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The relationship between implicit memory and implicit learning

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Two distinctions in the human learning literature are becoming increasingly influential; implicit versus explicit memory, and implicit versus explicit learning, respectively. To date, these distinctions have been used to refer to apparently different phenomena. Recent research suggests, however, that the same processes may be underlying performance in the two types of task. This paper reviews recent results in the two areas and suggests ways in which the two distinctions may be related.

Two dichotomies in cognitive psychology are becoming increasingly influential: implicit versus explicit memory, and implicit versus explicit learning, respectively. The interest in implicit memory can be indexed by the number of recent reviews of the topic (Lewandowski, Dunn & Kirsner, 1989; Richardson-Klavehn & Bjork, 1988; Roediger, 1990; Schacter, 1987; and Shimamura, 1986). The interest in implicit learning is smaller, but increasing, also indexed by the reviews (Berry & Dienes, in preparation; Broadbent, 1989; Lewicki, 1986; Reber, 1989). One surprising feature of the two literatures is the relatively small amount of cross-reference between them. For example, the recent collection of papers on implicit memory by Lewandowski *et al.* contains only one reference to implicit learning. Moreover, in cases where cross-reference has been made (e.g. Reber, 1989; Schacter, 1987), there has been no attempt to make any systematic comparison in terms of key features or underlying processes.

To date, the terms implicit memory and implicit learning have been used to refer to apparently different phenomena. Implicit rather than explicit memory is shown on tasks that do not require deliberate recollection of a past event although the event influences performance. Implicit rather than explicit learning is shown on tasks for which the subject learns to make the right decision (such as in controlling a complex system, or in classifying exemplars of an artificial grammar) without being able to justify the decision. The distinctions between implicit and explicit memory and between implicit and explicit learning are logically independent. For example, a person might be able to remember the episode in which he or she learned to make a right decision without being able to justify the decision. Recent evidence, however, suggests that the same processes might be underlying performance in both implicit

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memory and implicit learning tasks (e.g. Marescaux, Luc & Karnas, 1989). The purpose of the present paper is to review recent results in the two areas and to suggest ways in which the two distinctions may in fact be related. First, five key characteristics of implicit memory will be considered. Next, the implicit learning literature will be introduced, and then discussed in relation to these five characteristics. Finally, a number of theoretical convergences in the two fields will be highlighted.

Implicit memory

The majority of implicit memory research has been concerned with the phenomenon of direct or repetition priming, that is facilitation in the processing of a stimulus as a function of a recent encounter with the same stimulus. Repetition priming has been observed on a variety of tasks that do not make explicit reference to a prior study episode. The two tasks most frequently used are word completion and perceptual identification. In the word completion paradigm (e.g. Graf, Mandler & Haden, 1982; Tulving, Schacter & Stark, 1982) subjects are either given a word stem (e.g. win for window) or a fragment (e.g. –ar–va–– for aardvark) and are asked to complete it with the first word that comes to mind. Priming is shown by an increased tendency to complete the stems or fragments with words exposed on a prior study list. In the perceptual identification paradigm (e.g. Feustel, Shiffrin & Salasoo, 1983; Jacoby & Dallas, 1981) subjects are given a brief exposure to a stimulus and then attempt to identify it. Priming on this task is indicated by an increase in the accuracy of identifying recently exposed items relative to new items, or by a decrease in the amount of exposure time necessary to identify recently exposed items. Priming has also been shown on lexical decision tasks (e.g. Scarborough, Gerard & Cortese, 1979), free association tests (e.g. Williamsen, Johnson & Eriksen, 1965), face recognition tests (e.g. Bruce & Valentine, 1985), and reading transformed script (e.g. Masson, 1984).

Research to date has determined a number of important characteristics of performance on implicit memory tests in normal subjects. First, implicit memory seems to be very much tied to the surface characteristics of stimuli. A number of studies have demonstrated that performance on implicit but not explicit memory tests is substantially reduced by a modality shift between learning and testing. Jacoby & Dallas (1981), for example, found that changing modality of presentation from study (auditory) to test (visual) significantly reduced priming effects on perceptual identification performance, but had little or no effect on yes/no recognition performance. Similarly, Bassili, Smith & MacLeod (1989), Graf, Shimamura & Squire (1985) and Roediger & Blaxton (1987) reported that priming effects on word completion tasks were significantly reduced by a study test modality shift, whereas recall and recognition performance were largely unaffected. Other studies have shown that within the visual modality itself priming effects on lexical decision, fragment completion and reading tasks are highly sensitive to study test changes of various types of surface information (e.g. Kolers, 1975; Roediger & Blaxton, 1987; and Roediger & Weldon, 1987), whereas recall and recognition are less affected by such changes.

A second characteristic of performance on implicit memory tests concerns durability. A number of studies have manipulated retention interval and have found that implicit memory is less affected than explicit memory in some situations. Jacoby & Dallas (1981) and Tulving *et al.* (1982) using perceptual identification and word fragment completion tasks respectively, found that priming effects persisted with little change across delays of days and months, whereas recognition memory declined sharply across the same delays. Although several other researchers have demonstrated that implicit memory measures show slower decay over a particular retention interval than do explicit measures, the interpretation of such studies has been questioned by Richardson-Klavehn & Bjork (1988) have pointed out that scale differences often preclude comparison of forgetting rates across implicit and explicit measures, and that forgetting rates within the two classes of measures can be extremely variable.

Third, performance on implicit memory tasks is not affected by variations in the level or type of study processing. Jacoby & Dallas (1981), for example, assessed implicit and explicit memory performance following a study task that required elaborative processing (e.g. answering questions about the meaning of target words) or non-elaborative processing (e.g. deciding whether or not a word contains a particular letter). They found that yes/no recognition performance was higher following elaborative study tasks than non-elaborative tasks, whereas implicit memory performance was unaffected by the study task manipulation. Graf *et al.* (1982) reported a comparable pattern of results using stem completion as an index of implicit memory and free recall as an index of explicit memory. Similarly, Schacter & McGlynn (1989) found that implicit memory performance (assessed by a free association test) was invariant across several types of study task, whereas explicit memory performance (assessed by a cued recall test) was significantly affected.

The above three characteristics establish the *functional* independence of implicit and explicit memory. Tulving (1985; Hayman & Tulving, 1989*a*) has argued that *stochastic* independence is theoretically more constraining. Stochastic independence between two measures occurs when the probability of success on one measure is the same whether there is success or failure on the other measure. Indeed, a fourth characteristic of implicit memory is that it is said to be stochastically independent of the ability to recall or recognize words. A number of studies have reported that successful performance on implicit memory tests was uncorrelated with success or failure on explicit memory tests (e.g. Graf & Schacter, 1985; Hayman & Tulving, 1989*a* and Tulving *et al.*, 1982). Hayman & Tulving, for example, found that under conditions of successive tests, primed fragment completion was stochastically independent of yes/no recognition of study words. The probability of successful fragment completion in the second test was indistinguishable for studied words identified as 'old' in the preceding recognition test and for those identified as 'new' (even when both 'subject' and 'item' main effects had been accounted for (see Flexser, 1981)). Moreover, Hayman & Tulving (1989*b*) found that different types of implicit memory tests, unlike explicit memory tests, were stochastically independent of each other indicating further functional independence between implicit and explicit memory tests.

Finally, there is evidence that amnesics can display unimpaired performance on implicit but not on explicit memory tasks. A number of early studies by Warrington

& Weiskrantz (e.g. 1968, 1970, 1974) found that amnesic patients were severely impaired on free recall and recognition tests, but showed normal retention of a list of familiar words when tested using word stem or fragment completion methods. It was reported that patients often did not remember that they had been shown the original study list items and treated the word completion tests as a kind of guessing game. More recently, Graf, Squire & Mandler (1984) showed that the implicit/explicit nature of the test instructions was a critical determinant of performance in the Warrington & Weiskrantz paradigm. They found that when patients were told to use the word stems in order to remember study list items (explicit memory instructions) they were impaired relative to control subjects. However, when the patients were instructed to write down the first word that came to mind (implicit memory instructions) they showed comparable amounts of priming to the control subjects. Other studies have shown that amnesic patients show intact priming effects on a variety of implicit memory tests in addition to stem completion. These tests include perceptual identification (Cermak, Talbot, Chandler & Wolbarst, 1985), lexical decision (Moscovitch, 1982) and free association (Schacter, 1985; Shimamura & Squire, 1984).

Implicit learning

Before examining the extent to which the five characteristics outlined above apply to implicit learning, the relevant background studies will be briefly reviewed. Two key paradigms in the implicit learning literature are artificial grammar learning and the control of complex systems. In the former case, subjects are typically asked to memorize a set of letter strings generated from a synthetic grammar which defines authorized letters and the permissible transitions between them. Following this memorization phase, they are informed about the rule-governed nature of the stimuli and are asked to categorize new letter strings as grammatical or non-grammatical. Experiments have consistently shown that subjects perform well above chance on this categorization task, even though they are unable to verbalize the rules underlying their decision of well-formedness (e.g. Reber, 1976; Reber & Allen, 1978; and Reber, Kassin, Lewis & Cantor, 1980). Hence, the learning can be regarded as being implicit (see Reber, 1989, for a detailed review).

A number of more recent studies, however, have found that specific and fragmentary knowledge of study item components, in particular first and last letters and permissible bigrams or trigrams, is sufficient to account for grammaticality judgements. Experiments have shown that the knowledge underlying classification performance does transfer, at least partially, to scoring the relevant features of complete strings (Dulany, Carlson & Dewey, 1984), to filling in missing letters (McAndrews & Moscovitch, 1985), and to rating letter bigrams (Perruchet & Pacteau, 1990). It is not clear, however, to what extent these transfer tasks can be considered to be tests of explicit learning and to what extent tests of implicit learning.

As far as research on the control of complex systems is concerned, Broadbent and colleagues have carried out a series of experiments demonstrating the existence of distinct implicit and explicit learning modes (Berry & Broadbent, 1984, 1987, 1988; Broadbent, FitzGerald & Broadbent, 1986; Hayes & Broadbent, 1988). The tasks have typically involved subjects controlling the level of one or more variables by deciding on the value of one or more others. In the often-used sugar production task (Berry & Broadbent, 1984; Marescaux *et al.*, 1989; McGeorge & Burton, 1989 and Stanley, Mathews, Buss & Kotler-Cope, 1989), for example, subjects take on the role of manager of a small sugar production factory and are required to reach and maintain specified levels of sugar output by varying the number of workers employed. Berry & Broadbent (1984) showed that practice significantly improved ability to control these computer-implemented tasks, but had no effect on ability to answer post-task written questions. In contrast, verbal instruction on how to reach and maintain the target value significantly improved ability to answer questions but had no effect on control performance. Moreover, there was an overall significant negative correlation between task performance and question answering.

One criticism of the early studies is that the particular questions used for the post-task questionnaire may not have been appropriate to the particular hypotheses of the person learning to control the system. Berry (1984), however, used a range of question types and still found evidence for a dissociation. Furthermore, Stanley *et al.* asked people to practise at the task and then to explain verbally to somebody else how to control it. Although in this case people could choose their own form of words, their own performance improved before they could tell somebody else how to succeed. Individual learning curves associated with the tasks showed sudden improvements in performance, which were not accompanied by a similar increase in verbalizable knowledge. It does not seem to be the case, however, that performance and verbalizable knowledge are totally separate. Stanley *et al.* found that although a dissociation occurred at moderate levels of practice, highly practised subjects were able to give verbal statements that helped novices to perform more successfully.

Rather than simply demonstrating or denying dissociations, an alternative approach has been to look at conditions that give rise to either implicit or explicit learning. Berry & Broadbent (1988) found that the salience of the relationship between the input and output variables is a particularly important factor in this respect. In the case of the control tasks used by Berry & Broadbent (1984), Stanley *et al.* (1989) and others, the underlying relationship was relatively non-obvious or non-salient. Berry & Broadbent (1988) found that when this relationship was made more salient, people controlled the tasks in a more conscious and explicit way, and post-task questionnaire scores were high and positively correlated with control performance. Hayes & Broadbent (1988) provided further support for the distinction between implicit and explicit modes of learning by showing that explicit, but not implicit, learning was retarded by a concurrent memory demanding task.

Two other paradigms in the implicit learning literature, which have been used to a lesser extent than artificial grammar learning and the control tasks, are those of Lewicki (for example, Lewicki, Czyzewska & Hoffman, 1987; Lewicki, Hill & Bizot, 1988) and Nissen & Bullemer (1987; see also Willingham, Nissen & Bullemer, 1989). Lewicki *et al.* (1988) studied people's ability to improve their performance when the location of a visual target was determined by the pattern of its location on earlier trials. They found that after extended practice, subjects exhibited a substantial decrease in reaction time to target signals with predictable locations, although they were unable to articulate any of the complex rules which regulated the sequence of trials.

In the Nissen & Bullemer task, a light appeared in one of four locations on a screen and subjects were instructed to press the one key, out of the four available, that was below the light. A fixed 10-trial sequence of stimulus positions was used. Subjects were trained on the repeating sequence and then transferred to a random sequence. The results showed a rapid decrease in RT with training on the repeating sequence, together with a substantial increase in RT when transferred to the random sequence. Nissen & Bullemer suggested that the task provides an implicit assessment of learning, without the requirement for conscious remembering of the sequence.

Evidence for key characteristics

If implicit memory and implicit learning are related in some important way, then the key characteristics of performance on implicit memory tasks should also apply in relation to implicit learning tasks. This section looks at each of the five key characteristics of implicit memory and examines the extent to which they apply to implicit learning.

Is implicit learning tied to surface characteristics? Unlike studies of implicit memory, studies of implicit learning have not tended to introduce visual–auditory modality shifts. There is evidence, however, that implicit learning may also be tied to surface characteristics. Berry & Broadbent (1988), for example, found positive transfer of performance from one control task to another of the same underlying equation if the tasks were perceptually similar (both transport or both person interaction tasks), but not if they were perceptually dissimilar. The lack of transfer did not arise because subjects failed to realize they could apply their knowledge; informing subjects that the tasks were based on the same underlying equation actually deteriorated performance. Squire & Frambach (1990) also reported no transfer of learning between Berry & Broadbent's (1984) sugar production and person interaction tasks.

As far as artificial grammar learning is concerned, a few studies have looked at whether performance is affected by a change of letter set. In an early study, Reber (1969) found that the memory advantage of prior experience with strings was maintained if the letters were changed but the same grammar used. Similarly, Mathews, Buss, Stanley, Blanchard-Fields, Cho & Druhan (1989) found substantial transfer to different letter sets when the classification task was used (when feedback was given), although transfer was significantly less with the different rather than the same letters. Thus, identical visual information during acquisition and testing is not necessary to access the classification database. It should be noted, however, that when no feedback was given, transfer to different letter sets was much poorer. Hence, a major part of the transfer to different letter sets appears to depend on subjects being able to determine the mapping between old and new letters. It may be that transfer was sustained by a consistent articulatory coding of the stimuli (see also McGeorge & Burton, 1980).

Similar effects of perceptual embodiment on procedural tasks have been noted in other paradigms (e.g. Stadler, 1989; Willingham *et al.*, 1989). Stadler replicated the finding of Lewicki *et al.* (1987) that reaction time decreased in a visual search task when the general location of the targets could be predicted by a set of rules that subjects could not later report. Stadler further showed that the knowledge did not transfer when the precise location of the target was changed, although the general location was still predictable. Willingham *et al.* demonstrated that when subjects had learned a repeating spatial sequence on a serial reaction time task there was no transfer of performance if the perceptual characteristics (colours) of the display were changed.

One difficulty in assessing the similarities between implicit learning and implicit memory on this question is that in most cases the relevant experiments have not been carried out using explicit learning tasks. For example, it is not known whether people show transfer of learning across two dissimilar control tasks if the tasks are based on an equation which is known to give rise to explicit learning.

Is implicit learning more durable than explicit learning? The study that most directly addresses this question comes from artificial grammar learning. Allen & Reber (1980) tested knowledge of the grammatical structure of two artificial languages after a two-year hiatus. To do this they recalled subjects who had participated in the earlier Reber & Allen (1978) study and retested their classification knowledge. In the original study, Reber & Allen required subjects to learn two different artificial languages under two different training conditions (paired-associate learning and an observation procedure). The results were interpreted in terms of subjects having available three basic cognitive modes for acquiring knowledge of the grammars; these being, explicit rule induction, individuated memory or analogic strategy, and an implicit abstraction strategy.

In the Allen & Reber study, subjects were not informed that the test strings were the same as those seen two years before; they were simply reminded of the earlier experiment and asked to classify new stimuli. The results showed that even two years after learning, all subjects were significantly above chance at assigning grammatical status to test items. It was not the case, however, that all types of knowledge were equally robust. Allen & Reber argued that explicit conscious knowledge in particular appeared to be relatively fragile in nature, whereas knowledge acquired in the implicit mode could still be detected after the two-year hiatus. Subjects continued to make accurate judgements in the absence of verbalizable knowledge. 'While some blurring of structure knowledge comes with time, and subjects report that immediate intuitive apprehension of grammaticality is somewhat harder to come by, knowledge gained in the implicit mode is persistent in both form and quality' (Allen & Reber, 1980, p. 184).

Is implicit learning affected by variations in type of study processing? Studies of implicit learning have not tended to manipulate levels of study processing in the same way as studies of implicit memory. It has been shown, however, that encouraging subjects to use a deliberate hypothesis testing strategy does not benefit artificial grammar learning, or performance on non-salient computer control tasks (Berry & Broadbent, 1988; Reber, 1976). In contrast, the use of such a strategy does benefit performance on salient control tasks which have been found to give rise to explicit learning (Berry & Broadbent, 1988).

Is implicit learning independent of explicit learning? In addition to the characteristics discussed above, research with the control tasks has revealed further functional independence between indices of implicit and explicit learning. Berry & Broadbent (1984) and Broadbent *et al.* (1986), for example, found that practice led to an improvement in task performance but not in verbalizable knowledge, whereas detailed verbal instruction on how to control the tasks, led to an improvement in verbalizable knowledge but not to an improvement in control performance.

Stanley *et al.* (1989) provided further evidence to support the view that performance on the control tasks and verbalizable knowledge were functionally independent. They used a split regression technique to locate the point in each learning curve where performance initially began to improve. This was compared with an independently measured point where subjects began to demonstrate verbalizable knowledge. They found that individual learning curves showed sudden improvements in performance, which were not accompanied by a similar increase in verbalizable knowledge.

In terms of stochastic independence, Berry & Broadbent (1984) reported a very small *negative* correlation between task performance and verbalizable knowledge. People who were better at controlling the tasks were significantly worse at answering post-task written questions. Subsequent studies (e.g. Berry & Broadbent, 1987, 1988) have more usually found zero correlations between performance and verbalizable knowledge on non-salient control tasks, compared with positive correlations on salient control tasks, which are assumed to give rise to explicit learning.

Finally, Willingham *et al.* (1989) (using Nissen & Bullemer's repeating lights task) examined whether procedural knowledge could be acquired independently of explicit declarative knowledge, or whether one type of knowledge must be acquired first. They found that development of one type of knowledge seemed not to depend on the other. It was possible for subjects to acquire procedural information in the absence of declarative information and also to acquire declarative information in the absence of procedural information. They suggested that both procedural and declarative knowledge of the task sequence were acquired in parallel.

It should be noted that the above correlations are over subjects, whereas in the implicit memory literature correlations that include main effects of subjects or items are sometimes regarded as 'spurious' (e.g. Hintzman, 1980). However, to argue the main effect of, say subjects on two memory tasks is spurious is to say that there are some processes not theoretically interesting that affect both tasks. This implies that the data are being used to test a model sufficiently detailed to rule out some cognitive processes as irrelevant to its limited domain. But what cognitive processes could these be: Selective attention? Degree of elaborative coding? In the absence of a detailed model, and with the purpose of only determining in broad outline the structure of the memory system, all cognitive processes that affect both tasks may be regarded as theoretically informative. Indeed, the use of individual differences has often been regarded as a legitimate tool in investigating memory (e.g. Underwood, 1975), attention (e.g. Broadbent, 1987; Davies, Jones & Taylor, 1984) and cognition generally (e.g. Carroll, 1985; but see Fodor, 1983).

Further, correlations with memory tasks seem to give the same answer regardless of whether subjects, items, or other variables are used (Hayman & Tulving, 1989*a*,

p. 229). Thus, we can regard the comparison of the correlations over subjects obtained in the implicit learning literature with the correlations in the implicit memory literature as informative. Nonetheless, future research using implicit learning paradigms should investigate correlations 'homogenized' for subjects and items (Flexser, 1981), as in the implicit memory literature, to establish fully the claim for stochastic independence (see Tulving, 1985). Future research should also determine the stochastic independence of different implicit learning tasks to each other (e.g. Hayman & Tulving, 1989*b*). In conclusion, while the above evidence suggests that at least partly separate processes are involved, it is not yet strong enough to indicate stochastic independence.

Can amnesics display unimpaired performance on implicit learning tasks? No study to date has examined whether or not amnesic patients can learn artificial grammars. A recent study by Squire & Frambach (1990), however, has looked at whether or not they can learn to control dynamic computer implemented tasks. Squire & Frambach tested 14 amnesic patients, together with an age-matched control group, on Berry & Broadbent's sugar production and person interaction tasks. They found that in the initial training session (which consisted of 90 trials of practice) the amnesic patients learned at the same rate as the normal subjects. However, during a second session, which occurred approximately one month after the first, the amnesics performed significantly worse than the normal subjects. Squire & Frambach suggested that this is because by this stage of practice the normal subjects were starting to build up declarative (explicit) knowledge and could use this to improve performance still further. The amnesic patients, in contrast, were unable to do this.

Nissen & Bullemer (1987) found that patients with amnesia resulting from Korsakoff's syndrome were able to learn their repeating lights task. They found that the amnesic patients showed the same pattern of improvement with practice on the repeating sequence, and the same pattern of slowing on transfer to the random sequence, as did the normal age-matched controls. Verbal reports showed that none of the amnesic patients noticed the repeating sequence. In a follow-up study, Nissen, Willingham & Hartman (1989) replicated the earlier procedure but, in addition, tested performance on the repeating sequence one week later. The results showed a considerable degree of retention of the knowledge of the sequence by the amnesic and control subjects. Neither group demonstrated forgetting across the one-week delay.

Theoretical issues

In addition to the empirical similarities between implicit memory and implicit learning, there has also been theoretical convergence between accounts of the two phenomena. For both implicit memory and implicit learning, accounts have been proposed in terms of multiple memory systems (e.g. Berry & Broadbent, 1988; Reber, 1989; Squire, 1986; Tulving, 1985), instance theories (e.g. Broadbent *et al.* 1986; Brooks, 1978; Logan, 1988, 1990) and distributive memory theories (Dienes, 1990; Weber & Murdock, 1989).

In terms of multiple memory theories, accounts of implicit memory by Cohen (1984), Squire (1986, 1987) and Tulving (1985), and of implicit learning by Berry &

Broadbent (1988) and Reber (1989), have highlighted the declarative nature of explicit tasks and the procedural nature of implicit tasks. Squire, for example, suggests that the declarative system is responsible for conscious access to facts and past experiences and is necessary for performance on explicit tasks. In contrast, the procedural system (which is necessary for performance on implicit tasks) records the processing operations of the system as they are modified by events, but not their explicit description. Similarly, Tulving (1985) suggested that explicit tests tap the episodic memory system and implicit tests tap either the semantic or procedural memory systems. More recently, he has extended his account to distinguish between perceptual and conceptual priming (Tulving & Schacter, 1990). He suggests that perceptual priming and perceptual identification are expressions of a single perceptual representation system (PRS) which operates at the presemantic level, whereas conceptual priming seems to be based on operations of semantic memory. Clearly, if the multiple memory system approach is to be appealing, the number of separate systems should be kept to a minimum. It would be most parsimonious to assume that researchers in the implicit memory and implicit learning fields are investigating similar distinctions. The dependence of implicit learning on perceptual embodiment (e.g. Stadler, 1989) may well indicate the involvement of the PRS.

Multiple memory system accounts of implicit memory have been criticized by Roediger and colleagues (e.g. Roediger, 1990; Roediger & Blaxton, 1987; Roediger, Srinivas & Weldon, 1989). They argue that many dissociations between standard implicit and explicit memory tests may reflect the operation of different cognitive procedures required by the tests. Rather than assuming that implicit and explicit tests tap separate memory systems, Roediger's transfer appropriate processing approach assumes that memory tests are composed of various component processes and dissociations between tests reflect the operation of different processes. Roediger and colleagues argue that performance will benefit to the extent that procedures invoked by the test recapitulate those used during prior learning. An important dimension for their account lies in whether procedures are directed more at surface features of the stimuli during study and test (data driven processing) or at the deeper meaning of the stimuli (conceptually driven processing). The dependence of many implicit learning tasks on perceptual embodiment (e.g. Stadler, 1989) may indicate the importance of data-driven processing in such learning; the subjects' failure to describe the rules of the task may indicate the relative absence of conceptually driven processing. Berry (in press) has recently found some support for Roediger's approach in relation to implicit learning of the control tasks. Using the sugar production and person interaction tasks, Berry found no transfer of performance to conceptually the same task if subjects spoke their responses on the first set of trials, and typed them on the second. This latter result is slightly difficult to interpret, however, as there was some degree of transfer if subjects typed their responses on the first set and spoke on the second.

A problem with the transfer appropriate processing approach is that although it accounts well for dissociations between explicit and implicit tests in normal subjects, the evidence from amnesic patients seems to fit better with a multiple memory system approach. Tulving & Schacter (1990) have recently proposed a way beyond this impasse. They suggest that there is no necessary incompatibility between system theories and processing theories and that the basic assumptions of transfer appropriate processing can be incorporated into multiple memory system accounts. Systems need different processes within them, and these may give rise to transfer appropriate effects.

Instance theories of implicit learning reveal exactly how it may be construed as implicit memory. Broadbent *et al.* (1986) suggested that on the control tasks a subject could construct a 'look up' table which would determine the appropriate action by matching the current situation to the most similar of the entries already in the table. That is, performance on the control tasks can be seen to be a form of fragment completion in which the situation is the fragment and the previous action is to be completed. Indeed, Marescaux *et al.* (1989) recently provided evidence that subjects' knowledge of appropriate action on the control tasks is linked to previous situations. They found that experienced subjects could only generate correct responses in particular sampled situations if the situations were identical to ones experienced during earlier control performance, and if the previous responses had resulted in reaching target. Similarly, Brooks (1978) and McAndrews & Moscovitch (1985) provided evidence that subjects' responses in artificial grammar learning can be linked to particular instances. In the implicit memory literature, on the other hand, Logan (1988, 1990) has provided an instance theory of repetition priming. Instances of an event are encoded and retrieved in an obligatory fashion, in a similar way to the look-up table of Broadbent *et al.*

Instance theories are, in principle, compatible with either a multiple systems approach (e.g. the instances forming a look-up table may be stored in a different system to propositional memory); or a transfer appropriate processing approach (the instances forming a look-up table may have been formed with mainly data-driven processing); or with neither (there is no principled difference between the instances in a look-up table and other sorts of instances, e.g. those supporting free recall). Future research should explore these possibilities.

Distributive memory theories of implicit memory emphasize that the subject's task is usually to reconstitute a presented stimulus (Humphreys, Bain & Pike, 1989; Weber & Murdock, 1989). Weber & Murdock point out that reconstitution is a natural consequence of the processes of a distributive memory system such as Murdock's (1982) TODAM. Distributive models of memory also allow reconstitution of 'degraded' stimuli and thus generalization of the knowledge to novel stimuli. Perhaps this is the basis of implicit learning. Indeed, Dienes (1990) showed that reconstitution by a distributive memory system could account for subjects' classification of new stimuli on the artificial grammar learning task. He also showed how such a distributive system could be applied to learning the control tasks in an apparently similar way to subjects.

So far this section has emphasized how implicit memory and implicit learning can be seen in the same way theoretically. However, not all theories of implicit memory are consistent with the phenomena of implicit learning. Most noticeably, the 'activation' view of Graf & Mandler (1984) assumes that implicit memory results from activation of pre-existing representations. Implicit learning, on the other hand, requires the creation of new associations. Schacter (e.g. Graf & Schacter, 1989; Schacter & Graf, 1989; Schacter & McGlynn, 1989) has argued, however, that implicit memory paradigms can also reveal the formation of new associations. If subjects study unrelated word pairs, they are more likely to evince learning on a later stem completion task if the stem is presented in the context of the same word it was paired with rather than a different one. The interpretation of this finding is not uncontroversial: Lewandowski, Kirsner & Bainbridge (1989) argue that the finding indicates activation of specific word senses rather than the formation of new associations. Clearly, the resolution of this issue by future research is important for defining the link between implicit memory and implicit learning.

Conclusions

It is clear from the above discussion that there are a number of similarities between the implicit memory and implicit learning literatures in terms of both empirical findings and theoretical approaches. The convergence between the two areas is not such, however, that a unified theory can be developed. A number of crucial experiments still need to be carried out. In order to integrate our understanding of the two domains still further, it is necessary to see if certain phenomena observed in one domain also occur in the other. For example in terms of implicit learning, is the tendency to respond consistently to rewarded situations (Marescaux *et al.*, 1989) independent of subjects' ability to recall the response to the situation, and is it reduced by modality shifts? In terms of the implicit memory paradigm, can implicit memory for new associations occur selectively for rewarded stimuli? Experiments currently in progress are investigating these and other questions. We hope that the results of such experiments will open the way to a unified perspective of these two previously separate domains.

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