10

Access to consciousness: dissociations between implicit and explicit knowledge in neuropsychological syndromes

DANIEL L. SCHACTER, MARY PAT McANDREWS, AND MORRIS MOSCOVITCH

Neuropsychological analyses of cognition rely heavily on observations concerning the preserved and impaired abilities of brain-damaged patients. Perhaps the most striking and important lesson that has been learned from neuropsychological investigation of such patients is that specific cognitive functions can be disrupted selectively. For example, patients with lesions restricted to specific regions of the left hemisphere are typically impaired on various linguistic tasks and are unimpaired on spatial tasks, whereas the opposite is true of patients with lesions restricted to specific regions of the right hemisphere; damage to particular areas within the left hemisphere impairs certain linguistic functions and spares others; patients with lesions to the hippocampus and medial temporal regions are severely amnesic for recent events yet perform normally on tests of intelligence, perception, and language. Many other similar dissociations could be cited, and they have been used by neuropsychologists from the nineteenth century onward in attempts to fractionate cognition into isolable components or subsystems.

During the past decade or so, a growing number of neuropsychological studies have provided evidence of a dissociation that is somewhat different from the sort of dissociations noted above. The general form of this dissociation is similar across a variety of tasks and patient groups. A patient with a particular lesion and corresponding cognitive impairment is asked to perform a task that requires direct or explicit use of his impaired function; as expected, performance is extremely poor. The patient is then asked to perform another task that also taps the impaired function, but in an indirect or implicit manner. Now, the patient's performance may be quite good—in some cases entirely normal—even though he does not have conscious access to the knowledge required to perform the task. Variants of this striking dissociation—normal or near-normal knowledge together with severely impaired explicit knowledge—have been observed in patients with disorders of memory, language, visual perception, facial recognition, reading, and other cognitive functions.

The purposes of this chapter are to review evidence concerning dissociations between implicit and explicit knowledge in various neuropsychological syndromes, to discuss relevant empirical and conceptual issues, and to delineate the theoretical implications of the observed phenomena. It is our contention that the dissociations to be discussed in this chapter have important implications for understanding the relations among cognition, language, and consciousness both in normal and in brain-damaged populations.

The remainder of the chapter consists of four main sections. In the first, we review the evidence concerning dissociations between implicit and explicit expressions of knowledge in a variety of neuropsychological syndromes. In the second, we consider more closely the nature of and relations among the various phenomena described in the former section, and pay particular attention to the criteria used to assess patients' 'conscious awareness' of different types of information. In the third, we consider possible theoretical accounts of the reported dissociations and, in the fourth, we outline a model of implicit/explicit dissociations.

Before considering the relevant evidence, some brief remarks concerning our terminology should be made. In this chapter, implicit knowledge refers to knowledge that is expressed in performance without subjects' phenomenal awareness that they possess it, whereas explicit knowledge refers to expressed knowledge that subjects are phenomenally aware that they possess. We sometimes use the phrase 'failure to gain access to consciousness' to describe those situations in which implicit knowledge is expressed in the absence of explicit knowledge. Although the exact definition and assessment of implicit knowledge differs in the various clinical and experimental situations that we consider, the emphasis in all cases is on patients' lack of reflective awareness of knowledge that is revealed in task performance.

Implicit/explicit dissociations: a survey

We now examine evidence for dissociations between implicit and explicit knowledge in six neuropsychological conditions: amnesia, blindsight, prosopagnosia, dyslexia, aphasia, and hemi neglect. We then note briefly additional relevant observations that have been made in anosognosia, visual agnosia, and split-brain patients. Since we will be considering a wide variety of phenomena in diverse patient groups, it should be stated at the outset that we are aware that some of these phenomena may turn out to be related to one another only superficially. It will be evident to the reader that certain phenomena represent clearer and more compelling instances of implicit/explicit dissociations than do others. We have deliberately cast a rather wide net, however, because we think it is important to bring together as much *potentially* relevant evidence as possible. There have only been a few prior attempts to relate the various phenomena discussed here to one another (e.g. Marcel 1983; Schacter 1987; Weiskrantz 1977, 1980), and no detailed, comprehensive treatments exist. We would rather err by including some examples that in the end may not be genuine implicit/explicit dissociations than by omitting possibly relevant phenomena.

Amnesia

Amnesic patients suffer from a severe and selective inability to remember recent experiences and to learn various types of new information, despite preservation of most perceptual, linguistic, and intellectual skills. Lesions to either the medial temporal or diencephalic regions of the brain are typically necessary to produce a full-blown amnesic syndrome, although the critical damage can be produced by any number of aetiologies, including encephalitis, bilateral infarction, ruptured aneurysms, Korsakoff's disease, head injury, and others (for a review, see Hirst 1982; Moscovitch 1982; Schacter and Crovitz 1977; Squire and Cohen 1984; Weiskrantz 1985).

Amnesic patients' striking inability to remember recent experiences across even brief retention intervals (i.e. minutes) is usually revealed by laboratory tests that require *explicit* remembering, such as free recall, cued recall, and recognition. On these tests, subjects are instructed to deliberately 'think back' to a specific study episode and to produce information that they remember from the episode (recall), or to indicate whether they remember that a particular test item had been presented during a prior study episode (recognition).

Despite amnesic patients' poor performance on tests of explicit memory, it has been known for some time that they show implicit memory for recent experiences. For example, in one of Korsakoff's (1889) original papers on alcoholic amnesia, he described a patient who had been given an electrical shock and was later exposed to a case that contained the shock apparatus. Although this patient did not explicitly remember any shock experience, when he saw the case '. . . he told me that I probably came to electrify him, and meanwhile I knew well that he had only learned to know that machine during his illness' (1889, p. 512). Other clinical observations of this kind have been reported (e.g. Claparède 1951; MacCurdy 1928), but only recently have the implicit memory abilities of the amnesic patient been subject to careful experimental studies. These studies have shown that amnesic patients perform relatively well—and sometimes normally—on a variety of implicit memory tests in which subjects are not required to think back to any prior episode, and conscious or explicit recollection of previous experiences is not necessary for successful performance. Since much of this evidence has been reviewed elsewhere (e.g. Cohen 1984; Moscovitch 1982, 1984; Parkin 1982; Schacter 1985; Schacter and Graf 1986*b*; Shimamura 1986; Squire and Cohen 1984), we do not provide a detailed review here. The point we wish to highlight is that amnesic patients show implicit memory for recent experiences across a wide variety of tasks and materials.

Perhaps the earliest and best known example of implicit memory in amnesic patients is the research on motor skill learning in the densely amnesic patient H.M. reported by Milner and Corkin and their colleagues (Corkin 1965, 1968; Milner 1962; Milner *et al.* 1968). They found that H.M. showed excellent learning and retention of tasks such as pursuit rotor and mirror tracing across trials and sessions. Each time he performed one of these tasks, however, H.M. failed to recollect any previous experience with it. Similiar findings of preserved motor skill learning in other densely amnesic patients have been reported (e.g. Eslinger and Damasio 1985; Starr and Phillips 1970). It has also been demonstrated that amnesic patients can learn various other kinds of skills that are acquired gradually across multiple trials. For example, Cohen and Squire (1980) and Moscovitch *et al.* (1986) used a task introduced by Kolers (1975) which involves reading of mirror inverted script. Normal subjects become progressively faster at this task with practice. Both Cohen and Squire (1980) and Moscovitch *et al.* (1986) reported that amnesic patients acquired the skill of reading the transformed script at about the same rate as did control subjects. The amnesics, however, performed poorly on tests that required explicit remembering of the prior occurrence of the target materials. Nissen and Bullemer (1987) used a serial learning task in which subjects were exposed to a spatial array of lights and simply had to press a key beneath a light when it was activated. They found that when lights were activated according to a repeated serial pattern, both amnesic patients and control subjects responded more quickly than when a random pattern was used. Amnesic patients learned this task at a normal rate despite their severe impairment when asked to remember explicitly the sequence of lights in the repeating pattern.

Although the foregoing studies and others like them (e.g. Brooks and Baddeley 1976; Kinsbourne and Wood 1975; Martone *et al.* 1984) demonstrate implicit retention on skill learning tasks that are acquired gradually and rather slowly, a good deal of recent research has documented normal implicit memory for single episodes in amnesic patients. This line of research was initiated by the classic studies of Warrington and Weiskrantz (1968, 1970, 1974, 1978). In one experiment, for example, Warrington and Weiskrantz (1974) showed amnesic patients a list of familiar words and tested memory for the words with a standard yes/no recognition test, and with a task in which patients were given three-letter cues and were asked to indentify the words represented by the cues. As expected, amnesics performed disastrously on the explicit recognition test. However, they showed entirely normal retention on the letter cueing test: amnesics and controls completed the letter cues with about the same number of study list targets. More recently, Graf *et al.* (1984) showed that the implicit/explicit nature of test instructions is a critical determinant of performance in the Warrington and Weiskrantz paradigm. They found that when subjects were instructed to use three-letter word stems in order to *remember* study list items (explicit memory instructions), amnesics were impaired relative to control subjects. However, when subjects were instructed to write down the first word that came to mind (implicit memory instructions), amnesics and controls showed similar facilitations of test performance (similar results have been reported by Graf *et al.* 1985; Schacter 1985; Shimamura and Squire 1984). Such a performance facilitation is now referred to as direct or repetition priming (cf. Cofer 1967).

It has been established that amnesic patients show intact priming effects on a variety of implicit memory tasks in addition to stem completion. These tasks include word identification, in which subjects attempt to 'see' briefly exposed items (Cermak *et al.* 1985); lexical decision, in which subjects decide whether or not a letter string constitutes an English word (Moscovitch 1982); and free association to the initial words of highly related paired associates (e.g. 'table–chair'; Shimamura and Squire 1984) and linguistic idioms (e.g. 'sour grapes'; Schacter 1985). In these and other priming experiments discussed thus far, the critical items were familiar units (i.e. words, idioms) that are in some sense represented in memory prior to exposure on a study list. Recently, several investigators have examined whether amnesic patients also show priming effects on implicit memory tests for novel information that is not represented in memory as a single unit prior to experimental presentation. Cermak *et al.* (1985) found that Korsakoff amnesics do not show priming effects for non-words on a perceptual identification test, and Diamond and Rozin (1984) reported similar findings in a variety of patients with the stem completion test. Other studies, however, indicate that at least some amnesic patients do show implicit memory for novel information. In an experiment by Graf and Schacter (1985), subjects studied unrelated word pairs (e.g. 'window–reason') and were then given a stem completion test in which some items were presented in the same context as on the study list (i.e. 'window–rea—') and other items appeared in a different context (i.e. 'officer–rea—'). Graf and Schacter reasoned that implicit memory for a new association would be demonstrated if subjects completed more stems in the same context condition than in the different context condition. They observed an equivalent same/different context effect in amnesic patients and control subjects. In a subsequent study using the same paradigm, Schacter and Graf (1986*b*) found evidence of implicit memory for new associations in mildly amnesic patients, but not in severely amnesic patients.

Evidence from other priming studies indicates that even severely amnesic patients can show implicit memory for new associations. Moscovitch *et al.* (1986) assessed implicit memory with a task that involved reading and rereading unrelated pairs of degraded words in same and different context conditions. They found that patients with severe memory disorders, like control subjects, reread same context pairs faster than different context pairs, thereby indicating normal implicit memory for a new association. McAndrews *et al.* (1987) presented amnesics and controls with novel, difficult-to-comprehend sentences (e.g. 'The haystack was important because the cloth ripped') and asked them to generate the critical word that made the sentence comprehensible (e.g. *parachute*); critical words were provided if they were not generated. Sentences were shown again at delays of 1 min, 10 min, 1 hr, 1 day, and 1 week, and subjects were asked again to think of the critical word. McAndrews *et al.* found that severely amnesic patients showed substantial priming at all test delays, as indicated by enhanced generation of key words on the second presentation of a sentence relative to the first. However, these patients had virtually no explicit memory for the sentences: they performed at chance levels on a yes/no recognition test.

In addition to the various types of skill learning and priming effects that we have considered, amnesic patients have shown implicit memory for recent experiences in other experimental paradigms. Several studies have shown that amnesic patients can acquire new factual information, even though they do not explicitly remember having learned any facts and claim no familiarity with the information that they do retrieve (e.g. Schacter *et al.* 1984). Glisky *et al.* (1986*b*) examined whether amnesic patients could acquire complex factual knowledge necessary to operate, program, and interact with a microcomputer in a study that involved extensive repetition across numerous learning sessions. They found that a densely amnesic patient could learn to write programs, edit them, and use disk storage and retrieval operations. Yet this patient did not explicitly remember having learned anything about the computer, and claimed at the beginning of each session that he had never worked on a computer before. It has also been demonstrated that amnesic patients can acquire preferences for simple melodies that they do not explicitly recognize (Johnson *et al.* 1985), show classical conditioning of an eye-blink response without remembering prior conditioning sessions (Weiskrantz and Warrington 1979), produce bits and pieces of recently presented stories that they do not recollect having been told (Luria 1976), and show an increased skin conductance response (SCR) to previously studied emotional words that are not recognized explicitly (Nishio 1984, cited in Moscovitch 1985).

Blindsight

The term 'blindsight' was introduced by Weiskrantz *et al.* (1974) to describe the residual visual capacities of cortically damaged patients with blindness for a part of the visual field. Blindsight refers to the ability to make certain classes of responses, in the absence of explicit perceptual awareness, to stimuli presented in blind visual fields. For example, a patient who accurately points to the location of a bright light presented within his blind region may claim to have had no conscious visual experience of the stimulus and assert that he is 'guessing' the location.

The investigation of blindsight in humans was stimulated by primate research that showed that complete ablation of primary visual cortex does not result in permanent blindness. In the past decade there have been a number of compelling demonstrations that a similar type of residual visual function is also present in hemianopic humans with cortical damage. The most widely used paradigm involves localization of a stimulus presented briefly to one of several regions of the blind field along a chosen meridian. A cue is given to initiate the response, which requires the patient to 'guess' where the target had been. Under these conditions, hemianopic patients have been shown to make reasonably accurate localization judgements by pointing or reaching toward the target position (e.g. Perenin and Jeannerod 1975, 1978; Weiskrantz 1980; Weiskrantz *et al.* 1974; Zihl 1980) and making a verbal response such as 'top' or 'bottom' (e.g. Barbur *et al.* 1980; Weiskrantz 1980). In these studies accuracy was invariably poorer for stimuli presented within the scotoma than for stimuli in the intact visual field, and the effect was usually confined to locations between 0° and 45° eccentricity from the fixation point (but see Weiskrantz *et al.* (1974) for reports of a larger range). Yet however limited the effect, it is striking that any correlation between the target location and 'guessed' location is obtained, given that patients do not report an experience comparable to 'seeing' the stimuli in intact visual regions.

Weiskrantz (1980) argued that specific practice or shaping of the response is required for demonstrating blindsight localization. He reported that patients may initially fail the localization task unless they are initially trained on a relatively easy version, such as presentation of only the two extremes of the stimulus range. Using a five-position saccadic localization task, Zihl (1980) found that accuracy of blind-field localization responses increased over a few hundred trials to the point where it was indistinguishable from performance on intact-field presentations. Campion *et al.* (1983) have argued that the need for training, coupled with the fact that discrimination for blind-field stimuli is rarely normal, seriously weakens the argument that blindsight performance is based on a spared visual system that is functionally independent of normal (striate) vision. However, there are data demonstrating detection and use of information in the blind field that is equivalent to intact-field performance under conditions in which practice plays little or no role. Singer *et al.* (1977) found that the detection threshold for a part of the intact visual field which had been elevated by adaptation could be reset by 'adapting' a mirror-symmetric region in the blind field. These findings suggest that the mechanisms for location-specific detection and recruitment of visual attention are preserved in residual vision (cf. Singer *et al.* 1977). Although the neural mechanisms may be fully functional at the outset of localization training, it appears that subjects must learn to monitor and interpret their outputs in order to organize a response.

Aside from localization it has been reported that hemianopic patients can make various other visual discriminations when forced to guess. Weiskrantz (1980; also see Weiskrantz *et al.* 1974) has demonstrated that patients can discriminate between gratings of reasonably high spatial frequencies and an equally luminous homogeneous patch in the blind field and that acuity in some regions can surpass that in more eccentric regions of the normal visual fields. The same studies reveal that some patients can discriminate very simple figures (X vs. O, straight-sided vs. curved triangles) and line orientations (horizontal vs. vertical, vertical vs. diagonal) at accuracy levels well above chance. However, Perenin and Jeannerod (1975) failed to find evidence of pattern discrimination in hemidecorticate subjects using a more demanding task that required discrimination among eight alternatives. It has been suggested that orientation discrimination may be relatively well preserved in blindsight patients, whereas form identification remains impaired (Weiskrantz 1980). Indeed, Weiskrantz (1980) has reported double dissociation of detection and form discrimination for the blind and normal fields of one patient, with form judgements always worse in the blind field relative to the normal field even when detection is better in the scotoma.

Two additional sets of studies have shown that information presented to the blind field can influence patients' responses to stimuli presented in the intact field. The first case involves the completion effect, where simple geometric forms such as circles are presented with half the form in the sighted field and half in the scotoma. Bender and Teuber (1946) and Torjussen (1978) demonstrated that subjects often reported that the complete figure had been presented, whereas they failed to report any form when half-figures were presented to the blind field only and did not show completion when half-figures were presented to the intact field. The observed lack of completion when there is no objective stimulus delivered to the blind field provides crucial support for an interpretation of the completion phenomenon as residual vision rather than as inference or visual confabulation. Evidence of confabulatory completion has been found for hemianopic patients (e.g. Gassel and Williams 1963), but it appears to be confined to patients with damage involving the parietal area (Warrington 1962). A second type of interaction between normal and blind-field stimulation was reported by Richards (1973). He found that patients were able to discriminate between monocular presentation of a light or dark bar and binocular stimulation with two stereoscopically presented bars which were positioned symmetrically about the border of the scotoma. Discrimination performance in this 'straddle' condition was equivalent to discrimination when both bars were presented to intact regions. The completion and stereopsis studies suggest that further research on the modification of responses to visible stimuli by information presented in the 'unseeing' regions may be helpful in determining the limits of residual vision in humans.

What do patients 'perceive' under conditons where stimulation in the blind field produces accurate responding, and how are these perceptions and awarenesses different from those of conscious visual experience? The verbal reports of patients clearly indicate a strong phenomenal distinction between blindsight and normal vision. Investigators typically claim that patients virtually never report noticing that a stimulus has been presented to the blind region and they believe that they are 'just guessing', responding on the basis of a 'gut reaction' (e.g. Poppel *et al.* 1973; Weiskrantz 1980). However, most researchers have noted that some patients, on some trials, do indicate awareness of some kind of stimulation, and it is instructive to examine how they describe these experiences. A few patients studied by Richards (1973) reported sensations of a 'pinprick' or 'gunfire at a distance' when light bars were flashed to the blind field. Weiskrantz' patient D.B. stated that he sometimes had a 'feeling' that a figure was smooth or jagged when asked to discriminate between 'O' and 'X' (Weiskrantz *et al.* 1974), and another patient sensed 'a definite pinpoint of light' but, upon further probing, claimed that it did not 'actually look like a light [but] . . . nothing at all' (Weiskrantz 1980, p. 378). The hemidecorticate subjects studied by Perenin and Jeannerod (1978) reported feeling that a bright light had been turned on in the impaired field and was spreading toward the intact field, although they had no conscious idea about the stimulus location or form. After considerable practice and training, subjects appear to develop a heightened awareness or sensitivity to information presented in the blind region, particularly with moving, or otherwise salient, stimuli. Thus D.B. now is reported to be 'aware' that something has been presented and roughly where it was (Weiskrantz 1980). Similarly, two of Zihl's (1980) patients were sometimes able to 'feel' the correspondence between eye movement and target position, and were able to indicate the relative accuracy of their localization responses after several hundred trials.

These occasional reports of awareness of some event in the blind field have been seized upon by critics of the blindsight phenomenon, who claim that it is simply a matter of cautious responding on the basis of near-threshold vision produced by scattered light (e.g. Campion *et al.* 1983). Although we are in agreement with the view that blindsight 'awarenesses' are profoundly different from the 'awareness' of conscious visual experience (e.g. Weiskrantz 1977, 1980, 1986), it may appear somewhat paradoxical to acknowledge that blindsight patients have some 'awareness' of 'unseen' stimuli. Natsoulas (1982) offers the analogy of a sleepwalker manoeuvring in an unfamiliar environment as a way of revolving this conceptual paradox:

For, in order for the sleepwalker to manoeuvre in this way, he must have some perceptual awarenesses of the environment. But, of course, such a person remains a sleepwalker; he does not know what he is doing, or that he intends to do anything, or that he is having perceptions in his environment while sleepwalking. The acts of consciousness which are his perceptual awarenesses during the episode are not conscious acts of consciousness (p. 88).

Similarly, the perceptions or awarenesses of hemianopic patients in a localization task do not appear to be 'conscious' perceptions. These patients do not experience the environment as 'appearing to' them, and they lack the capacity to comment upon, monitor, and manipulate their blind-field visual world.

It is also difficult to see how explanations such as those proposed by Campion *et al.* (1983) can account for an inability to discriminate form in an area of the scotoma characterized by good visual acuity, or why it would predict that thresholds for detection, orientation discrimination, and localization can themselves be dissociated (Weiskrantz 1980). The force of these criticisms is also weakened by a recent demonstration of an analogue to blindsight in the tactile modality (Paillard *et al.* 1983). A patient with hemianaesthesia of the right side due to damage to parietal sensory cortex was often able to point to locations on the 'unfeeling' limb touched by the experimenter, although the authors noted that her tactile deficit was so severe that she could cut or burn herself without noticing. However, it should also be noted that not all patients who are tested demonstrate residual vision in blindsight paradigms (e.g. Weiskrantz 1980) and that the degree of awareness of stimuli presented in the blind field varies over patients (cf. Campion *et al.* 1983). Some of these discrepancies are likely attributable to the precise locus and extent of cortical and subcortical damage in different patients. Patients are typically selected solely on the basis of visual field defects, rather than on the basis of lesion site and extent. The generally accepted anatomic basis for residual vision following destruction of striate cortex involves midbrain input to prestriate cortex (e.g. Trevarthen 1970), and destruction of these areas and projections in naturally occurring brain lesions is a likely source of confusion in the existing literature.

The nature and extent of blindsight are still a matter of some dispute, and it is not clear whether the phenomenon demands the interpretation originally given to it (e.g. a form of non-striate vision). However, we think that there is sufficient evidence to indicate that, at the phenomenal level, blindsight represents a genuine dissociation between implicit and explicit perceptual knowledge.

Prosopagnosia

Prosopagnosia refers to a deficit in ability to recognize and identity familiar faces; it is typically produced by bilateral lesions to occipito-temporal cortical regions, but a significant number of cases have been reported with unilateral right-hemisphere lesions (for a review, see Damasio 1985). Although there is some debate about whether prosopagnosic patients' difficulties are restricted entirely to *facial* recognition (e.g. Damasio 1985; Damasio *et al.* 1982), nearly all investigators would agree that the cardinal sign of prosopagnosia is a lack of familiarity with faces that ought to be recognized easily by the patient (e.g. spouse, children, friends). Recently, both psychophysiological and behavioural studies have revealed that prosopagnosic patients possess implicit knowledge of faces that they cannot recognize explicitly.

Consider first the psychophysiological evidence. Bauer (1984) reported a case study in which a prosopagnosic patient was shown pictures of famous faces (e.g. actors, politicians) and family members. While viewing an individual face, the patient was read a series of five names—one was the correct name of the exposed face, and the other four were lures. For the famous faces, lure names were drawn from the same category as the target (i.e. another actor or politician); for the family faces, lure names were other family members. Skin conductance responses (SCRs) to the names were recorded. Bauer found that the prosopagnosic patient failed to name any of the familiar faces spontaneously, and selected the correct name at a chance level (20 per cent correct), whereas control subjects' performance was almost perfect. However, the patient exhibited a maximal SCR on each trial to 60 per cent of the correct names, which was significantly above chance expectation; control subjects exhibited maximal SCRs to 90 per cent of correct names. In a subsequent study, Bauer *et al.* (1986) replicated the results of the famous faces-names task with a different prosopagnosic patient: despite selecting names for famous faces at a chance level, the patient showed maximal SCRs on individual trials to over 60 per cent of the correct names. By contrast, they observed no evidence of preserved electrodermal responding on a task involving *unfamiliar* faces.

Tranel and Damasio (1985) also reported psychophysiological evidence of implicit recognition of faces in prosopagnosia. They exposed two prosopagnosic patients to familiar and unfamiliar faces and recorded SCRs. One patient completely failed to recognize explicitly any of the familiar faces. However, she showed consistently larger SCRs to the familiar faces than to the unfamiliar faces. The second patient was able to recognize explicitly familiar faces of people she knew prior to the illness that led to her prosopagnosia (encephalitis), but could not recognize faces of people she had met since her illness (e.g. hospital staff). Nevertheless, this patient showed larger and more consistent SCRs to familiar than to unfamiliar faces from both time periods.

Behavioural evidence suggestive of implicit knowledge of faces in prosopagnosia was reported initially by Bruyer *et al.* (1983). Bruyer *et al.* devised a task that required a prosopagnosic patient to match names with famous faces;

the names were either arbitrarily assigned to the faces or were correct names. Even though the patient did not explicitly recognize the famous faces and could not name them, he had more difficulty learning to match the faces with arbitrary names than with real names. This interference effect indicates that some information about the faces was available, although the patient was unable 'to gain conscious access to these stored data' (1983, p. 280). It should be noted, however, that Bruyer *et al.*'s patient was not completely prosopagnosic, so interpretive caution must be exercised regarding the implicit/explicit nature of his preserved knowledge. In more extensive and systematic studies, described in detail elsewhere in this volume (see Young 1988), de Haan *et al.* (1987) reported results that are consistent with and extend the observations of Bruyer *et al.* They studied the performance of a young man (P.H.) who became prosopagnosic after a closed head injury on a variety of facial processing tasks involving familiar (i.e. famous) and unfamiliar (i.e. unknown) faces. Although P.H. did not explicitly recognize any of the familiar faces, his performance benefitted from familiarity in a manner similar to that observed in normal subjects. For example, on a matching task that required subjects to make same–different judgements regarding the identity of two simultaneously exposed faces, P.H., like normal controls, responded more quickly when a judgement involved famous faces than when it involved unknown faces. Similarly, like Bruyer *et al.*, de Haan *et al.* found that P.H. was slower to learn name–face pairings when a name was incorrectly paired with a familiar face than when it was correctly paired with the true face. De Haan *et al.* also observed evidence of interference from unrecognized familiar faces in a Stroop-like paradigm. For example, when asked to decide whether a visually presented name is that of a pop star (e.g. Mick Jagger), P.H. showed a pattern of interference effects on this task that was identical to that observed in control subjects.

The only notable difference between P.H. and controls is that he was consistently slower to respond on all facial processing tasks, perhaps because of generalized response slowing. However, the patient's *pattern* of response across experimental conditions was influenced by familiarity in the same manner as was controls' performance, thereby indicating that information about a face's familiarity was accessible to, and exerted an influence on, facial processing. Indeed, P.H. appears to have access to much the same informaton about facial familiarity as normal subjects do. The difference, however, is that P.H.'s knowledge of familiar faces is entirely implicit, and does not give rise to the phenomenal experience of familiarity reported by neurologically intact individuals.

Dyslexia

Studies on reading without awareness form a substantial subset of the literature on perception without awareness. Claims about various aspects of the phenomenon, including its very existence, continue to be as controversial today as they have been for as long as the phenomenon has been studied (for reviews, see Dixon 1971, 1982; Eriksen 1960; Marcel 1983; Cheesman and Merikle 1985; Holender 1986). Some authors, such as Marcel, have turned to the neuropsychological literature for evidence in support both of the phenomenon and of particular models used to explain it.

With regard to reading, the neuropsychological evidence is weak but tantalizing. Though much has been written in the past few years about a variety of acquired dyslexias, most especially deep and surface dyslexia (Coltheart *et al.* 1980; Patterson *et al.* 1985), very few studies speak directly to the issue of reading without awareness. What they do provide is evidence about the existence and organization of component processes involved in normal and pathological reading, as well as some indirect evidence about access of the output of those processes to consciousness. The only studies concerned directly with the issue of reading without awareness deal with the syndrome of alexia without agraphia caused by a lesion to the left occipital and posterior temporal cortex and to the splenium of the corpus callosum. Some of the patients who suffer from this syndrome have lost the ability to recognize whole words visually and must resort, instead, to a letter-by-letter decoding strategy in order to read. Three recent reports, by Landis *et al.* (1980), Shallice and Saffran (1986), and Coslett (1986), claim that these subjects have implicit lexical knowledge of visually presented words in the absence of explicit identification of them.

In each of these studies, words were presented in the intact left visual field at exposure durations that were too short for the subjects to decode the words letter-by-letter. Despite claiming to be unable to identify words, Landis *et al.*'s (1980) subject was able to choose 'intuitively' (p. 49) and correctly from a large array on a table those objects that were denoted by different target words on five out of seven trials. The objects were selected so that for every target object there was another object whose name began with the same letter as that of the target. Only when the subject consciously tried to decode the word letter-by-letter and based his choice on the first (and only) letter he could decode, did his performance deteriorate. Landis *et al.* concluded that explicit 'visual–verbal reading' (p. 52) interferes with 'iconic reading' in which the unconscious associations between a word and its corresponding image are activated. Iconic reading allows for automatic access to semantic information which then influences the subject's 'intuitive' choices in a word–object matching task.

Shallice and Saffran (1986) investigated more thoroughly the preserved whole-word reading abilities of their patient. On a binary semantic classification task for words he could not read explicitly, their subject performed correctly on some categories and poorly on others. He also performed well above chance on a lexical decision task. In both the semantic tasks performance was not dependent on his ability to identify the first couple of letters of the word nor on his knowledge of sequential dependencies among letters in the word. Though he was insensitive to the appropriateness of word affixes, his performance supported the conclusion that he based his lexical and semantic decisions on 'morphemic properties of the string and not on orthographic familiarity alone' (1986, p. 444). It should be noted, finally, that his performance with visual presentation, though impressive in light of his inability to identify the words explicitly, was none the less inferior to his performance with auditory presentation. Coslett (1986), in a brief abstract, described findings similar to those of Shallice and Saffran. He reported that three patients with alexia without agraphia performed at above-chance levels on a lexical decision test under conditions in which explicit word identification was precluded. He also reported that all patients were capable of semantic categorization of non-identified words. In contrast to the results reported by Coslett and by Shallice and Saffran, however, other patients with similar syndromes could neither distinguish words from non-words, semantically classify the words (Patterson and Kay 1982), nor match the words to a picture (Warrington and Shallice 1980) if they could not first identify the word explicitly. Why such a discrepancy in performance should exist among the various patients remains to be determined.

There is also a report of an effect that could be considered the converse of letter-by-letter reading, namely implicit letter recognition in the absence of explicit letter identification or naming. Friedman (1981) showed that subjects who could not name letters, nor match lower with upper case letters, were none the less able to distinguish orthographically acceptable non-words from unpronounceable letter strings. Because the two types of non-words were equivalent in their similarity to real words, decisions about orthographic acceptability must have been based implicitly on letter identification.

The evidence from these two classes of patients suggests that failure to gain access to consciousness can probably occur at either high or low levels in the hierarchy of processes involved in word recognition. It also suggests that some caution must be exercised in ascribing the patients' deficit to an impairment of a particular subsystem in reading rather than to the output of that subsystem, or to some other system whose representational content can be manipulated voluntarily and apprehended consciously. The implications of this statement to studies of deep and surface dyslexia should be clear. Until implicit knowledge of phonology or word form is assessed, one cannot conclude safely that the phonological and lexical routes to reading are impaired in deep and surface dyslexia, respectively.

Aphasia

The two classical aphasic syndromes, Broca's aphasia and Wernicke's aphasia, have as one of their main symptoms an impairment in processing syntactic and semantic information, respectively. Agrammatism in Broca's aphasia, initially thought to occur primarily in speech production, has in the last 15 years been shown to be a feature of speech comprehension as well. Patients who are agrammatic in speech also have difficulty appreciating the syntactic structure of sentences. Similarly, the semantic deficit of Wernicke's aphasics is reflected both in language reception and in language production. Their speech, though fluent and often grammatically correct, is characterized by a paucity of appropriate content words, by frequent circumlocutions and semantic paraphasias, and by occasional neologisms. Until recently the agrammatism in Broca's aphasia was thought to result from damage to a syntactic parser that decodes incoming sentences and confers grammatical structure on speech output. The semantic deficit in Wernicke's aphasia was believed to arise from an impairment or loss of semantic representation of words. Recently, both interpretations have been challenged by new evidence showing that syntactic and semantic abilities of both Broca's and Wernicke's aphasics, respectively, seem to be far better preserved than had previously been suspected. As we will show below, a brief review of this evidence suggests that, in part, the deficits of both types of aphasic patients may be described as a failure in access of syntactic and semantic information to consciousness.

Consider first the evidence concerning Broca's aphasia. In an interesting and neglected study, Andrewsky and Seron (1975) asked an agrammatic, French aphasic to read or complete sentences with words that could either be functors or content words (this patient is also a deep dyslexic; J. Marshall, personal communication). For example, the French word 'car' could mean either 'bus' or 'because' depending on how its role or position is specified in a sentence. In a variety of tests, they showed that the patient would either misread or omit the word when it was a functor, but read or supply it correctly when it was a substantive. They concluded that Broca's aphasics act like grammatical filters that pass semantic, but delete syntactic, information. Whatever the correct interpretation of this phenomenon, the aphasic subject's performance presupposes some implicit grammatical knowledge. How else would he know when to supply or omit the target word?

Andrewsky and Seron's (1975) demonstration resembles other similar observations suggesting that agrammatic aphasics retain implicit knowledge of grammars, despite the fact that their behaviour on explicit tests of comprehension and production indicated that they were generally insensitive to syntactic structure (Goodglass *et al.* 1970). It was Frederici's (1982) and especially Linebarger *et al.*'s (1983) observations, however, that focused attention on just how well preserved the agrammatic aphasics' syntactic abilities seem to be.

Instead of only testing the agrammatic patients' language comprehension and production, Linebarger *et al.* and Frederici had them make judgements of syntactic well-formedness of sentences. In general, Linebarger *et al.*'s and

Frederici's subjects scored between 80–100 per cent correct on most of the types of rule violation, suggesting that some syntactic abilities were preserved. This performance contrasted with the patients' generally poor ability to use this information in the comprehension and production of sentences. Unlike Andrewsky and Seron's (1975) findings, Frederici's and Linebarger *et al.*'s do not fit the mould that implicit grammatical knowledge is preserved. Judgements of grammatical acceptability seem to be no less explicit than apprehension of sentence meaning based on syntax, and thus do not represent a failure to gain access to consciousness as such. Rather, these observations indicate an inability to use preserved information in the service of higher order functions, such as language comprehension and production, which may occur because the output of a syntactic parser is disconnected from some processes but not others.

Several studies of patients with Wernicke's aphasia conform more closely to the notion that only implicit linguistic knowledge is preserved. In a series of experiments using lexical decision tasks, Milberg and Blumstein (1981; see also Blumstein *et al.* 1982; Milberg *et al.* in press) showed that Wernicke's aphasics appear to have sensitivity to semantic aspects of words despite being impaired in their ability to use that information on explicit tests of comprehension and on explicit judgements of semantic relatedness. Thus, when required to make yes/no judgements regarding the semantic relatedness of word pairs, a task that requires explicit knowledge of semantic information, Wernicke's patients performed at chance levels. A quite different pattern of results was observed on the lexical decision task, which requires the subject to decide whether a letter string forms a word in the lexicon. Response latencies to words are faster when the target item (e.g. *money*) is preceded by a related word (e.g. *bank*) than when it is preceded by an unrelated word (e.g. *tree*) or a non-word string (e.g. *bukler*). Like normal people, patients with Wernicke's aphasia had shorter response latencies in the related than in the unrelated word condition, both when the items were presented visually (Milberg and Blumstein 1981) and when they were presented acoustically (Blumstein *et al.* 1982). The consistency with which they showed a 'related' advantage was as high as in normal people, and did not correlate at all with the aphasics' performance on explicit tests of auditory comprehension, reading, and judgements of semantic relatedness, all of which correlated significantly with each other.

In a subsequent experiment, Milberg *et al.* (in press) showed that the Wernicke's aphasics' representations are not restricted to highly associated or related items without reference to their meanings, but rather include the semantic knowledge necessary for disambiguating words. In a modification of a lexical decision task first used by Schvaneveldt *et al.* (1976), Milberg *et al.* asked subjects to indicate whether the third item of an auditorily presented triplet was a word or not. In the critical condition, the second word of each triplet was a semantically ambiguous word, such as 'bank'. In Wernicke's aphasics, as in normal people, lexical decisions to the target word 'money' were shorter when the interpretation of the middle word was concordant with the target (coin–bank–money) than when it was not (river–bank–money).

Wernicke's aphasics, as Broca's aphasics, seem to have far greater linguistic knowledge than they can put to use in comprehension and production. However, we cannot be certain that the implicit/explicit dichotomy provides an adequate account of the preserved and impaired abilities of these patients; the observed dissociations may be explicable with reference to different types of linguistic processes. We include these phenomena to highlight the possibility that the implicit/explicit distinction is relevant to them, and thereby encourage future research that explores the issue directly. We believe that, in the final analysis, the role of conscious processes in aphasic disorders will have to be taken into account by linguistic models.

Hemineglect

This syndrome is characterized by an impaired ability to attend to the egocentric side of space contralateral to the damaged hemisphere. The syndrome takes its severest form following right parietal lobe lesions, but can also occur following left-sided lesions and also unilateral lesions to other areas of the brain (Mesulam 1981; Gainotti *et al.* 1986). The question relevant to the concerns of this chapter is whether there is evidence that the subject is influenced by information in the neglected field, information which, by definition, does not reach conscious awareness. The evidence, though rather sparse and sometimes anecdotal, generally favours the view that in hemineglect, as in other syndromes, the patient has available much more information than he exhibits on explicit tests.

Informal observation during recovery from the severe, acute phase of the syndrome indicates that patients can sometimes report stimuli from the neglected side of space but mistakenly locate them in the intact field. Even when unilateral neglect is complete, there is a strong suggestion that the spatial extent of the neglected region may influence the size or extent of the region over which attention is allocated, at least in some subjects. Thus, given a piece of paper on which to draw, a patient will confine his drawing to the right of an imaginary line, which will shift, sometimes dramatically, as the width of the piece of paper changes. Similar observations are made with regard to a patient's copy of drawings. It is the size and symmetry of the target object that determines, in part, what is neglected and what is attended.

These anecdotal observations are supported by a more formal study of line bisection in patients with unilateral neglect of the left side of space. By looking at where the subjective midpoint was, Bisiach *et al.* (1983) calculated that for some patients the inferred extent of a line grew as the length of the line increased, whereas for other patients it remained constant. One interpretation of the performance of the first class of patients is that information from the neglected part of the line biases the subject's estimate of the line's length. By contrast, the performance of patients who perceive a line of constant length is influenced by information only from the attended field.

Other evidence for the influence of unattended information on the neglected side comes from a study by Volpe *et al.* (1979) concerning the phenomenon of extinction to double simultaneous stimulation. This occurs when presentation of a single stimulus anywhere in the visual field results in an accurate description of it, but simultaneous presentation of two stimuli to the left and right visual fields results in accurate description of only the right visual field stimulus. Volpe *et al.* observed the extinction phenomenon in four patients with right parietal lobe tumours who were shown either pictures of common objects or familiar words simultaneously in the two visual fields. In addition, they required patients to make same/different judgements regarding the two stimuli. All four patients performed the same/different task at high levels of accuracy, ranging from 88 to 100 per cent correct judgements. Two patients 'felt that something had appeared' in the left field, but 'were unable to characterize it' (1979, p. 723); the other two patients 'were completely unaware that anything had been presented' (p. 724) to the left field. Yet, as indicated by their accurate same/different judgements, these patients had implicit knowledge of stimuli that they could not explicitly identify. Similar conclusions are suggested by studies of reading. Both Kinsbourne and Warrington (1962) and Bisiach *et al.* (1983) report that reading ability of patients with right parietal lesions varies according to the type of orthographic information that is available on the left. Thus, if required to read a word, the patient will tend to neglect the letters on the left, but the number of letters neglected changes according to whether they are pronounceable or not; or, if pronounceable, on the function they serve in determining the pronunciation or meaning of the non-neglected portion of the word.

It should be noted that the phenomena of hemineglect can be viewed in two ways. One view, that makes hemineglect analogous to the other phenomena we have considered, is that the deficit is one in which spatially coded information from one side fails to gain access to consciousness automatically, much as various other types of information can fail to do so. This places spatially coded information on the same level as visual, facial, or linguistic information. A second possibility, however, is that the deficit does not entail a failure of a specific type of information to gain access to consciousness, but rather involves difficulties in engaging attentional mechanisms that are necessary for bringing various types of information from one side to conscious awareness. In effect, the second view places the deficit closer to the level of consciousness itself, rather than at the level of an input path to consciousness from a particular informational system. Thus it should be kept in mind that observations of implicit knowledge in hemineglect patients may demand a different interpretation than similar observations in other syndromes.

Other observations

Although the foregoing descriptions present the bulk of the evidence concerning implicit/explicit dissociations in neuropsychological syndromes, scattered observations suggestive of similar phenomena can be found in other types of patients. Recent research conerning inter hemispheric transfer in split-brain patients suggests that some high-level information may be exchanged between the hemispheres though neither side is explicitly aware of the information that has been transferred. For example, when information is presented directly to the left hemisphere the patient can name it, and when it is projected directly to the right hemisphere the patient can point to it. Performance on these explicit tests is at chance if each hemisphere is asked to report on information received by its neighbour. Nevertheless, through implicit measures such as priming, each hemisphere can reveal that it possesses information received from the other (e.g. Holtzman *et al.* 1981; Sergent in press; Zaidel 1982).

Another kind of implicit/explicit dissociation has been reported briefly by Margolin *et al.* (1983). They found that a patient with severe visual object agnosia could derive some meaning from stimuli that were not explicitly recognized. Although he recognized and named only three of 24 pictures of common objects, he was able to make accurate judgements concerning the size of the real-life object and state whether it was living or inanimate in 22 instances. Margolin *et al.* argued that their study '. . . emphasizes the importance of differentiating between the awareness of knowledge and knowledge which is preconscious' (1983, p. 242). Warrington (1975) reported a somewhat different type of evidence suggestive of preserved implicit knowledge in visual agnosia. She observed that two agnosic patients showed better short-term memory for real words than nonsense words—yet the patients did not explicitly recognize the real words and could not state their meaning.

Clinical observations concerning the phenomenon of anosognosia—unawareness and/or denial of deficits following hemiplegia, hemianopia, and other neuropsychological disorders—suggest that anosognosic patients may possess implicit knowledge of deficits that they deny explicitly. Weinstein *et al.* (1964), for example, argued that:

> . . . the term 'anosognosia', meaning 'lack of knowledge', is not wholly accurate. The patient indicates knowledge of the neglected extremities by referring to them in such expressions as a 'dummy' and a 'rusty piece of machinery'. Patients who deny that they are ill subscribe to hospital routine and express no surprise when they are told, for

example, that they are to have a craniotomy. The very fact of the selectiveness indicates some knowledge of the deficit . . . (p. 384).

Weinstein and Friedland (1977) made similar observations, describing a patient with left hemiplegia who denied that his left arm was paralysed, yet referred to it as '. . . a canary claw, yellow and shrivelled' (p. 60).

Characteristics of implicit/explicit dissociations

The studies reviewed in the previous section indicate clearly that patients who are characterized by a variety of neuropsychological deficits show implicit knowledge under conditions in which explicit knowledge is poor or entirely absent. The quality and quantity of evidence for implicit/explicit dissociations varies widely, from isolated and rather loosely controlled clinical and experimental observations to rigorous studies that have been replicated under a variety of conditions. Thus, while we cannot be certain that each and every one of the cited observations represent genuine, replicable dissociations between implicit and explicit expressions of knowledge, we think that there is sufficient evidence to support the general proposition that implicit/explicit dissociations can be observed across a variety of patients, tasks, and stimuli. The critical question, of course, concerns the proper interpretation of these phenomena: How can we best characterize the observed implicit/explicit dissociations? To what extent and in what sense are they related to one another? And what can these dissociations teach us about normal cognition and consciousness? To set the stage for addressing these questions we will delineate some of the critical characteristics of the evidence that has been discussed thus far.

Since the phenomena of interest have been observed in widely disparate patients and paradigms, it is important to try to point out some of the similarities and differences among them. We can begin by noting that four broadly different types of evidence for implicit knowledge have been cited. The first comes from situations in which similar or identical types of information are being tapped on implicit and explicit tests, but the responses required from the patient differ. For example, in blindsight studies patients deny explicitly perceiving a particular stimulus attribute (e.g. location) and then show implicit access to that attribute on various types of forced-choice tests. Similarly, Milberg and Blumstein's studies of Wernicke's aphasia (Blumstein *et al.* 1982; Milberg and Blumstein 1981; Milberg *et al.*, in press) indicate that information concerning semantic relatedness can be revealed implicitly by associative priming effects, though the same or similar information cannot be used on explicit tests of semantic relatedness.

A second, similar type of evidence for implicit knowledge derives from studies in which patients' task performance is affected by experimental variables whose influence presupposes access to information that the patient cannot express explicitly. De Haan *et al.*'s (1987) demonstration that a prosopagnosic's performance is affected by variations in facial familiarity, Bisiach *et al.*'s (1983) finding that extending the length of a line in a patient's neglected field influences line bisection performance, and Warrington's (1975) finding that word meaning influences agnosic patients' short-term memory performance are examples of this kind of evidence.

The third type of evidence for implicit knowledge, which is not always easy to distinguish unequivocally from the first two, comes from studies in which an implicit test can be performed on the basis of different information than is needed for successful performance on an explicit test. Many studies of amnesic patients are of this type. For example, implicit memory can be revealed on a skill learning task that taps a quite different kind of information than is required for explicit remembering of a recent experience. Similarly, patients can show priming of familiar words on a stem completion test, even though they fail to remember these words on cued recall tests that require explicit access to contextual information regarding the occurrence of a word in a particular time and place. Other results, however, are more difficult to classify. For example, the finding that some amnesic patients show implicit memory for newly acquired associations on stem completion (Graf and Schacter 1985; Schacter and Graf 1986*b*), serial learning (Nissen and Bullemer 1987), and reading tests (Moscovitch *et al.* 1986) could be interpreted as indicating that these patients have implicit access to contextual information, but cannot gain explicit access to it. Alternatively, it is possible that different types of contextual information are required for implicit and explicit memory of new associations (e.g. Schacter and Graf 1986*a*). The fourth type of evidence is provided by studies in which implicit knowledge has been revealed by *physiological* measures, such as in the SCR studies of prosopagnosia by Bauer (1984) and Tranel and Damasio (1985).

The foregoing classificatory scheme may not enable us to place each relevant study unambiguously into one and only one of the four categories, but it does provide at least a rough taxonomy of the kinds of evidence that we have considered. However, some further issues must be considered in order to provide a basis for discussing alternative accounts of the observed dissociations. The first issue concerns whether or not patients' performance on the task or measure used to assess implicit knowledge was normal with respect to that of control subjects. Several studies have provided evidence for normal access to implicit knowledge. Perhaps the strongest evidence comes from studies of amnesic patients which have demonstrated normal priming effects on various implicit memory tests (e.g. Graf *et al.* 1984, 1985; Graf and Schacter 1985; Moscovitch *et al.* 1986; Schacter 1985; Shimamura and Squire 1984; Warrington and Weiskrantz 1970, 1974) and which have also shown normal perceptual and motor skill learning (e.g. Brooks and Baddeley 1976; Cohen and Squire 1980; Eslinger and Damasio 1985). Normal performance on an implicit measure has also been observed in some studies of blindsight (e.g. Singer *et al.* 1977; Richards 1973). In several studies which used reaction time as a dependent measure, ascertaining whether patients perform normally on an implicit task is not entirely straightforward. Studies of serial pattern learning in amnesia (Nissen and Bullemer 1987), semantic priming in aphasia (Blumstein *et al.* 1982; Milberg and Blumstein 1981), and facial processing in prosopagnosia (de Haan *et al.* 1987) have all demonstrated that patients and controls show identical *patterns* of performance on implicit tests, but also indicate that patients' overall response latencies are significantly slower than those of controls. If one attributes these elevated latencies to generalized response slowing that is unrelated to the specific functions tapped by an implicit test, which we believe is a reasonable inference in the cited studies, then these data, too, can be considered as evidence for normal access to implicit knowledge.

However one classifies the reaction time experiments, the majority of studies that we have reviewed do not provide evidence of normal performance on an implicit measure; rather, they simply indicate that patients have *some* access to implicit knowledge. In several studies, data from normal controls were not presented, so it is not possible to evaluate whether patients' implicit knowledge is normal (Bisiach *et al.* 1983; Bruyer *et al.* 1983). In other studies, however, the data reveal that patients' performance on an implicit measure, though above baseline, is impaired with respect to controls' performance. Conforming to this description are prosopagnosic patients' SCR responses (Bauer 1984; Tranel and Damasio 1985); many of the 'guesses' made by blindsight patients (e.g. Pöppel *et al.* 1979; Weiskrantz *et al.* 1974); alexic patients' lexical decisions and semantic categorizations (Coslett 1986; Friedman 1981; Landis *et al.* 1980; Shallice and Saffran 1986); neglect patients' same/different judgements (Volpe *et al.* 1979); and some implicit memory phenomena in amnesics, including acquisition of factual knowledge (Glisky *et al.* 1986*a*, 1986*b*; Schacter *et al.* 1984), classical conditioning (Weiskrantz and Warrington 1979), and some reports of skill learning (Brooks and Baddeley 1976; Milner *et al.* 1968). The theoretical implications of normal vs. impaired access to implicit knowledge will be discussed shortly.

The second point concerns the nature of the evidence and criteria that were used to support statements such as 'the patient was not consciously aware of X' or that a certain type of information 'failed to gain access to consciousness'. In the majority of cases, lack of explicit or conscious knowledge was inferred from patients' subjective verbal reports. Thus, in blindsight and hemineglect, patients' claims that they do not see anything in a specific portion of the visual field are taken as evidence that they lack conscious perceptual knowledge; in prosopagnosia, lack of explicit knowledge of facial familiarity is inferred from patients' reports that they do not recognize a face as familiar; in alexia without agraphia, patients' reports that they cannot read a word are the basis for arguing that they lack explicit knowledge of its identity; and, in many studies of amnesia, lack of explicit memory is based on patients' yes/no judgements that they do not remember the prior occurrence of a test stimulus. However, reliance on yes/no judgements is not the only way in which lack of explicit knowledge has been inferred. In studies of Broca's aphasia, for example, patients' chance performance on forced-choice matching tests is one basis for concluding that they do not possess explicit knowledge of syntax (e.g. Schwartz *et al.* 1980), and, in some studies of amnesia (e.g. Squire *et al.* 1985; Warrington and Weiskrantz 1974), patients perform at chance or near-chance levels on explicit tests of memory. As we shall see in the next section of the chapter, the fact that lack of explicit knowledge has been revealed on both yes/no and forced-choice tests has significant implications for theoretical accounts of implicit/explicit dissociations.

The third important point to note about dissociations between implicit and explicit knowledge is that they are *domain-specific*. By 'domain-specific' we mean that patients generally do not have serious problems gaining explicit access to information in cognitive domains outside of their deficit. For example, amnesic patients have no difficulty on explicit tests of perception, language, comprehension, or reading. Similarly, Wernicke's aphasics would have little or no difficulty on the explicit perceptual tests that blindsight and prosopagnosic patients cannot perform, whereas these two types of patients would experience little difficulty on the explicit tests of semantic comprehension that the Wernicke's aphasic cannot perform (assuming, of course, that the test was adminstered in the appropriate modality).

In asserting that implicit/explicit dissociations are domain-specific, we do not wish to imply that each of the patient groups we have discussed is entirely free of cognitive deficits in all domains outside of their primary impairment. What we do want to stress, however, is that implicit/explicit dissociations do not represent *global* disorders of consciousness or awareness.

Theoretical accounts of implicit/explicit dissociations

We now consider alternative theoretical views of the phenomena we have reviewed. Since few investigators have considered these phenomena as a group, there is a corresponding lack of theories directed at all or even most of the relevant observations. Accordingly, we will consider ideas that have been discussed with respect to a subset of the relevant phenomena and that we think merit consideration. Our discussion concerns three possible accounts of implicit/explicit dissociations which we will argue are inadequate. In the next section, we outline a general approach that we think will prove to be more fruitful.

Conservative response bias?

As is well known, signal detection analyses of perception and memory separate performance into two components: d', which reflects an observer's sensitivity to a particular signal, and β, which reflects the response criterion used to make a judgement concerning the presence or absence of that signal. Given the identical signal, an observer with a cautious response criterion would make a negative judgement regarding its presence while an observer with a lenient criterion would make a positive judgement. It is conceivable that implicit/explicit dissociations arise because patients have an extremely cautious response criterion: they are unwilling to acknowledge the presence of a signal that they can, in fact, detect. As noted earlier, such an argument has been made by Campion *et al.* (1983) regarding phenomena of blindsight. They contended that blindsight patients have access to degraded perceptual information and, as sometimes occurs when only a degraded signal is available, are quite cautious about acknowledging its presence. This kind of argument has not yet been advanced to account for other cases of apparent implicit/explicit dissociations, but it merits some consideration.

Although it may be applicable to certain cases, the response bias argument advanced by Campion *et al.* can be rejected as a general account of implicit/explicit dissociations on both empirical and logical grounds. First, as discussed in the previous section, there are reports in which lack of access to explicit knowledge is indexed by performance on forced-choice tests, and a response bias argument cannot account for these results. Second, the notion that the cautious criterion is attributable to patients' dependence on 'degraded' information is only tenable when patients' performance on an implicit test is impaired with respect to that of control subjects. Yet we have pointed out that a number of different instances of *normal* performance on implicit test have been documented. Where is the 'degraded' information in these cases?

In addition to these empirical considerations, there are logical and conceptual difficulties with this view. Even when failure on an explicit test is documented by yes/no procedures and success on an implicit test is revealed by forced-choice procedures, it is not clear what it means to invoke a response criterion argument: Does one wish to imply that the patient 'really does' have explicit access to the information that he denies perceiving, understanding, or remembering? This question has been raised by several commentators in discussions of blindsight (Natsoulas 1982; Underwood 1983; Weiskrantz 1983) and of perception without awareness in normal subjects (Bisiach 1986; Fowler 1986; Paap 1986; Wolford 1986). We, like they, think that a positive answer to the question misses the very essence of the phenomena under consideration. And even if the question makes some sense when directed at phenomena such as perception without awareness, where extremely brief stimulus exposures are given and subjects may sometimes be 'unsure' of whether or not they saw anything, it is less applicable to many of the dissociations that we have discussed, where information is made available to the subject without any artificial restrictions. For example, to assert that the Wernicke's aphasic 'really understands' the semantic relations between a presented pair of words or that the prosopagnosic is 'really familiar' with a face that he has unlimited time to inspect is not a terribly satisfying account of these phenomena. The difference between the concept of implicit knowledge and cautious response criterion is illustrated nicely by Weiskrantz' (1986) description of the 'blindsight' experiences of patient D.B. within his scotoma, and the 'degraded vision' experiences of D.B. in amblyopic regions of the visual field:

> . . . the qualitative difference between the seeing field and the scotoma was reported as being very clear by D.B. Thus, in the spared amblyopic crescent in the left half-field while vision was fuzzy he nevertheless reported it as *vision*. Measured visual acuity was, in fact, poorer in that region of the field than it was in the scotoma . . . but despite this the subjective experience in the crescent was reported to be definitely and unambiguously of 'seeing', in contrast to the scotoma, where he said he was not even aware of the bright back-projected display within which the grating was generated (1986, p. 147).

Disturbance of consciousness or language?

We have noted that the primary, though not the sole source of evidence for lack of explicit or conscious knowledge is the patient's report of his subjective experience. This report is usually expressed verbally. It is therefore possible that the various dissociations are best described not as failures to gain access to consciousness but rather as failures to gain access to language production mechanisms. Perhaps the patient is in some sense 'consciously aware' of the information that we have referred to as 'implicit', but is unable to express this awareness verbally. Dissociations of this kind, in which language production mechanisms are isolated from specific processing systems, are familiar in neuropsychology and have been considered at great length by Geschwind (1965) in his well-known discussion of disconnection syndromes.

There are several reasons why we do not think that a disruption or disconnection of language production mechanisms plays an important role in implicit/explicit dissociations. First, implicit knowledge can itself be expressed verbally. For example, an amnesic patient who completes the stem 'tab—' with the recently experienced word 'table', without any explicit memory for having seen the word before, is expressing implicit memory for a recent experience with a verbal response. Similarly, forced-choice judgements of various kinds that reveal implicit knowledge involve verbal stimuli and require linguistic responses. Weiskrantz (1986, p. 169) noted specifically that the 'blindsight guesses' of his patient D.B. could be expressed verbally or non-verbally. Second, lack of explicit knowledge can be shown without requiring a verbal response. For example, some severely amnesic patients who show implicit memory effects perform at chance levels on two-alternative forced-choice recognition tests for recently exposed non-verbal materials (i.e. faces) in which they could show explicit memory by simply pointing to the correct face (e.g. Warrington and Weiskrantz 1982). Third, in those neuropsychological syndromes in which impairment of language production mechanisms is crucial, such as naming disorders, the phenomenology of the disturbance is quite different from what we have described. For example, an anomic patient who cannot explicitly produce the name of a familiar object in a picture will often have explicit access to many kinds of information about it, and state that he 'knows' perfectly well what the object is and does. This phenomenal experience of 'knowing' contrasts sharply with the absence of such experiences when knowledge is expressed implicitly in the studies that we have considered.

While we certainly do not want to suggest that language and consciousness are unrelated, and also recognize that language is the principal vehicle for expressing and communicating conscious, explicit knowledge, we do not think that disrupted access to language mechanisms plays a significant role in implicit/explicit dissociations. It is instructive in this regard to compare the phenomena discussed here with some of those observed in split-brain patients. As noted earlier, when stimuli are confined to the left visual field and thus projected to the right hemisphere, patients may not state verbally what they see. However, if allowed to use their left hand to select the presented stimulus from a number of alternatives, patients can do so with a high degree of accuracy (e.g. Gazzaniga and LeDoux 1978). But we would not want to call this a dissociation between implicit and explicit knowledge. Rather, the dissociation appears to reflect the right hemisphere's limited ability to express its knowledge and experience verbally together with its ability to express itself non-verbally. A variety of observations (e.g. Sperry *et al.* 1979) suggest that the right hemisphere possesses extensive conscious awareness but has difficulty organizing a verbal response and thus cannot express its 'awareness' through language when it is disconnected from the verbal mechanisms in the left hemisphere. This kind of phenomenon demands a different theoretical interpretation than the implicit/explicit dissociations that we have discussed. Indeed, Weiskrantz (1986, p. 169) has pointed out that split-brain patients do not show implicit/explicit dissociations when given the same experimental tasks that produce such dissociations in D.B. and other blindsight patients. However, as discussed earlier, there are reports of implicit knowledge of information transferred between the hemispheres in split-brain patients. This evidence, like other phenomena we have discussed, cannot be accounted for in terms of a verbal/non-verbal distinction.

Different systems for implicit and explicit knowledge

A quite different explanatory approach than the foregoing ones is to attempt to identify implicit and explicit expressions of knowledge with distinct and dissociable neural systems. By this view, each of the dissociations we have discussed would indicate the presence of two different systems within a particular domain; one of them can produce conscious, explicit knowledge and one of them cannot. Thus dissociations in blindsight would be interpreted in terms of two different visual systems, a conscious, explicit system that is impaired and an unconscious, implicit system that is preserved; dissociations in prosopagnosia would lead to the postulating of two different facial recognition systems; dissociations in Wernicke's aphasia would be explained in terms of the two different comprehension systems; dissociations in amnesia would require postulation of two separate memory systems; and so on. This 'multiple systems' approach to explaining implicit/explicit dissociations has been pursued most vigorously in the amnesia literature (cf. Cohen 1984; Moscovitch 1982; Schacter and Tulving 1982; Squire and Cohen 1984).

To illustrate what we believe are the strengths and weaknesses of this approach, let us consider the distinction between procedural and declarative memory systems that has been discussed extensively in amnesia research (Cohen 1984; Squire and Cohen 1984). The distinction was proposed to account for the dissociation between preserved skill learning/priming and impaired explicit remembering in amnesic patients. Normal skill learning in amnesics was attributed to a spared procedural system, in which learning is expressed as on-line modifications of procedures or processing operations that are not accessible to conscious awareness. By contrast, amnesics' inability to remember recent experiences and to learn new facts was attributed to an impaired declarative system, which represents facts and events in a manner that permits them to be consciously remembered. By this view, conscious or explicit remembering is a *property* of the declarative system.

Although this distinction accounts reasonably well for preserved skill learning in amnesic patients, it has difficulty accounting for some properties of priming effects (for a discussion, see Schacter, 1987). More importantly, it is extremely difficult to attribute all of the diverse implicit memory phenomena observed in amnesic patients to the procedural system. For example, amnesic patients can learn various types of factual information, yet do not explicitly remember having learned any facts (e.g. Glisky *et al.* 1986*a*, *b*; Schacter *et al.* 1984). It does not seem reasonable to attribute implicit memory phenomena of this kind to a procedural system, since acquisition of factual knowledge is allegedly the responsibility of declarative memory. Similarly, it would not make much sense to attribute implicit memory for affect in amnesic patients (Johnson *et al.* 1985) to the procedural system. The critical point is that manifestations of implicit memory in amnesic patients are simply too diverse to be attributed to a particular memory system that lacks the capacity for conscious remembering. Although *some* of these phenomena (e.g. perceptual and motor skill learning) may reflect the operation of a dissociable memory system (cf. Sherry and Schacter 1987), amnesic patients can express implicit memory for recent experiences in ways that do not fit with such a view.

Returning to implicit/explicit dissociations outside of amnesia, it is the sheer diversity of situations in which implicit expressions of knowledge can be observed that leads us to believe that postulation of multiple processing or memory systems in each situation—one responsible for implicit knowledge, the other for explicit knowledge—is likely to be of limited value.

Toward a model of implicit/explicit dissociations

Having discussed and found wanting several possible accounts of the reviewed phenomena, we close the chapter by sketching the outline of a general approach to implicit/explicit dissociations that we think is worth exploring further. Our purpose here is not to provide a detailed model of the various dissociations, but rather to suggest the broad outlines of an appropriate model and to target key issues that will have to be addressed by such a model.

There are two critical observations that motivate our approach. The first is the *generality* of implicit/explicit dissociations: They have been observed across different types of stimulus information, response requirements, cognitive functions, and subject populations. The fact that similar dissociations are observed in such diverse circumstances persuades us that it is useful to seek a common explanation for them, rather than attempt to postulate different explanations to account for each of the dissociations individually. This general idea has been suggested previously regarding some of the phenomena we have discussed by Marcel (1983), Schacter (1987), and Weiskrantz (1977, 1980, 1986). The second critical observation concerns the *selectivity* of the dissociations. Patients' inability to gain access to explicit knowledge is domain-specific and does not represent a global disorder of conscious awareness.

In view of these considerations, we hypothesize that (a) conscious or explicit experiences of perceiving, knowing, and remembering all depend in some way on the functioning of a common mechanism, (b) this mechanism normally accepts input from and interacts with a variety of processors or modules that handle specific types of information, and (c) in various cases of neuropsychological impairment, specific modules are disconnected from the conscious mechanism.

The idea that conscious experiences depend in some way on the functioning of a specific mechanism has been proposed by several investigators. This mechanism has been referred to as a commentary system (Weiskrantz 1978, 1986), conscious processing system (Posner 1978), selector input (Shallice

1972), high-level operator (Johnson-Laird 1983), output of a left-brain interpreter (Gazzaniga 1985), and executive system (Hilgard 1977). Each of these and other conceptualizations of a 'conscious mechanism' differ in various ways that will not be discussed here. They are similar, however, in so far as they all subscribe to the general notion that conscious awareness of a particular stimulus requires involvement of a mechanism that is different from the mechanisms that process various attributes of the stimulus, a notion that makes neurobiological as well as psychological sense (Dimond 1976). If, as numerous theorists have argued recently, processing of different kinds of information is handled by specialized modular systems (e.g. Fodor 1983; Gazzinga 1985; Shallice 1981), it is a short and straightforward step to suggest that in some cases of neuropsychological impairment a conscious mechanism is disconnected selectively from a specific module. Such a disconnection need not involve damage to the conscious mechanism itself, and thus would not result in a global disruption of conscious awareness; it would produce the kind of domain-specific impairments that were observed in the studies reviewed earlier. Note also that the idea of 'disconnection' as used here need not imply a disconnection of fibre tracts that link various brain structures, as in the classical discussions by Geschwind (1965). Rather, our use of disconnection refers more generally to a failure of a processor or module to gain access to a conscious mechanism, and does not make any assumptions about the nature of the neurological disruption that produces the access failure.

The foregoing is no more than a summary sketch of an approach to implicit/explicit dissociations (for a more detailed exposition, see Schacter, in press). However, even these rather general ideas raise some difficult problems. For example, assuming a basic separation between modular processing systems and conscious experience, one could still hypothesize that *multiple* conscious mechanisms exist or, similarly, that each modular system is associated with its own conscious mechanism. The notion of a disconnection between modular processing and conscious mechanisms could be invoked as easily in this scenario as in a scenario involving just a single conscious mechanism. But how could we distinguish between these two scenarios? At the present time we see no unequivocal way of doing so, and think that the matter ought to be left open for the time being. However, there is one consideration that favours the idea of a single conscious mechanism. In a system composed of multiple modules that operate in parallel and largely independently of one another, a critical function of a conscious mechanism is to *integrate* the various modular outputs (e.g. Baars 1983; Johnson-Laird 1983). If each module were associated with its own conscious mechanism, the integrative function of consciousness could not be served; one would have to postulate a yet higher level conscious mechanism that integrates the output of the module-specific conscious mechanisms. Though such a possibility should not be dismissed out of hand, it may be more parsimonious to assume a single conscious mechanism until the data dictate otherwise.

A second problem that will have to be confronted by models of the kind we advocate is related to the notion that implicit/explicit dissociations in neuropsychological syndromes are attributable to a *disconnection* between a specific module and the conscious mechanism. Another possibility is that the dissociations are attributable to damage at the modular level. It is conceivable that damaged modules send degraded outputs to a conscious mechanism, outputs which are sufficient for implicit but not explicit expressions of knowledge. Alternatively, it is possible that a module needed for performance on an explicit task is damaged, and that a different module supports performance on an implicit task, a module that does not normally have access to the conscious mechanism. Though these possibilities cannot always be readily distinguished from the disconnection idea, we can suggest some guidelines for differentiating between them. To support the notion that a particular implicit/explicit dissociation reflects disconnection of a conscious mechanism from the output of modular processing, two kinds of evidence would appear to be critical. First, patients should show normal or near-normal performance on an implicit task. If patients perform normally on an implicit task, it is difficult to argue that implicit knowledge is based on the degraded output of a damaged module. Second, patients should perform normally on implicit tasks that tap the same kind of information that is tapped by an explicit task. If it can be shown that patients have access to the same kind of information that control subjects do, and lack only conscious awareness of it, it is difficult to argue that different modules are needed to perform the two types of tasks. Although various pieces of evidence discussed here conform to one of these two criteria, and some data come reasonably close to fulfilling them both, the results required by our hypothesis remain to be demonstrated unambiguously. Documentation of such results thus represents an important challenge for future research.

Whatever the strength of evidence for the present view, it seems quite unlikely that all instances of implicit/explicit dissociations will be attributable to 'pure' disconnection between a specific module and a conscious mechanism. Undoubtedly, many cases will involve both disconnection and damage at the modular level. Moreover, it is likely that the interaction between individual modules and an hypothesized conscious mechanism is not all or none (i.e. absolute disconnection vs. normal communication); different degrees of disruption of this interaction are surely possible. Consideration and investigation of the hypothesis proposed here, however, should provide further insight into the basis of implicit/explicit dissociations and thereby contribute to our understanding of the nature of conscious awareness.

Acknowledgements

The work described in this chapter was supported by a Special Research Program Grant from the Connaught Fund, University of Toronto, and by the

Natural Sciences and Engineering Research Council of Canada, Grant U0361 to D. L. Schacter. We thank Edoardo Bisiach, Alfonso Caramazza, Peter Graf, John Marshall, Dan Tranel, and Andy Young for useful comments and criticisms, and thank Carol A. Macdonald for help with preparation of the manuscript.

References

Andrewsky, E. L. and Seron, X. (1975). Implicit processing of grammatical rules in a classical case of agrammatism. *Cortex*, **11**, 379–90.

Baars, B. J. (1983). Conscious contents provide the nervous system with coherent, global information. In *Consciousness and self-regulation. Vol. 3*, (ed. R. J. Davidson, G. E. Schwartz, and D. Shapiro), pp. 41–79. Plenum, New York.

Barbur, J. L., Ruddock, K., and Waterfield, V. A. (1980). Human visual responses in the absence of the geniculo-calcarine projections. *Brain*, **103**, 905–28.

Bauer, R. M. (1984). Autonomic recognition of names and faces in prosopagnosia: a neuropsychological application of the guilty knowledge test. *Neuropsychologia*, **22**, 457–69.

——, Verfaellie, M., and Valenstein, E. (1986). Autonomic recognition of faces in prosopagnosia depends upon premorbidly stored representations. Paper presented to the meeting (February) of the International Neuropsychological Society, Denver, Col.

Bender, M. B. and Teuber, H.-L. (1946). Phenomena of fluctuation, extinction and completion in visual perception. *Archives of Neurology and Psychiatry*, **15**, 627–59.

Bisiach, E. (1986). Through the looking-glass and what cognitive psychology found there. *The Behavioral and Brain Sciences*, **9**, 24–6.

——, Bulgarelli, C., Sterzi, R., and Vallar, G. (1983). Line bisection and cognitive plasticity of unilateral neglect of space. *Brain and Cognition*, **2**, 32–8.

Blumstein, S. E., Milberg, W., and Shrier, R. (1982). Semantic processing in aphasia: evidence from an auditory lexical decision task. *Brain and Language*, **17**, 301–15.

Brooks, D. N. and Baddeley, A. D. (1976). What can amnesic patients learn? *Neuropsychologia*, **14**, 111–22.

Bruyer, R. *et al.* (1983). A case of prosopagnosia with some preserved covert remembrance of familiar faces. *Brain and Cognition*, **2**, 257–84.

Campion, J., Latto, R., and Smith, Y. M. (1983). Is blindsight an effect of scattered light, spared cortex, and near-threshold vision? *The Behavioral and Brain Sciences*, **6**, 423–86.

Cermak, L. S., Talbot, N., Chandler, K., and Wolbarst, L. R. (1985). The perceptual priming phenomenon in amnesia. *Neuropsychologia*, **23**, 615–22.

Cheesman, J. and Merikle, P. M. (1985). Word recognition and consciousness. In *Reading research: advances in theory and practice. Vol. 5*, (ed. D. Besner, T. G. Waller, and G. E. Mackinnon), pp. 311–52. Academic Press, New York.

Claparède, E. (1951). Recognition and 'me-ness'. In *Organization and pathology of thought*, (ed. D. Rapaport), pp. 58–75. Columbia University Press.

Cofer, C. C. (1967). Conditions for the use of verbal associations. *Psychological Bulletin*, **68,** 1–12.

Cohen, N. J. (1984). Preserved learning capacity in amnesia: evidence for multiple memory systems. In *Neuropsychology of memory*, (ed. L. R. Squire and N. Butters), pp. 83–103. Guilford Press, New York.

—— and Squire, L. R. (1980). Preserved learning and retention of pattern-analyzing skill in amnesia: dissociation of 'knowing how' and 'knowing that'. *Science*, **210,** 207–9.

Coltheart, M., Patterson, K. E., and Marshall, J. C. (ed.) (1980). *Deep dyslexia*. Routledge and Kegan Paul, Andover, Hants.

Corkin, S. (1965). Tactually-guided maze learning in man: effects of unilateral cortical excisions and bilateral hippocampal lesions. *Neuropsychologia*, **3,** 339–51.

—— (1968). Acquisition of motor skill after bilateral medial temporal-lobe excision. *Neuropsychologia*, **6,** 255–65.

Coslett, H. B. (1986). Preservation of lexical access in alexia without agraphia. Paper presented at the 9th European Conference (June) of the International Neuropsychological Society, Veldhoven, The Netherlands.

Damasio, A. R. (1985). Disorders of complex visual processing: agnosias, achromatopsia, Balint's syndrome, and related difficulties of orientation and construction. In *Principles of behavioral neurology*, (ed. M. M. Mesulam), pp. 259–88. F. A. Davis, Philadelphia, PA.

——, Damasio, H., and Van Hoesen, G. W. (1982). Prosopagnosia: anatomic basis and behavioral mechanisms. *Neurology*, **32,** 331–41.

De Haan, E. H. F., Young, A., and Newcombe, F. (1987). Face recognition without awareness. *Cognitive Neuropsychology*, **4,** 385–415.

Diamond, R. and Rozin, P. (1984). Activation of existing memories in the amnesic syndrome. *Journal of Abnormal Psychology*, **93,** 98–105.

Dimond, S. J. (1976). Brain circuits for consciousness. *Brain, Behaviour and Evolution*, **13,** 376–95.

Dixon, N. F. (1971). *Subliminal perception: the nature of a controversy*. McGraw-Hill, Maidenhead, Berks.

Dixon, N. F. (1981). *Preconscious processing*. John Wiley, New York.

Eriksen, C. W. (1960). Discrimination and learning without awareness: a methodological survey and evaluation. *Psychological Review*, **67,** 279–300.

Eslinger, P. J. and Damasio, A. R. (1985). Severe disturbance of higher cognition after bilateral frontal lobe ablation: patient EVR. *Neurology*, **35,** 1731–41.

Fodor, J. A. (1983). *The modularity of mind*. MIT Press, Cambridge, MA.

Fowler, C. A. (1986). An operational definition of conscious awareness must be responsible to subjective experience. *The Behavioral and Brain Sciences*, **9,** 33–5.

Frederici, A. D. (1982). Syntactic and semantic processes in aphasic deficits: the availability of prepositions. *Brain and Language*, **15,** 245–58.

Friedman, B. R. (1981). Preservation of orthographic knowledge in aphasia. *Brain and Language*, **14,** 307–14.

Gainotti, G., d'Erme, P., Monteleone, D., and Silveri, M. C. (1986). Mechanisms of unilateral spatial neglect in relation to laterality of cerebral lesions. *Brain*, **109,** 599–612.

Gassel, M. M. and Williams, D. (1963). Visual function in patients with homonymous hemianopsia-III. The completion phenomenon: insight and attitude to the defect and visual functional efficiency. *Brain*, **86,** 229–60.

Gazzaniga, M. S. (1985). *The social brain.* Basic Books, New York.

—— and LeDoux, J. E. (1978). *The integrated mind.* Plenum, New York.

Geschwind, N. (1965). Disconnexion syndromes in animals and man. *Brain*, **88,** 237–94.

Glisky, E. L., Schacter, D. L., and Tulving, E. (1986*a*). Computer learning by memory-impaired patients: acquisition and retention of complex knowledge. *Neuropsychologia*, **24,** 313–28.

——, ——, and —— (1986*b*). Learning and retention of computer-related vocabulary in memory-impaired patients: method of vanishing cues. *Journal of Clinical and Experimental Neuropsychology*, **8,** 292–312.

Goodglass, H., Gleason, J., and Hyde, M. (1970). Some dimensions of auditory language comprehension in aphasia. *Journal of Speech and Hearing Research*, **13,** 595–606.

Graf, P. and Schacter, D. L. (1985). Implicit and explicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **11,** 501–18.

——, Squire, L. R., and Mandler, G. (1984). The information that amnesic patients do not forget. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **10,** 164–78.

——, Shimamura, A. P., and Squire, L. R. (1985). Priming across modalities and priming across category levels: extending the domain of preserved function in amnesia. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **11,** 385–95.

Hilgard, E. R. (1977). *Divided consciousness.* John Wiley, New York.

Hirst, W. (1982). The amnesic syndrome: descriptions and explanations. *Psychological Bulletin*, **91,** 435–60.

Holender, D. (1986). Semantic activation without conscious identification in dichotic listening, parafoveal vision, and visual masking: a survey and appraisal. *The Behavioral and Brain Sciences*, **9,** 1–66.

Holtzman, J. D., Sidtis, J. J., Volpe, B. T., Wilson, D. H., and Gazzaniga, M. S. (1981). Dissociation of spatial information for stimulus localization and the control of attention. *Brain*, **104,** 861–72.

Humphrey, N. K. (1970). What the frog's eye tells the monkey's brain. *Brain, Behaviour and Evolution*, **3,** 324–37.

Johnson, M. K., Kim, J. K., and Risse, G. (1985). Do alcoholic Korsakoff's syndrome patients acquire affective reactions? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **11,** 27–36.

Johnson-Laird, P. N. (1983). *Mental models.* Harvard University Press.

Kinsbourne, M. and Warrington E. K. (1962). A variety of reading disability associated with right hemisphere lesions. *Journal of Neurology, Neurosurgery, and Psychiatry*, **25,** 208–17.

—— and Wood, F. (1975). Short term memory and the amnesic syndrome. In *Short-term memory*, (ed. D. D. Deutsch and J. A. Deutsch), pp. 258–91. Academic Press, New York.

Kolers, P. A. (1975). Memorial consequences of automatized encoding. *Journal of Experimental Psychology: Human Learning and Memory*, **1**, 689–701.

Korsakoff, S. S. (1889). Etude médico-psychologique sur une forme des maladies de la mémoire. *Revue Philosophique*, **5**, 501–30.

Landis, T., Regard, M., and Serrant, A. (1980). Iconic reading in a case of alexia without agraphia caused by a brain tumor: a tachistoscopic study. *Brain and Language*, **11**, 45–53.

Linebarger, M. C., Schwartz, M. F., and Saffran, E. M. (1983). Sensitivity to grammatical structure in so-called agrammatic aphasics. *Cognition*, **13**, 361–92.

Luria, A. R. (1976). *The neuropsychology of memory*. V. H. Winston, Washington, DC.

McAndrews, M. P., Glisky, E. L., and Schacter, D. L. (1987). When priming persists: long-lasting implicit memory for a single episode in amnesic patients. *Neuropsychologia*, **25**, 497–506.

MacCurdy, J. T. (1928). *Common principles in psychology and physiology*. Cambridge University Press.

Marcel, A. J. (1983). Conscious and unconscious perception: experiments on visual masking and word recognition. *Cognitive Psychology*, **15**, 197–237.

Margolin, D., Friedrich, F., and Carlson, N. (1983). Visual agnosia and optic aphasia: a continuum of visual-semantic dissociation. *Neurology*, **33**, 242.

Martone, M., Butters, N., Payne, M., Becker, J., and Sax, D. S. (1984). Dissociations between skill learning and verbal recognition in amnesia and dementia. *Archives of Neurology*, **41**, 965–70.

Mesulam, M. A. (1981). A cortical network for directed attention and unilateral neglect. *Annals of Neurology*, **10**, 309–25.

Milberg, W. and Blumstein, S. E. (1981). Lexical decision and aphasia: evidence for semantic processing. *Brain and Language*, **14**, 371–85.

——, ——, and Dworetzky, B. (in press). Processing of lexical ambiguities in aphasia. *Brain and Language*.

Milner, B. (1962). Les troubles de la mémoire accompagnant des lésions hippocampiques bilatérales. In *Physiologie de l'hippocampe*. Centre National de la Recherche Scientifique, Paris.

——, Corkin, S., and Teuber, H. L. (1968). Further analysis of the hippocampal amnesic syndrome: 14 year follow-up study of H.M. *Neuropsychologia*, **6**, 215–34.

Mohler, C. W. and Wurtz, R. H. (1977). Role of striate cortex and superior colliculus in visual guidance of saccadic eye movements in monkeys. *Journal of Neurophysiology*, **40**, 74–94.

Moscovitch, M. (1982). Multiple dissociations of function in amnesia. In *Human memory and amnesia*, (ed. L. S. Cermak), pp. 337–70. Lawrence Erlbaum Associates, Hillsdale, NJ.

—— (1984). The sufficient conditions for demonstrating preserved memory in amnesia: a task analysis. In *Neuropsychology of memory*, (ed. L. R. Squire and N. Butters), pp. 104–14. Guilford Press, New York.

—— (1985). Memory from infancy to old age: implications for theories of normal and pathological memory. *Annals of the New York Academy of Sciences*, **444**, 78–96.

——, Winocur, G., and McLachlan, D. (1986). Memory as assessed by recognition and reading time in normal and memory-impaired people with Alzheimer's disease and other neurological disorders. *Journal of Experimental Psychology: General*, **115**, 331–47.

Natsoulas, T. (1982). Conscious perception and the paradox of 'blind-sight'. In *Aspects of consciousness*, (ed. G. Underwood), pp. 79–109. Academic Press, New York.

Nissen, M. J. and Bullemer, P. (1987). Attentional requirements of learning: evidence from performance measures. *Cognitive Psychology*, **19**, 1–32.

Paap, K. R. (1986). The pilfering of awareness and guilt by association. *The Behavioral and Brain Sciences*, **9**, 45–6.

Paillard, J., Michel, F., and Stelmach, G. (1983). Localization without content: a tactile analogue of 'blind sight'. *Archives of Neurology*, **40**, 548–51.

Parkin, A. (1982). Residual learning capability in organic amnesia. *Cortex*, **18**, 417–40.

Patterson, K. E. and Kay, J. (1982). Letter-by-letter reading: psychological descriptions of a neurological syndrome. *Quarterly Journal of Experimental Psychology*, **34A**, 411–41.

——, Marshall, J., and Coltheart, M. (ed.) (1985). *Surface dyslexia in adults and children*. Lawrence Erlbaum Associates, New York.

Perenin, M. T. and Jeannerod, M. (1975). Residual vision in cortically blind hemifields. *Neuropsychologia*, **13**, 1–17.

—— and —— (1978). Visual function within the hemianopic field following early cerebral hemidecortication in man: I. Spatial location. *Neuropsychologia*, **16**, 1–13.

Poppel, E., Held, R., and Frost, D. (1973). Residual visual function after brain wounds involving the central visual pathways. *Nature*, **243**, 295–6.

Posner, M. (1978). *Chronometric explorations of mind*. Lawrence Erlbaum Associates, Hillsdale, NJ.

Richards, W. (1973). Visual processing in scotomata. *Experimental Brain Research*, **17**, 333–47.

Schacter, D. L. (1985). Priming of old and new knowledge in amnesic patients and normal subjects. *Annals of the New York Academy of Sciences*, **444**, 41–53.

—— (1987). Implicit memory: history and current status. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **13**, 501–18.

—— (in press). On the relation between memory and consciousness: dissociable interactions and conscious experience. In *Varieties of memory and consciousness: essays in honor of Endel Tulving*, (ed. H. L. Roediger and F. I. M. Craik). Erlbaum Associates, Hillsdale, NJ.

—— and Crovitz, H. F. (1977). Memory function after closed head injury: a review of the quantitative research. *Cortex*, **13**, 150–76.

—— and Graf, P. (1986*a*). Effects of elaborative processing on implicit and explicit memory for new associations. *Journal of Experimental Psychology: Learning, Memory, and Cognition* **12**, 432–44.

—— and —— (1986*b*). Preserved learning in amnesic patients: perspectives from research on direct priming. *Journal of Clinical and Experimental Neuropsychology*, **8**, 727–43.

—— and Tulving, E. (1982). Memory, amnesia, and the episodic-semantic memory distinction. In *The expression of knowledge* (ed. R. L. Isaacson and N. E. Spear), pp. 33–65. Plenum Press, New York.

——, Harbluk, J. L., and McLachlan, D. R. (1984). Retrieval without recollection: an experimental analysis of source amnesia. *Journal of Verbal Learning and Verbal Behavior*, **23**, 593–611.

Schvaneveldt, R. W., Meyer, D. E., and Becker, C. A. (1976). Lexical ambiguity, semantic context, and visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, **2**, 243–56.

Schwartz, M. F., Saffran, E. M., and Marin, O. S. M. (1980). The word order problem in agrammatism. I. Comprehension. *Brain and Language*, **10**, 249–62.

Sergent, J. (in press). A new look at the human split brain. *Brain.*

Shallice, T. (1972). Dual functions of consciousness. *Psychological Review*, **79**, 383–93.

—— (1981). Neurological impairment of cognitive processes. *British Medical Bulletin*, **37**, 187–92.

—— and Saffran, E. (1986). Lexical processing in the absence of explicit word identification: evidence from a letter-by-letter reader. *Cognitive Neuropsychology*, **3**, 429–58.

Sherry, D. F. and Schacter, D. L. (1987). The evolution of multiple memory systems. *Psychological Review*, **94**, 439–54.

Shimamura, A. P. (1986). Priming effects in amnesia: evidence for a dissociable memory function. *Quarterly Journal of Experimental Psychology*, **38A**, 619–44.

—— and Squire, L. R. (1984). Paired-associate learning and priming effects in amnesia: a neuropsychological study. *Journal of Experimental Psychology: General*, **113**, 556–70.

Singer, W., Zihl, J., and Poppel, E. (1977). Subcortical control of visual thresholds in humans: evidence of modality specific and retino-topically organized mechanisms of selective attention. *Experimental Brain Research*, **29**, 173–90.

Sperry, R. W., Zaidel, E., and Zaidel, D. (1979). Self recognition and social awareness in the deconnected minor hemisphere. *Neuropsychologia*, **17**, 153–66.

Squire, L. R. and Cohen, N. J. (1984). Human memory and amnesia. In *Proceedings of the Conference on the Neurobiology of Learning and Memory*, (ed. J. McGaugh, G. Lynch, and N. Weinberger), pp. 3–64. Guilford Press, New York.

——, Shimamura, A. P., and Graf, P. (1985). Independence of recognition memory and priming effects: a neuropsychological analysis. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **11**, 37–44.

Starr, A. and Phillips, L. (1970). Verbal and motor memory in the amnestic syndrome. *Neuropsychologia*, **8**, 75–88.

Torjussen, T. (1978). Visual processing in cortically blind hemifields. *Neuropsychologia*, **16**, 15–21.

Tranel, D. and Damasio, A. R. (1985). Knowledge without awareness: an autonomic index of facial recognition by prosopagnosics. *Science*, **228**, 1453–4.

Trevarthen, C. (1970). Experimental evidence for a brain stem contribution to visual perception in man. *Brain, Behaviour and Evolution*, **3**, 338–52.

Underwood, G. (1983). Verbal reports and visual awareness. *The Behavioral and Brain Sciences*, **3**, 463–4.

Volpe, B. T., LeDoux, J. E., and Gazzaniga, M. S. (1979). Information processing of visual stimuli in an 'extinguished' field. *Nature*, **282**, 722–4.

Warrington E. K. (1962). The completion of visual forms across hemianopic field defects. *Journal of Neurosurgery and Psychiatry*, **25**, 208–17.

—— (1975). The selective impairment of semantic memory. *Quarterly Journal of Experimental Psychology*, **27**, 635–57.
—— and Shallice, T. (1980). Word form dyslexia. *Brain*, **103**, 99–112.
—— and Weiskrantz, L. (1968). New method of testing long-term retention with special reference to amnesic patients. *Nature*, **217**, 972–4.
—— and —— (1970). Amnesia: consolidation or retrieval? *Nature*, **228**, 628–30.
—— and —— (1974). The effect of prior learning on subsequent retention in amnesic patients. *Neuropsychologia*, **12**, 419–28.
—— and —— (1978). Further analysis of the prior learning effect in amnesic patients. *Neuropsychologia*, **16**, 169–76.
—— and —— (1982). Amnesia: a disconnection syndrome? *Neuropsychologia*, **20**, 233–48.
Weinstein, E. A. and Friedland, R. P. (1977). Behavioral disorders associated with hemi-inattention. In *Advances in neurology. Vol. 18*, (ed. E. A. Weinstein and R. P. Friedland), pp. 51–62. Raven Press, New York.
——, Cole, M., Mitchell, M. S., and Lyerly, O. G. (1964). Anosognosia and aphasia. *Archives of Neurology*, **10**, 376–86.
Weiskrantz, L. (1977). Trying to bridge some neuropsychological gaps between monkey and man. *British Journal of Psychology*, **68**, 431–5.
—— (1978). A comparison of hippocampal pathology in man and other animals. In *Functions of the septo-hippocampal system*, Ciba Foundation Symposium 58, pp. 373–87. Elsevier, Amsterdam.
—— (1980). Varieties of residual experience. *Quarterly Journal of Experimental Psychology*, **32**, 365–86.
—— (1983). Evidence and scotomata. *The Behavioral and Brain Sciences*, **3**, 464–7.
—— (1985). On issues and theories of the human amnesic syndrome. In *Memory systems of the brain: animal and human cognitive processes*, (ed. N. Weinberger, J. McGaugh, and G. Lynch), pp. 380–415. Guilford Press, New York.
—— (1986). *Blindsight*. Oxford University Press, New York.
—— and Warrington, E. K. (1979). Conditioning in amnesic patients. *Neuropsychologia*, **17**, 187–94.
——, ——, Sanders, M. D., and Marshall, J. (1974). Visual capacity in the hemianopic field following a restricted occipital ablation. *Brain*, **97**, 709–28.
Wolford, G. (1986). A review of the literature with and without awareness. *The Behavioral and Brain Sciences*, **9**, 49–50.
Young, A. W. (1988). Functional organization of visual recognition. In *Thought without language*, (ed. L. Weiskrantz), pp. 78–107. Oxford University Press.
Zaidel, E. (1982). Reading by the disconnected right hemisphere: an aphasiological perspective. In *Dyslexia. Neuronal, cognitive and linguistic aspects*, (ed. Y. Zotterman), pp. 67–91. Pergamon Press, Oxford.
Zihl, J. (1980). 'Blindsight': improvement of visually guided eye movements by systematic practice in patients with cerebral blindness. *Neuropsychologia*, **18**, 71–7.