (Wiggs et al., 1996). This evidence is contrary to the HERA hypothesis (Nyberg et al., 1996) according to which semantic information retrieval primarily involves left frontal cortex activation whereas episodic information retrieval, i.e., recollection, primarily involves right frontal cortex activation. Frontal cortex mediation of the retrieval of the two forms of memory may not differ provided that complexity of the information retrieved is matched as well as other factors related to the difficulty of the monitoring processes. If there is a non-trivial difference, this will probably relate to the fact that personally experienced context usually does not lie at the focus of attention.

The second comment concerns the effortful/automatic retrieval contrast, proposed by Knowlton and Squire (1995) for the episodic/semantic distinction, and the nature of the storage processes for episodic and semantic memory. It would seem more likely that retrieval of items and item-item associations (i.e., semantic memory retrieval) will differ qualitatively from the retrieval of item-context associations (i.e., episodic memory retrieval) if the storage mechanisms for the two differ qualitatively as well. Such an argument cannot be made in general form, as discussed above and in the third Section, because some item-item associations, just like item-context associations, are cross-regional. However, it still might be possible to argue that some item and item-item familiarity depends on different storage processes from item-context and other cross-regional associations. All memory is ultimately associative so if different kinds of association are stored in qualitatively different ways, then it should be possible to identify markers for these differences. One such marker, already discussed, is whether an association is stored within one region or in several regions. This marker suggests that there may be a distinction between item and some item-item associative information that is represented and stored in one cortical region and item-context and other item-item associations that are represented in several neocortical regions. If this is correct, then storage within one region is insufficient for producing the subjective feeling that enables items to be integrated from their associated components into new higher level wholes because this feeling of unity is lacking in those item-item associations that are represented in one region.

There is also evidence which suggests that strengthening already established item associations depends on different storage processes from those involved in creating new associations. Thus, Reinitz et al. (1994) found that forming new associations demands attention whereas strengthening the links of an established item association does not although it is unclear whether forming new item associations makes lesser attentional demands than forming new item-item or item-context associations. This distinction between strengthening item associations and creating new associations of as yet unspecifiable properties does not seem to be supported, however, by a study of Kroll et al. (1996). In this study, medial temporal lobe amnesics were found to falsely remember lures that were recombinations of the syllables of presented words (for example, if "valley" and "barter" were targets, "barley" might be a falsely recognized recombination lure) more often than normal people. Surprisingly, under the experimental conditions, the patients' Yes/No recognition was normal as their hit rate and false alarm rate to unrelated lures did not differ from that of the normal subjects. If hippocampal lesions impair the storage of associations, this study suggests that they are impaired at much more than the storage of new cross-region associations (as was discussed in the third Section) because the words used in this study were surely already integrated items. As recognition was normal when unrelated lures were used, it is hard to argue that the impaired association is one between a word and the study context. When recombination lures were used, however, amnesic recollection of the words was not normal with the Yes/No recognition tests of the kinds used by Kroll et al. (1996). So the study may imply that strengthening of established within region item associations is also impaired by hippocampal system damage provided this is only tapped by use of the recombination lures. This would mean that the brain regions involved in semantic and episodic memory closely overlap and include the hippocampal system. Different retrieval mechanisms would seem less probable if this is true.

The above interpretation is not necessarily correct because patients may perform badly with the recombination lures either because they fail to create new associations between the components of the words and their study context or because they are actually more likely than normal people to form new associations between components of neighbouring words as Kroll et al. suggest. Further research will be needed to decide between these different interpretations. All the interpretations are compatible with the view that subjects can treat already stored items both as integrated wholes and as associated components whereas stored item-item or item-context associations can only be treated componentially. This suggests that item storage may share the properties of item-item and item-context storage, but also possess an additional property dependent on qualitative or quantitative processing storage differences. In summary, Kroll et al.'s study raises problems for the view that the brain mechanisms involved in strengthening already established item associations differ from those involved in creating new memories not only for item-context associations, but also for item-item associations. Although some evidence supports the existence of distinct storage processes, none gives support to a general distinction between semantic and episodic memory storage.

A third and related comment, important for specifying and testing the framework, needs to be made about whether item familiarity is based on perceptual fluency, semantic fluency or both. We described earlier that Keane et al. (1995) have reported that a patient with posterior neocortical damage showed impaired perceptual ISIM on some tasks, but apparently intact recognition. Gabrieli et al. (1995) have also reported that this patient, M.S., showed intact familiarity when this was measured either by the PD procedure or the Remember/Know procedure. Although without the modifications discussed in the previous section, these procedures will not give accurate estimates of familiarity, they do reliably show that it contributed to recognition, and, given that performance was estimated to be normal in M.S., familiarity may well have been approximately normal. Familiarity could have been intact in M.S. because in him and others it derives from an attribution that is based mainly on semantic fluency rather than the kind of perceptual fluency that underlies M.S.'s impaired ISIM. In support of this possibility, Wagner et al. (in press) have found that familiarity as measured by both PD and Remember/Know procedures is influenced by semantic manipulations more than perceptual ones. Semantic fluency is presumably the more fluent reactivation of representations comprising the recognized item and some of its most overlearnt and automatically accessed semantic features. In other words, it may be based on semantic associations that were already established at the time of encoding so that their strengthening could be achieved with minimal effort at encoding. This is supported by evidence that familiarity is unaffected by dividing attention during encoding (for example, Jennings and Jacoby, 1993), an effect similar to what is found with the encoding of already established associations (Reinitz et al., 1994). Future work needs to determine in more detail how dependent familiarity is on semantic (as opposed to perceptual) fluency, to confirm that the encoding as well as the retrieval of the semantic representation is automatic, and to determine whether enhanced fluency merely depends on established semantic associations being strengthened at study or whether it also needs new associations to be formed.

In episodic recognition situations, complex item-context associations are always reactivated from partial cues. This reactivation may often be easy, rapid and strong, but not always. Sometimes the memory is only reactivated after a considerable time has passed and great effort has been expended in an active search process. However, even when this happens the reactivation has a spontaneous quality that plausibly underlies a feeling of emergence that is likely to be enhanced fluency's chief perceptual result when representations are reactivated from partial cues. The initially encoded cues are often insufficient to trigger the fluency mechanism that will activate the target memory representation so that active search is required before there is the possibility of having an input to the memory attribution mechanism. The need for active search is likely to be greater in free recall than it is in recognition because the cues are more partial. This possibility is supported by studies in which attention has been divided at test when subjects were trying to recall or recognize items (Craik et al., 1996). Recall, like recognition, can obviously be either of episodes or item-item associations, but there is no strong reason to believe that it works differently in these two situations. One thing that we would expect is that when item-context associations are very strong, little or no active search may be required to achieve the encoding of sufficient features of the memory representation for the automatic fluency and attribution processes to be triggered. In such cases, dividing attention at test will have a far weaker effect than when recollective memory is less strong. This should apply both with recognition and recall. Also, when either of these forms of explicit memory occurs unintentionally, retrieval will not have been directed by an active search process so should be effortless.

Familiarity feelings in recognition, as assessed by the modified PD procedure, are not affected by dividing attention at test. In terms of our framework this means that active search is not required to trigger the fluency mechanism that leads to the familiarity attribution. Nevertheless, this observation needs to be justified as we have argued above that feelings of familiarity may be based on semantic fluency as well as perceptual fluency. Unless semantic fluency is solely based on the strengthening of already established associations between items and their semantic features, it must involve forming new associations and so should be reduced by dividing attention not only at study, but also at test. We suspect that the major difference between familiarity and more effort-demanding retrieval is not one of kind, but of degree. Familiarity is based on item representations. In recognition, these are likely to be encoded with sufficient completeness to trigger the fluency mechanism without the need to call on active search processes. When the item is presented at test, its perceptual and central semantic features are likely to be encoded fairly automatically so the entire memory representation should be triggered by the fluency mechanism. In contrast, when newly learnt associative information underlies fluency, the initially encoded information would probably be inadequate to trigger the fluency mechanism so that active search may often be necessary. This is because the components of the target memory association representation initially encoded would be likely to be far more incomplete. In other words, item familiarity may be less effort demanding than explicit memory for newly learnt associations because it typically involves more transfer appropriate processing (Morris et al., 1977).

We are postulating that three kinds of process operate on memory representations which contain different kinds of information that are possibly stored in algorithmically distinct ways. It is becoming increasingly possible to use PET and fMRI to determine which brain regions are activated or deactivated by the processes of enhanced fluency, attribution and active search, and to see how the regions affected correspond to where the retrieved memory representations are likely to be. Relevant studies may in the future be able to test whether the four component redundancy model is correct. Studies should be capable of identifying fluency effects in the regions where the memories are represented. For example, as already discussed, if fluency produces a reduction in blood flow or blood oxygenation within the representational region, this might be expected both when there is explicit memory and when there is only ISIM for the same information. There may be difficulties in interpreting neuroimaging studies, however, as is illustrated by a recent finding with fMRI by Martin (1996). In this study, enhanced fluency of object picture naming was associated with deactivation of the cortical regions likely to represent the relevant information whereas recognition of the pictures was associated with activation of the same regions. At first sight, this finding seems clearly inconsistent with the redundancy account of explicit memory and strong evidence against it. First impressions may nevertheless be mistaken because attention is known to increase activity in the regions where it is focused (Orban et al., 1996), and it seems likely that attention to items in a recognition will be different and also greater than in an indirect memory test. The problem may be soluble if procedures can be used for partialling out the effects of the kinds of attention used in the two kinds of memory test. If this can be done, the redundancy account should predict similar activation in the representing sites in both explicit and implicit memory unless attribution is shown to cause changes in the same sites.

Using neuroimaging to identify what brain structures attribution affects may also not be easy even if it affects regions not involved in memory representation. Thus, if representation of complex associations involves the hippocampus initially as suggested, among others, by Alvarez and Squire (1994), then hippocampal activity would also be expected to be greater at initial encoding rather than at retrieval if enhanced fluency means deactivation of the representing region. It might be possible to identify the effects of memory attribution if subjects could be induced to show fluency effects with remembered information without making memory (or other) attributions because they do not see themselves as being in a memory context. The activation or deactivation that they might show when they are encouraged to make memory attributions should produce additional kinds of brain activation. Whether the activations are in different regions from where the memory representation is located will need to be determined. Easy interpretation of such studies may, however, be hard to achieve because, once again, unless they are partialled out, different patterns of attention may blur the key changes. Also, active search will have to be minimalized when subjects make explicit memory judgements or its activational effects partialled out.

Neuroimaging and the study of lesion effects have already been quite successful at identifying which brain regions are affected by active search. Research in both areas strongly suggests that the frontal lobes play a key role in active search (for example, see Schacter et al., 1996; Moscovitch, 1995a and b). This region is believed to mediate the kind of planning activities that are related to problem solving, and which are likely to underlie active search. Neuroimaging studies have found that memory retrieval produces activations not only in posterior regions such as the parietal cortex and precuneus, but also in the right frontal cortex even when verbal materials are being retrieved (for example, see Squire et al., 1992). Squire and his colleagues found this effect of right frontal cortex activation with verbal cued recall, but not with stem completion. This is consistent with the notion that active search is mediated in part at least by the right frontal cortex. Thus, it should be used with cued recall, which is an intentional retrieval process, but not verbal fluency tasks, which are not. In an elegant study, Rugg and colleagues (Rugg, 1996) found that intentional, relative to incidental, recognition produced more activation in the right frontal cortex. As active search will probably only occur in the intentional condition, this confirms the central role of the frontal cortex in this process.

Pathologies of memory other than amnesia need to be explained by the four component redundancy model. It is of course well-known that temporal lobe epilepsy can give rise to feelings of deja vu and jamais vu, pathological forms of memory experience that are caused by medial temporal lobe pathology. This is interesting, but it needs to be shown what kind of information these abnormal memory feelings are based on. Do they, for example, involve feelings of familiarity for single items, recollection of complex associations between items, or both? This is important because medial temporal lobe lesions probably disrupt storage of item-item and item-context associations, but have little or no effect on item storage. In other words, if the lesions do not affect storage of single item information, but do affect familiarity for this information, then they may be disrupting the making of memory attributions in which case attribution should produce activation changes in this region in neuroimaging studies.

The existence of deja vu and jamais vu suggests that erroneous feelings of memory can be produced pathologically at very high levels. This suggestion is borne out by the existence of confabulation in which patients produce a very high level of false memories about which they are confident. Having poor memory is not sufficient to produce this state. Indeed, it may even be necessary to have at least a moderate level of memory in order to produce confabulations (see Moscovitch, 1995b). Many confabulators have frontal lobe damage (for example, see Kapur and Coughlan, 1980) and the condition can clearly be produced by lesions that are unrelated to amnesia. The functional deficit that underlies confabulation may be illuminated by a phenomenon seen in normal subjects in which high levels of false memory are produced under conditions in which lists of words are presented such that in each list all the words are strong associates to a non-presented word (Roediger and McDermott, 1995). When subjects are given either free recall tests after each list or a Yes/No recognition test after being presented with a series of such lists, they make a surprisingly high number of false memory responses to the non-presented strong associates. Also, they claim to remember, i.e., recollect, the same proportion of these lure items as they do studied words. Schacter et al. (submitted) have shown with a PET study that both true and false memory for items in the Roediger and McDermott paradigm produced equivalent levels of medial temporal lobe activation, which perhaps reflected the equivalent degree and type of memory feeling associated with true and false memories. Schacter, Verfaellie and Pradere (1996) have also found that amnesics were less susceptible than control subjects to the false recognition effect, which, they argued, might be because it depends on remembering the same kinds of semantic and associative information as does accurate recognition, and this is something the amnesics cannot do.

In these pathological and normal cases, it is as if information for which there is no true memory very strongly produces the feeling that there is memory for it. It seems as if the enhanced fluency and memory attribution processes are producing feelings of memory that are being interpreted as evidence for things that are untrue. The most likely explanation for the high level of false memories is that the active retrieval search processes are not working effectively, either because of difficult local conditions or because they are pathologically impaired (Moscovitch, 1995b). Moscovitch postulates that the search processes involve monitoring, evaluating, and verifying recovered memories. He argues that events are not organized at storage into a structured historical order, but only in terms of their similarity to each other. This is a critical point when it comes to deciding at retrieval whether or not a memory is of a particular situation. When subjects engage in an active search, they may activate several representations en route to the activation of a representation, which they decide is of the target information. Each stage will be marked by monitoring processes, which may not differ in kind from the monitoring process used at the final stage when it is decided that the memory is of target information. This monitoring process will often fail even when it is working normally, let alone when it is disrupted through damage to the frontal association cortex.

A possible example of a monitoring failure is provided by the Roediger and McDermott paradigm in which subjects may feel they remember lure items from the study episode because they remember actually thinking about them when the strongly associated target words were presented. The monitoring process should have excluded genuine, but irrelevant memories like these from being accepted because more information was required about the retrieved memory. For example, the subject might remember that the word was in their mind just before they were shown a genuine target word and so conclude wrongly that they are recollecting it from the study episode as a presented target item. In other words, the monitoring task is too hard. This suggests that if subjects monitoring was focused by telling them that they need to check whether they were shown an item rather than merely thought about it during the study episode, then the tendency to make an abnormal number of false alarms would be drastically reduced or abolished. The study needs to be done, but this prediction is supported by Schacter et al.'s (submitted) PET study in which only genuine memories of the auditorily presented words produced activation in the temporoparietal regions likely to be involved in processing and representing auditory verbal information. This study suggests that only true memories are likely to be of associations between words and auditory presentation, one implication of which is that if subjects were asked to report not just whether they remembered a word, but whether they remembered it being spoken or something equally specific and relevant, they would not do this with lure items except at a very low level. In support of this suggestion, Johnson (1996) has found that subjects are lees likely to remember perceptual characteristics of lures than of targets, but remember what they thought about them at more or less equal levels. She also found that subjects claimed to remember fewer lures when they made these judgements.

There is evidence from a recent study of Schacter et al. (1996) that the hypothesized failure to monitor candidate memories sufficiently so as to determine whether they relate to a target situation, which occurs in normal subjects, can occur in a much more drastic form after damage to the frontal cortex regions that mediates the executive processes required for monitoring. Schacter and his colleagues reported that a patient with right frontal cortex damage made an abnormally high number of false alarms in Yes/No recognition tests. This tendency was only blocked when the patient studied categorized lists and was shown foils from unstudied categories. In other words, it was as if he was prepared to accept any item as remembered that met very broad desiderata such as "could have been a member of a list of words that I studied". With such patients, it needs to be explored whether they can retrieve sufficient information to correctly reject false memories if they used more specific desiderata, and also whether they can be made to use more specific desiderata (so that, as it were, the experimenter takes the place of their frontal lobes).

The view just considered is that false memories result from a failure of monitoring in the active search process, and not from any peculiarity associated with either the enhanced fluency or memory attribution mechanisms. When frontal lobe lesions damage the active search mechanism, confabulation is a possible consequence, particularly if the lesion disrupts temporal memory (see Mayes, 1988 for a discussion) so that there is less retrieved information available. This account is consistent with the four component redundancy model. But the existence of normal and pathological false memories related to failure of active search mechanisms also indicates that the notion of active search needs more development.

The development is necessary because false memories are hypothesized to occur even when subjects are remembering something that is true. For example, they correctly remember thinking about a lure item during the study phase, but then incorrectly infer that the item was part of the study phase. In many situations, we need to remember specific things so may wrongly infer that we have remembered them when we have in fact remembered correctly something else and not the target information. This could mean either that the remembered information does not come from a particular experienced context or that it is not the fact for which one was searching. Inferring whether or not a true memory is also a target is likely to involve effort even if it involves no further active search, i.e., when the subject infers that target information is being remembered. Only when retrieval is involuntary may such effortful reasoning not occur because the rememberer is probably uninterested in checking that the memory corresponds to some "target". When subjects merely have to decide that something is familiar or famous, the level of monitoring required may be so low that the degree of effort involved is undetectable. But when a subject has to decide whether a memory is of a particular context, then effort is likely to be involved even when active search has not been used in the business of arriving at the memory in question. This is not, of course, to imply that this final stage monitoring may not itself require active search. For example, in order to decide whether a memory is genuine a subject may have to retrieve actively whether they heard it or thought it. In so far as checking is involved, therefore, all intentionally retrieved explicit memories may involve some degree of effortful monitoring. In summary, even when aware memory for a target is activated automatically without using active search, some degree of effort may be needed to check that the memory is of a target. This process is a sub-component of active search.

The above discussion suggests that active search involves: (1) processes that lead to the encoding of cues which are sufficient to trigger enhanced fluency and memory attribution so that an aware memory results and (2) reasoning processes to check whether aware memories correspond to targets. Future work will need to analyse these processes, and their degree of overlap, in more detail. Their postulation does, however, have at least two implications. The first implication is that confidence in a memory depends on two factors. The first factor is how strong the memory feels, which must depend on things like the degree to which fluency is enhanced above baseline levels and the ease with which attribution operates. The second factor is how closely the felt memory seems to correspond to the target memory (particularly with episodic memory). For example, a rememberer might feel strongly that a word was seen immediately after another word, but the words could have appeared in other lists than the target one so he or she remains unconfident that the remembered word came from the study list. If experiments can be devised to separate the two factors, it will be interesting to see whether associative memories usually feel stronger than non-specific item memories. One might expect this on the grounds that it is easier to tell when associative representations "pop out" at above baseline levels. This might be harder to judge with single item reactivations partly because of greater variability of the baseline and partly because the only obvious interpretation of associative reactivations relates to memory whereas this is not true of item reactivations. If the above expectations are correct, one prediction might be that indirect memory tasks measuring reaction times to well studied appropriate associations (to minimized the role of active search) will show greater speed-ups than that seen with equally studied single items.

The second implication concerns memory judgements when there may be no feeling of memory for a target. It has long been accepted that factors other than feelings of memory influence decisions in recall and recognition tasks. For example, even if the fluent activation of an item-context association leads to a feeling of recollection, subjects may reject the information represented as a memory because it conflicts with other recollections which are accepted more strongly. This can be regarded as a coherence factor. Factors like this are undoubtedly secondary to the memory feeling produced by fluency-based attribution as this is the bedrock on which coherence judgements have to be based. Coherence might be used to reach recognition or recall judgements in two situations. First, it may be used when there is conflict between recollections based on fluency attributions so that coherence needs to be used to decide the issue. Second, if a representation is highly consistent with other representations for which there are strong feelings of memory, then subjects may decide that the first representation must also be a memory even though they have no feeling of memory for it. It seems likely that the reasoning/checking subcomponent of active search uses the coherence criterion so that its use will be effortful and depend on frontal cortex mediation.

Use of the four component framework encourages consideration of the possibility that a pathological level of false memories when not caused by frontal lobe lesions may derive not from breakdown of the active search mechanism, but either from a disturbance of the memory attribution process or of the enhanced fluency process. If the former disturbance occurs, then memory attributions will be made even though there is no evidence that representations are being activated more fluently. This could be examined in those confabulators who seem to have no problems with active search and show normal fluency effects. Such work could be done both behaviourally and with PET/fMRI studies that attempt to locate which brain regions are activated by memory attributions.

With respect to disturbances of the fluency mechanism, subliminal priming indicates that subjects' fluency enhancement feels the same regardless of what causes it so if it has a pathological source, they will probably not be aware of this. Further support for the possibility that some disturbance of the fluency mechanism could produce an abnormal number of false memories is supported by experiments that demonstrate memory illusions based on using non-memory manipulations of item fluency. For example, Lindsay and Kelley (1996) have shown that when subjects are given a list of easy and difficult word fragments in a cued recall test so that particular words are either fluently or non-fluently generated, they report knowing an increased number of items whether or not these have been studied. The authors interpreted this as an illusion of item familiarity, but suggest that similar illusions of recollection may be produced by manipulations (such as giving misinformation about a whole event or its details) that cause a whole event to come fluently to mind. These illusions make it seem more likely that a pathological disturbance of the fluency mechanism could produce false memories. If the fluency mechanism were disturbed in confabulators, they would be expected to show abnormal fluency enhancements to far more foil items than is seen in normal subjects, i.e., their baselines would be raised. In summary, use of the four component framework suggests that false memories in brain damaged people may result from deficits in any of the three processes: enhanced fluency, memory attribution, or active search. Therefore, exploring the nature of false memory in normal and brain damaged people provides a means of testing and elaborating the four component redundancy model.

6. Conclusion

In this paper, we have argued that aware and unaware memory for all kinds of fact and personally experienced event information depend on the interactions between four kinds of mechanism: enhanced fluency of activation or memory representations; attributions based on detectable features of the enhanced fluency; active search; and the storage processes that strengthen the links between the components of memory representations. Exploring the likely interactions between these four kinds of process leads us to argue: (1) that unaware memory depends on enhanced fluency alone or enhanced fluency with a non-memory attribution, (2) that every kind of aware memory always depends on enhanced fluency and a memory attribution and sometimes on active search. What is new here is the detailed exploration of the implications of these ideas and the discussion of how they can be tested. To anyone who disbelieves the redundancy account of how feelings of memory arise, the following challenge has to be met: If aware memory feelings do not arise from a memory attribution based on a non-informational feature accompanying the activation of a memory representation, what does produce them? To our knowledge, no-one has produced a convincing answer to this question.

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