The Decoupling of "Explicit" and "Implicit" Processing in Neuropsychological Disorders

Insights Into the Neural Basis of Consciousness?

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ABSTRACT: A key element of the distinction between explicit and implicit cognitive functioning is the presence or absence of conscious awareness. In this review, we consider the proposal that neuropsychological disorders can best be considered in terms of a decoupling between preserved implicit or unconscious processing and impaired explicit or conscious processing. Evidence for dissociations between implicit and explicit processes in blindsight, amnesia, object agnosia, prosopagnosia, hemi-neglect, and aphasia is examined. The implications of these findings for a) our understanding of a variety of neuropsychological disorders, b) the conceptualization of normal cognitive functioning, c) the neural basis of consciousness, and d) the clinical rehabilitation of brain-injured individuals are also discussed.

1. Background

That other half of your body in which you still have feeling, sensation - and hence awareness - now seems your whole body. Thus half is whole (Hewson, 1982, p. 1). This quote is from a patient who developed hemi-neglect (that is, impaired processing of one side of space) and hemiplegia (that is, paralysis of one side of the body) following a stroke. The quote illustrates a key feature of the disorder of neglect; namely, a lack of awareness of one half of the world, or - in this instance - a lack of awareness of one half of the individual's own body. The characterisation of neuropsychological disorders generally focuses on the overt impairments associated with the disorders. Thus, the defining feature of neglect is an impairment of attention towards one half of the world, the defining feature of the amnesic syndrome is a specific deficit in long-term memory, and the defining feature of aphasia is an impairment in some aspect of language functions. However, in many neuropsychological disorders, it has become very apparent that these deficits are not always absolute. Some preserved information processing in the impaired domain can often be demonstrated if examined appropriately. However, this preserved functioning is typically not associated with conscious awareness of preserved processing. Thus, there is often a dissociation between what the patient reports (i.e. information of which they have conscious awareness, or explicit knowledge) and the preserved information processing that can be demonstrated in these patients without their conscious awareness (i.e. their implicit knowledge, as evidenced -- for example, by their behaviour). Such a distinction between implicit and explicit processing has now been demonstrated in a range of neuropsychological disorders. The issue which this piece seeks to address is whether this is -- in fact -- the best way of conceptualizing these disorders; and, if so, what this implies regarding a) possible clinical therapies in brain-injured patients as well as b) the architecture of cognition and c) the neural basis of consciousness in non brain-damaged individuals.

A key element of the distinction between explicit and implicit cognitive processing is the presence or absence of awareness. There has been recent interest in the question of whether it is reasonable to consider different sub-types of consciousness and whether these putatively different subtypes of consciousness can be selectively impaired in particular cognitive domains (see, for example, Young & Block, 1996). While we acknowledge these proposed distinctions, in this piece we choose to refer to explicit knowledge as relating to those aspects of cognition which are available to the individual's conscious awareness, while - by contrast - implicit processing refers to aspects of cognitive functioning which are unavailable to consciousness. Thus, for example, Graf and Schacter (1985) state (with respect to the domain of memory and amnesia): implicit memory is revealed when performance on a task is facilitated in the absence of conscious recollection; explicit memory is revealed when performance on a task requires conscious recollection of previous experiences (p. 501).

The methods used to test for the presence of implicit processes differ from those used to test explicit functioning. For example, explicit memory is typically examined directly, by asking an individual deliberately to recall previous events. Implicit memory, on the other hand, is typically examined by evaluating performance on tests that depend in an indirect way on memory for previous events, as usually exemplified by a change in behaviour. Although the tests for implicit and explicit processing differ across cognitive domains and among different neuropsychological disorders, they all have at their core this shared distinction between direct and indirect tests of cognitive processing. For example, in the domain of blindsight, impaired direct or explicit processing of visual information (in which individuals are asked what they see) is typically contrasted with preserved indirect or implicit processing of information (in which individuals are typically asked to guess and/or indicate through their behaviour the location of an object in their visual field).

Of course, in healthy individuals it is difficult to decouple explicit and implicit processing, because the two are usually concomitant and operate in (more or less) seamless harmony. One is reminded of Kenneth Craik's (1943) famous point, that the better a well-made system functions, the less aware we are of its constituent mechanisms and processes. In this essay, we will therefore rely on information derived from individuals who have sustained a brain lesion (or lesions) that has rendered them deficient in one or more domains in their cognitive functioning. More specifically, the brain lesions considered here are typically cortical (rather than subcortical) and have damaged the explicit, direct or conscious form of cognitive processing while leaving implicit, indirect or non-conscious forms of cognitive processing either absolutely or relatively intact. Although we acknowledge that the non-human literature is often highly informative, especially with respect to the delineation of relevant anatomical circuits, we focus on the human literature in this review, because the emphasis in this essay is functional rather than anatomical (i.e. the focus is on possible dissociations between different forms of information processing, rather than on their neural substrates per se). In addition, many of the capacities referred to in this essay (especially consciousness itself) are imbued with language, and it is especially challenging to generalize in a clear and valid manner from non-humans to humans where language mediation is a potentially important factor. Finally, with respect to human research, while we acknowledge the contribution of neuroimaging studies in the investigation of the mind-brain nexus, because of the vast scope of the neuropsychology literature (as well as some concerns that have been expressed regarding elements of the neuroimaging methodology - such as the use of the subtraction technique), we focus here on the implications of brain injury in neuropsychological patients.

The evidence for dissociations between implicit and explicit processing in blindsight, amnesia, object agnosia, prosopagnosia, hemi-neglect, and aphasia is examined in this piece. Because of the large volume of each of these literatures, we here present a selective but -- we believe -- representative and illustrative narrative review (for further, more wide-ranging discussion of the scientific investigation of brain injury and consciousness, we refer the reader to other relevant publications; for example, Baars, 1988; Crick 1984; Dennett, 1991; Mandler 1975; Marcel 1983; Marcel & Bisiach 1988; Milner & Rugg 1992; Posner & Rothbart 1992; Schacter, McAndrews & Moscovitch, 1988; Shallice 1988; Weiskrantz 1986). We here explore the extent to which the types of dissociations observed across these domains (blindsight, amnesia, object agnosia, prosopagnosia, hemi-neglect, aphasia) can be subsumed within a general framework of conscious (i.e. explicit) versus unconscious (i.e. implicit) processing. We also consider the extent to which our conclusions may have implications for our conceptualization of the architecture of normal cognitive functioning and the structure of consciousness, as well as for clinical practice and possible rehabilitation. One central -- albeit extremely challenging -- issue that we will attempt to tackle concerns whether implicit processes merely represent normal cognitive processes with consciousness awareness - as it were -

simply "split off", or whether -- following cortical brain injury -- some reorganization of implicit cognitive processes also occurs.

A critical (and related) conceptual issue concerns whether implicit and explicit modes of cognitive processing are - in fact - categorically distinct, or whether apparently preserved implicit processing in the presence of apparently impaired explicit processing simply represents a more degraded modus operandi of the cognitive system as a whole, i.e. with "explicit" and "implicit" processes in fact lying on a functional continuum. This issue is sometimes phrased in the neuropsychology literature in terms of the problem in making robust inferences based on the observation of single dissociations. Such inferences may well be susceptible to the logical objection that the observed difference is simply a product of the differential level of information processing resources required by the processes and mechanisms being investigated. To make this point more clearly, in the current context this logical objection takes the following form: that deficits in explicit processing in the absence of deficits in implicit processing following brain injury do not in fact occur because implicit and explicit phenomena represent qualitatively different modes of operation. Rather, according to this view, it is argued that a) explicit and implicit processes lie on a functional continuum, b) tasks requiring more explicit processing are typically more demanding of cognitive resources, and c) cortical brain injury affects the more demanding type of processing more severely than the less demanding type of processing, within a particular cognitive domain. Where a double dissociation has been reported in the literature between explicit and implicit modes of processing (such as has been claimed in the amnesia literature), this "level of difficulty" explanation seems somewhat implausible. But to what extent is this position plausible where such double dissociations have not been reported? This issue will also be considered in this piece. In summary, in this essay we consider the implications of proposing a generic distinction between implicit and explicit processes, first, for our understanding of neuropsychological disorders, and, by extension, for our understanding of the architecture of normal cognitive functioning and the neural basis of consciousness. The relevance of our conclusions for possible clinical rehabilitation regimes will also be considered. Our fundamental goal here is to be provocative and stimulate debate on this important set of issues.

2. Blindsight

A considerable body of work has investigated the relationship between conscious and unconscious processing in blindsight. Indeed, blindsight perhaps represents the prototypical example in the neuropsychology literature of a condition providing evidence for a distinction between explicit and implicit cognitive processing. A lesion of the visual striate cortex leads to a loss of vision in the corresponding part of the visual field. The term "blindsight" refers to reports after brain injury of cases demonstrating preserved implicit processing of visual information presented in the affected "blind" region of the visual field, without explicit awareness - or conscious experience - of vision in this region. This preserved implicit processing can be demonstrated by asking the brain-damaged patient to make visual discriminations about the stimulus being presented using forced-choice testing.

For example, some patients with blindsight retain the ability to localize stimuli in the "blind" field if tested appropriately. As an illustration, Weiskrantz, Warrington, Sanders, and Marshall (1974) tested DB, a patient who had developed a left hemianopia following surgery to the right occipital lobe. When asked to point to the location of a stimulus in his blind field, DB was much more accurate than would be predicted by chance. He could also discriminate the orientation of different lines (vertical compared to horizontal), and he could discriminate between a cross and a circle with high accuracy. However, DB maintained that he could consciously see nothing when these visual stimuli were being presented to him in his "blind" field, even though he was clearly capable of performing some processing of these stimuli.

It seems that the shape of objects presented in the blind fields can also be discriminated by blindsight patients. Marcel (1998) found that two patients with almost complete right hemianopias (i.e. blindness for half of the visual field) were capable of making appropriate grasping movements towards objects presented in their blind field. These participants were presented in their blind hemifield with spheres or cylinders of different sizes, at different distances, and in different orientations. The patients were asked to reach and grasp the object normally, while maintaining their gaze on a fixation point located centrally in the visual field. Marcel analyzed the patients' hand orientations just prior to grasping the object for accuracy of grasp (as measured by wrist orientation, finger shape and grasp aperture). Both "blindsight" participants that were tested performed well above chance on the dimensions of shape, size, and orientation of the objects, although they insisted throughout testing that their responses were merely guesses.

Another interesting set of findings in "blindsight" concerns the influence that stimuli presented in the "blind" visual field can exert on judgments about stimuli presented in the intact visual field. As an example, Marcel (1998) presented words to the blind hemifield of the two hemianopic patients described above, and asked them to state the meaning of ambiguous words (e.g. PALM) subsequently presented in their intact field. The word presented in the blind field was related to the target word with respect to one of its two meanings (e.g. TREE or HAND). In testing, the meanings given by the participants to the ambiguous word presented in the intact field were biased by the presentation of the related word in the blind field in both patients. This influence occurred at a level well above that expected by chance. These findings are important because they indicate that stimuli presented in the blind field can be processed to a "deep" level (the words were clearly processed semantically), without being consciously perceived. Conversely, the presence of stimuli in the spared visual field can affect the direction of "attention" toward targets in the blind field of blindsight patients. Kentridge, Heywood and Weiskrantz (1999) presented symbolic cues (arrows) to the spared visual field of a blindsight participant and measured reaction times to stimuli presented to the blind field. The patient was required to press a button when he thought that a stimulus (presented concurrently with an auditory cue, for the purposes of signalling) had been presented in the blind field. When the cue in the intact field pointed toward the location of the target stimulus in the blind field, the response time was significantly reduced compared to when the cue in the good field did not point towards the target stimulus in the bad field. Cues presented in the participant's blind field were also effective in reducing reaction times to the target, whether or not these cues indicated that the target would appear at the same or at a different location to the cue. The cues in the "blind" field were also effective whether or not they elicited any sense of visual awareness. Kentridge et al. (1999) concluded from their findings that spatial cuing and conscious awareness therefore could not be one and the same process. This finding potentially has important implications for our conceptualization of consciousness and its relationship to attention, given the widespread use of similar cuing techniques in the covert attention literature (see, for example, Posner & Rothbart, 1992).

Marcel (1998) demonstrated that conscious awareness of shapes can also be induced in the blind visual fields of blindsight patients. Two hemianopic participants (already described above) were able to perceive illusory contours in their degraded hemifields. Illusory shapes were induced by Kanizsa figures (discs with cut-out segments). These were aligned in such a way as to induce an illusory triangle spanning both the affected and unaffected hemifields. Both participants reported seeing a bright triangle extending across the midline of the visual field in 70 to 85 percent of trials in which the illusory triangle was complete, and in only 10 to 25 percent of trials when the Kanizsa figures did not complete a triangle. However, neither participant could reliably discriminate the inducing shape in the blind field (discs and squares with cut-out segments were used in 50 percent of trials each) when asked to do so. These results are intriguing, because they indicate that some preserved perception of a spatially coherent stimulus can actually be induced in participants who otherwise report no visual awareness in their blind field.

Preserved reflexes of the visual system have also been demonstrated in patients with blindsight. Weiskrantz, Cowey, and Barbur (1999) demonstrated pupillary reflexes in the blind hemifield of a patient with hemianopia resulting from almost total destruction of the striate cortex with spared extrastriate visual areas. These authors examined whether pupillary responses to stimuli presented in the blind field are always accompanied by a feeling of awareness that an event has occurred - even though the event cannot be "seen" - or whether, under certain conditions, the pupillary response can be elicited in the absence of awareness of the event taking place. The participant in this experiment reported an awareness of stimuli (equiluminant gratings or colour blocks) when presented with an abrupt onset and offset, and - under these conditions - a pupillary constriction was observed. However, this blindsight participant reported no awareness of these stimuli if they were presented with a gradual onset and offset (his reports of "awareness" in these conditions were similar to conditions when there were no stimuli presented), yet he still showed a pupillary response. The authors of this paper suggest that pupillometry may be capable of revealing which implicit visual "channels" remain intact after damage to the striate cortex, since this method does not rely on patient's explicit or "willed" performance (using the traditional blindsight methodology, patients are often reluctant to "guess" the location or appearance of a stimulus presented in the blind field when they are adamant that they cannot see anything). Note, however, that the use of pupillometry to uncover remaining "unconscious" processing within the visual system assumes that the pathways responsible for the pupil reflex are the same as those responsible for the implicit processing that has been previously observed in blindsight.

Although the emphasis of this piece is on functional dissociations, it is interesting (and perhaps informative) to reflect upon which neural pathways mediate blindsight. In humans, the predominant visual pathway projects via the dorsal lateral geniculate nucleus (dLGN) to the striate cortex in the occipital lobes (approximately 90 percent of the fibres of the optic nerve project to the striate cortex via this route). Some fibres from the dLGN project to extrastriate regions of the visual cortex. In addition, a large number of fibres of the optic nerve branch to other, non-cortical regions of the brain, including the superior colliculus, pulvinar, pretectum, and ventral lateral geniculate nucleus (Cowey & Stoerig, 1991). The brain lesions in patients who exhibit "blindsight" typically occur between the dLGN nucleus and the primary visual cortex. The consensus view is that spared extrastriate pathways in blindsight patients underlie the preserved implicit visual processing observed in these patients, although it does not seem entirely clear whether the extrastriate pathways involved are predominantly cortical or subcortical.

However, Campion, Latto, and Smith (1983) questioned the claim that these extrastriate pathways are the neurological basis of blindsight. These authors claimed that the blindsight results are artefacts. They argue that the residual visual functioning in blindsight patients is the result of light being scattered from the stimuli to parts of the retina separate from the scotoma, and/or the consequence of spared striate cortex. However, both of these claims have subsequently been disputed.

The scattered-light theory would seem to apply only if the background lighting during testing is low (allowing the scattered light from the stimulus to other parts of the retina be used effectively as a cue). By contrast, when patient DB was tested with black stimuli on a brightly lit background, he could nevertheless accurately make the distinction between different stimuli - for example, between a cross and a circle (Weiskrantz, 1990). Furthermore, when DB was tested in his natural blindspot in his blind field, he performed at chance levels, even though the scattered light from stimuli presented to this spot on the retina should be the same (or even greater, given its relative proximity) as for stimuli presented in other parts of the blind field (Weiskrantz, 1987).

The second objection of Campion et al. (1983), that "blindsight" is the result of spared striate cortex, is difficult to dispute in human blindsight patients, because it is difficult to demonstrate unequivocally that all of the striate cortex has been removed or destroyed by the lesion in a given patient. However, studies with non-human primates have provided some insight into the neurocognitive processes involved in blindsight. After total removal of the striate cortex bilaterally, a chimpanzee was shown to be able to perform visual discriminations similar to those observed in blindsight patients (Humphrey, 1970, 1972), indicating that these visual discriminations are possible via extra-striate pathways. Although this evidence does not prove that extra-striate pathways are the basis of blindsight performance in human patients, it indicates that - in a closely related species - extrastriate pathways can mediate visual processing of a similar nature to that observed in blindsight patients.

At the present time, the consensus view within neuropsychology is therefore that blindsight most likely represents a genuine phenomenon illustrating the possible dissociation following posterior cortical damage between elements of explicit and implicit visual processing. With respect to the important question of the logical basis of this conclusion, it should be noted that -- although rare -- cases have been reported in the neuropsychology literature of selective deficits in the localisation of objects (for example, Brain, 1941; Cole, Schutta & Warrington, 1962; Holmes, 1918; Holmes & Horrax, 1919; Ratcliff & Davies-Jones, 1972; Riddoch, 1935). This issue has not been considered extensively in the neuropsychology literature. However, it is possible that further consideration of those rare cases manifesting selective impairment in the perception of stimulus location after cortical brain injury may provide highly informative evidence regarding a possible double dissociation with respect to the presenting features of blindsight.

3. Amnesia

The focus in this section will be on impairments in long-term memory underlying the amnesic syndrome. Deficits of long-term memory can involve impairments in the formation of new memories and the accessing of memories for past events (see Foster, J.K. & Jelicic, M. [1999] and Mayes [1988] for reviews). The inability to remember new events, occurring since the onset of the condition, is referred to as anterograde amnesia, while the inability to remember events that occurred prior to the onset of an amnesic condition is referred to as retrograde amnesia. In severe forms of the "amnesic syndrome" - such as in Korsakoff's syndrome (a condition which can affect chronic alcoholics) - both anterograde and retrograde amnesia are typically present. For example, the patient may be incapable of remembering events which have occurred just a few minutes ago, as well as events from his or her life preceding the brain injury. Despite these severe memory impairments, amnesic patients typically have preserved working memory (as measured by tests such as digit span). Amnesic individuals can also typically learn new skills, although they cannot explicitly remember having learned them. Furthermore, if amnesic participants are tested using an indirect measure of memory, they usually show preserved implicit memory.

Preserved implicit memory was suggested in the clinical literature many years ago. For example, the French neurologist of the same name identified the Claparéde effect in the early years of the twentieth century, whereby Claparéde placed a pin in his hand before shaking hands with an amnesic patient. After shaking hands a few times, the patient apparently became reluctant to be greeted by Claparéde, even though she was apparently unaware that she had ever met him before. Preserved implicit memory has since been clearly demonstrated in a formal experimental context in amnesic patients. For example, Warrington and Weiskrantz (1970) tested learning in four amnesic participants using degraded stimuli. The participants were presented with sequential versions of word lists at different levels of visual completeness: an extremely degraded version of each word was presented, followed by a more complete word, followed by the complete word. The task was to identify each word as rapidly as possible. The lists of words were presented five times, followed by a test of free recall, a test of recognition, and a partial information test (in which the participants were again presented with the degraded words and asked to identify them). Amnesic participants performed poorly on the tests of recall and recognition (i.e. direct, explicit tests of memory). However, on the partial information test - when they were presented with the degraded words - their performance was similar to that of controls, in terms of the speed with which they identified the words. This indirect test therefore indicated preserved implicit memory in amnesia, in the absence of explicit memory.

Cohen and Squire (1980) studied four Korsakoff patients and one patient who had become amnesic after a stab wound to the diencephalon. These participants were tested on a mirror reading task on three consecutive days, and then again 13 weeks later. With non-repeated words, the amnesic participants learned the mirror reading skill at the same rate as control participants, and even after 13 weeks they were as proficient as controls at the task (although they could not consciously remember having previously learned the task). With words that were repeated across all four testing sessions, control participants performed significantly better than amnesic participants. This was interpreted as indicating an advantage in controls of being able to remember consciously the words that had been previously presented to them. However, the learning curve of both control and amnesic participants was steeper for repeated words than for non-repeated words. Compared with controls, the amnesic participants performed poorly on a recognition test of the presented stimuli which was administered after three days of testing, illustrating a dissociation between explicit knowledge and preserved implicit or procedural knowledge.

A similar effect can be seen when amnesic patients are tested using word stems (typically, the first three letters of words) and asked to complete the stem to make the first word that comes to mind. Graf, Squire, and Mandler (1984) presented word lists to amnesic and control participants, then asked them to complete word stems with the first word that came to mind (some words were from the original lists, and some were new words). On a test of recall for the word lists, the amnesic participants were severely impaired compared to control participants. However, a priming effect was observed for both amnesic and control participants on the stem completion task: the word stems were more likely to be completed with previously studied words than with new words, and the amnesic participants performed as well as controls on this task, despite a lack of explicit memory for the test items. Using a similar task, Graf and Schacter (1985) found that amnesic participants could "learn" new associations between words as well as control participants. Lists of word-pairs were presented visually to amnesic patients and controls, whose subsequent recall and word-pair completion (using a test which was ostensibly unrelated to the initial word-pair learning test) were measured. The completion of the word stems with studied words was well above the level of chance for the amnesic and control participants. In both participant groups, there was a larger priming effect when the word-pair stems were presented at test in the same context as the one in which they were learnt than when they were presented in a different context at learning and test. Furthermore, there was no difference between the performances of the amnesic and control groups on this word stem task, although in a recall task the amnesic patients performed very poorly compared to controls. Thus a priming effect for word-associations was demonstrated in amnesic participants in the absence of explicit recollection. The effects reported by Graf and Schacter (1985) have been replicated by Gabrieli, Keane, Zarella, and Poldrack (1997) using a task in which word-pairs were read aloud, and then were presented visually at threshold durations for identification (threshold was defined for individual participants as detection on 30 percent of trials). Control participants and amnesic participants showed a greater priming effect - indicated by better identification - for word pairs which had been presented in the initial study phase than for pairs which were constituted by recombining words from the study phase. The performance of amnesic participants on an explicit test of memory for these word-pairs was impaired compared to controls, again demonstrating a dissociation between preserved implicit (or "unaware") memory for new associations and impaired explicit (or "aware") memory for these associations.

Preserved implicit memory in an amnesic participant has also been demonstrated for arithmetic reasoning. Delazer and Benke (1999) presented series of numbers to a severely amnesic participant, whose task was to provide the next number in the series. The first series in a trial was defined as the prime, and the second series - which required the same algorithm as the first series for completion - was defined as the target. The prime series was separated from the target series by a distracter series. Reaction times were not different between the amnesic participant and the controls, and were faster to the target than to the prime series. However, the amnesic participant was unable to answer correctly whether he had answered a similar problem before (his explicit memory was at the level of chance). Delazer and Benke (1999) concluded that the priming effects observed in this amnesic participant was generated by an abstract stage of processing (i.e. in formula generation), since all of the prime and target series had different perceptual features, and all required different calculations and answers.

Another feature of implicit memory which has been found to be preserved in amnesic participants is the acquisition of category knowledge. Reed, Squire, Patalano, Smith, and Jonides (1999) presented amnesic and control participants with a group of related cartoon animals, and then asked them to classify a second set of animals as in terms of whether they belonged to the first group or not. Amnesic participants performed as well as controls at classifying new animals. However, they were impaired on a recall task, which assessed their ability to describe the animals from memory. The learning of a new categorization system therefore did not appear to depend on intact declarative or explicit memory for the animals.

Despite the range of evidence for the existence of separate processes underlying implicit and explicit retention, a number of criticisms have been raised concerning the methods used to measure conscious and unconscious memory processes, and the interpretations of the results of such experiments. (Indeed, some of these criticisms may well be relevant for other cognitive domains.) The processes underlying performance on a test ostensibly measuring one form of memory may not be limited to the processes claimed to be "tapped" in that task. For example, implicit memory can influence performance on direct tests of memory designed to tap explicit memory, and vice versa (Dunn & Kirsner, 1989).

Dunn & Kirsner (1989) emphasised the importance of distinguishing between the component processes a task is thought to involve, and the processes it actually does involve. For example, in tasks thought to tap implicit memory following prior exposure to stimuli using stem completion, the participant is instructed to say the first word that comes to mind. Clearly, explicit memory for the study list can aid in the completion of this task, and falsely elevate the estimate of "implicit" memory performance.

Jacoby, Toth and Yonelinas (1993) have tried to address the problem of conscious and unconscious contamination on tests of implicit and explicit memory. These authors employed a "process-dissociation" procedure to estimate the influence of implicit processing using an inclusion task and an exclusion task. First, in the inclusion task, participants were asked to complete word-stems with words recalled from a previously studied list, or, failing this, with any word that came to mind. The inclusion task, therefore, included a component of conscious memory or recollection, and a component of "unconscious" or "automatic" memory processing. Previously studied words which were correctly generated by participants in the inclusion condition could - therefore - be due to either automatic memory processing or to conscious recollection. Second, in the exclusion task, participants were, by contrast, asked to complete the word-stem with words that were not presented earlier. Previously studied words which were mistakenly generated by participants in the exclusion condition could - therefore - only be due to automatic memory processing, accompanied by a failure to recall that the word was presented earlier. Jacoby et al. (1993) proposed that the probability of conscious memory or recollection could be calculated as performance on the inclusion task minus performance on the exclusion task. An estimate of automatic influences of memory can also be calculated (although of course this includes the baseline chance of randomly completing a stem with a particular word). Jacoby et al. (1993) found that the estimate of automatic (unconscious) influences of memory did not change during a divided attention task compared to a full attention task, whereas the estimate of conscious recollection was decreased in the divided attention condition. Jacoby et al. (1993) point out that these findings are consistent with previous implicit-explicit findings in normal participants. While the measures of implicit memory which do not use a "process dissociation" procedure may overestimate the influence of implicit processing due to the problem of conscious contamination, this does not - of course - necessarily discount the implicit/explicit dissociation found in amnesic participants, since direct tests of memory in these patients often reveal a severe deficit of explicit memory. (Although this deficit may - of course - be even greater if possible implicit contamination were reliably eliminated from the study of amnesics' explicit memory performance.)

A second possible confound in the implicit-explicit literature is that the tasks used to measure implicit and explicit memory generally require different modes of processing. Thus, Roediger (1990) argued that the experimental evidence for the existence of implicit ("unaware") and explicit ("aware") memory as two distinct memory systems can be reinterpreted in terms of the modes of processing involved in the two types of task (see Foster & Jelicic, 1999, for a review). Tests of implicit memory often rely on the matching of perceptual operations between study and test, and they are therefore data driven. Tests of explicit memory often rely on meaning, and are therefore conceptually driven. The standard tests of explicit and implicit memory are free recall (conceptually driven), and completion of word fragments (perceptually driven). Therefore, difference between the performance on explicit and implicit tests may be due to different modes of processing (with respect to transfer-appropriate processing between study and test), and not due to the involvement of distinct explicit and implicit memory systems. Blaxton (1989) used two data driven tests and two conceptually driven tests covering all four combinations of the data-driven/conceptually-driven distinction and the implicit/explicit distinction, and provided evidence that the type of processing could in fact explain the observed results better than an explanation based on the memory systems involved in the tasks. However, the transfer-appropriate processing approach does not handle amnesic data well (see Foster & Jelicic, 1999): amnesic individuals show preserved implicit memory on conceptually driven tests (McAndrews, Glisky, & Schacter, 1987). Participants in the experiment conducted by McAndrews et al. (1987) were presented with puzzle sentences which they were asked to make sense of (e.g. "The haystack was important because the cloth ripped", which is understandable in the context of the word "parachute"). Severely amnesic patients were tested at intervals of up to one week, and performed better (at all intervals) on the puzzle sentences that they had encountered previously compared with the ones they had not encountered, despite having no recollection of being shown the sentences before. The transfer-appropriate processing model proposed by Roediger therefore highlights important dimensions of the processes underlying indirect and direct tests of memory, but does not discount the preservation of implicit memory in amnesic participants, despite impaired explicit memory. Finally, with respect to the neural basis of implicit memory phenomena, these may well vary across the different subtypes of implicit memory that have been reported. For example, preserved conditioning in amnesia may well be mediated primarily via the typically intact circuitry of the cerebellum, preserved motor learning largely via the basal ganglia and preserved priming predominantly via those cortical regions which subserve the perceptual experience of the original event (see Foster & Jelicic, 1999, for a review of these and related issues).

There is, therefore, substantial and wide-ranging evidence for selective preservation of implicit memory in amnesia. Furthermore, this preserved capacity seems to apply to implicit memory for new as well as for old associations. Of course, one should bear in mind that this may not be true for all cases of amnesia, as this may depend on the aetiology of the memory loss. In particular, there has been a tendency in the past to group together individuals with amnesia according to the severity of the functional manifestation of their anterograde deficit. This is despite the observation that the aetiology of the amnesia in question may significantly impact upon the functional characteristics of the memory loss (for example, the degree of retrograde memory loss seems typically to be greater in Korsakoff's amnesia compared with medial temporal lobe amnesia). Although we focus on functional dissociations in this piece, considerations of the neural "hardware" implicated in a specific neuropsychological case or disorder may also be informative when considering the neuropsychology of memory, as well as cognitive domains. However, this is a controversial issue which we will not attempt to tackle here (the reader is referred to Churchland & Sejnowski [1992], Ellis & Young [1988], Fodor [1983], Marr [1982] and Shallice [1988] for a consideration of this and related theoretical issues).

Another important question that has already been referred to in preceding sections concerns whether apparently selective preservation of implicit memory in fact merely reflects preservation of quantitatively less resource-demanding processes, rather than reflecting a qualitative preservation of an implicit "module". For reasons of scope and length, we will not consider this issue in great detail here. However, the interested reader is referred to Keane, Gabrieli, Mapstone, Johnson & Corkin (1995) for a report of double dissociations in implicit and explicit memory after bilateral occipital lobe or medial temporal lobe lesions, respectively. Therefore, on the double dissociation criterion specified in the introduction to this piece, it appears that the selective preservation of implicit memory in amnesia is a genuine phenomenon rather than simply an artefact of contrasting levels of cognitive difficulty across implicit and explicit tasks.

4. Neglect

The term "unilateral neglect" refers to the tendency of patients to show impaired processing of one half of space. The side of space that is neglected is typically contralateral to the location of brain damage. This attentional deficit often arises from damage to the right parietal lobe, with most patients reported in the literature with this lesion site manifesting left-sided unilateral neglect (see Mesulam, 1985 for a review). Left neglect has also been documented following damage to the frontal lobes, cingulate gyrus, striatum and thalamus. The dominant view in the literature is that spatial attention is the result of a distributed network involving each of these regions (Mesulam, 1999). Patients with left-sided neglect may fail to dress the left half of their body, eat food on the left half of their plate, notice objects on their left, read words printed on the left side of the page, or even read the left half of each word. When asked to bisect a horizontal line, these patients tend to estimate the midpoint to be closer to the side of their brain lesion (because - it is argued - they disregard the side of space contralateral to the lesion).

Nevertheless, several studies suggest that some processing of visual information on the neglected side does occur in patients with hemineglect. For example, on the line bisection task just mentioned, Riddoch and Humphreys (1983) have investigated the effects of cueing and noted that the tendency for neglect patients to bisect the line towards the side of their brain lesion could be reduced if a cue, such as a digit, was presented at the left-hand end of the line.

In another study, Volpe, LeDoux, and Gazzaniga (1979) showed an effect of preserved processing on the neglected side of space using a same/different recognition methodology. Pictures were presented simultaneously to the left and right visual fields of four participants with left hemineglect. The participants fixated centrally, and were asked whether the left/right stimuli were the same or not. The stimuli were again presented bilaterally, and the participants were asked to name the pictures. All neglect patients performed well above chance for the same/different judgements (88 to 100 percent correct). However, their performance on the naming task was severely impaired for stimuli presented on the left when they were paired with a different stimulus on the right.

Two participants with neglect could not name any of the stimuli on the left in these trials (and, in fact, denied that any stimuli were presented), and two were accurate for only 23 and 48 percent of trials (compared to 90 and 95 percent accuracy, respectively, in these patients for the same/different judgements). This discrepancy between performance on the same/different judgements (in effect a forced-choice task), and the naming of the stimuli again may illustrate an implicit-explicit dissociation in these neglect patients. In perhaps the most well known experiments purporting to demonstrate the explicit-implicit distinction in neglect, Marshall and Halligan (1988) also demonstrated preserved processing of visual information despite a lack of apparent awareness in a neglect patient. The participant was presented with two line drawings of houses, identical except that one house had flames emerging from the left side. The houses were judged to be identical by the patient. However, when she was asked which house she would prefer to live in, she chose the house without the flames in 17 of 21 trials (i.e. much more often than would be predicted by chance). These findings were interpreted by the authors as indicating preserved implicit processing of the left side of the building by this neglect patient, despite no expressed, overt awareness of the flames.

However, Doricchi and Galati (2000) note that in the Marshall and Halligan (1988) study, it was unclear whether the participant selected the non-burning house because of an implicit semantic understanding of the flames, or because of an implicit preference for symmetrical stimuli. In an initial experiment, Doricchi and Galati replicated the findings of Marshall and Halligan (1988), using symmetrical stimuli, which in a "damaged" form were asymmetrical (with the damage on the left of the item). When presented with two pictures of an object, one damaged, one intact, the neglect patient showed a clear preference for the undamaged, symmetrical item. In a second study, the stimuli were drawings of asymmetrical objects, and in their "damaged" state they were symmetrical (e.g. a pipe with a bowl at either end). On 17 out of 18 trials, the patient again chose the undamaged item as being the preferable one, despite explicitly judging the drawings to be the same. The findings of Doricchi and Galati (2000) therefore indicate that the preference for "undamaged" items in this patient cannot be accounted for by an implicit preference for symmetry. Instead, these results indicate that implicit semantic processing of the left half of the pictures had occurred, such that naturally symmetrical items were judged to be preferable when presented in their natural symmetrical state, whereas naturally asymmetrical items were judged to be preferable when presented in their natural symmetrical state.

In a related reaction-time task, Audet, Bub, and Lecours (1991) found that a patient with unilateral neglect was faster at responding to a letter located centrally if it was presented with the same letter located in the neglected visual field than if the central letter was presented with a different letter in the neglected field. McGlinchey-Berroth, Milberg, Verfaellie, Alexander and Kilduff (1993) used a semantic priming task and found evidence for implicit processing of visual stimuli presented in the neglected visual field. Four patients with hemineglect following right-sided lesions and 10 unimpaired participants were presented with a picture-prime in either the right or left visual field (while they fixated centrally), followed by a centrally presented target letter-string (words and non-words), which they were required to judge as a real word, or a non-real word. A jumbled picture was presented on the side opposite the prime, at the same time as the prime, to avoid a bias in the participant's allocation of attention at this stage of the experiment. The picture-primes were either semantically related or unrelated to the target letter-string. In control participants, reaction times to target real words were faster if the target was preceded by a related picture prime in either visual field. In the patient group, the same pattern of results was found: reaction times to targets preceded by a related prime were faster than those preceded by an unrelated prime. Surprisingly, no difference in priming effect was observed between the presentation of primes to the left (neglected) visual field and the right visual field in these neglect patients. These results suggest that - in at least some neglect patients - visual information presented in the neglected visual field can be used. Furthermore, the nature of the task suggests that at least some types of information presented in the neglected field may be processed to the level of meaning.

In the next part of their study, McGlinchey-Berroth et al. (1993) performed a second experiment to determine whether patients had explicit awareness of the picture primes used in the first experiment. Picture-primes were again presented to either the left or right visual field, together with a scrambled "filler" picture in the opposite field, while the participant fixated centrally. This was followed by the presentation of two target pictures, the prime picture and a non-prime picture, located centrally, one above the other. The participant's task was to indicate which of the target pictures they had just seen. The control group was very accurate on this task. However, the neglect patients performed at chance levels for the primes presented in their left (poor) visual field, and above chance (74% correct) for primes presented in their right (good) visual field. The results of these two experiments can be interpreted in terms of spared implicit processing of visual information presented in the neglected visual field, in the absence of explicit recognition (or awareness) of this information.

Reading has also been investigated with a similar outcome. For example, Berti, Frassinetti, and Umilta (1994) examined "non-conscious reading" in a patient with left-sided hemineglect who exhibited neglect dyslexia (a tendency to omit letters on the left side of words). These authors examined possible interference effects with this patient using a modified Stroop test. Words, or -- in the modified version of the test, only the initial letters of words - were presented in either congruent or incongruent conditions in which the words spelled the colour or did not spell the colour of the ink in which the word was written, respectively). In the conditions where only the initial letters of the word were presented, the remaining letters were represented by "X's. In this modified Stroop test, the participant's task was to name the colour of the ink (as per the instructions in the conflict condition of the conventional Stroop task). When he had been asked simply to read the words, the participant made frequent omissions of the letters on the left side of each word. However, his performance on the Stroop task indicated preserved processing of the words, since his colour naming times were slower on both the incongruent whole words and incongruent partial words compared to congruent words. These results indicate that there was preserved semantic processing of the words and partial words in this patient, and suggest that implicit processing in neglect can be noted with verbal as well as pictorial materials.

With respect to the neural basis of implicit phenomena in the neglect syndrome, although this has not been investigated extensively, one may speculate that this may be mediated via the contralateral cerebral hemisphere, and/or the other preserved elements of the multi-component neural circuitry which Mesulam (1999) and other workers have identified as mediating the representation of spatial attention.

From this selective review of the relevant literature, it is clear that there is evidence across a range of stimulus materials of preserved implicit processing in the absence of explicit processing following cortical damage in unilateral hemispatial neglect. However, it is challenging to conceptualise what would represent a double dissociation in this domain. For example, with respect to the burning house experiment of Marshall and Halligan (1988), a double dissociation would be revealed if there were another patient reported who could describe the flames appearing on the side of one of the houses, but showed no behavioural or implicit preference for the house without the flames, as per their study. This itself may reveal more about the aesthetic preferences of that person rather than his or her impaired explicit processing. As another example, with respect to the study conducted by Volpe, LeDoux, and Gazzaniga (1979), it is possible that there are patients who would manifest a selective impairment in being able to make the same/different stimulus judgement while at the same time being able to consciously name the presented items (perhaps due to some subtle visual impairment which impaired stimulus matching but did not significantly impact upon stimulus naming), but to our knowledge such patients have not been reported in the neuropsychology literature. Therefore, for reasons of lack of proof or of experimental intractability, the jury must remain out for the time being on whether demonstrations of selective preservation of implicit processing in the domain of unilateral neglect reflect a "modular" distinction between implicit and explicit processes in this domain, or alternatively merely reflect pseudo-dissociations due to the task used occupying different positions on the functional continuum of "implicit-explicit" task difficulty.

A final point concerning neglect is that it is accompanied in some cases by anosognosia, i.e. denial and/or lack of awareness of the illness or deficit, accompanied by an apparent inability to acknowledge that one is disabled. This may occur for a variety of different neuropsychological impairments - suggesting that the patient is not consciously aware of at least some elements of his or her difficulties - although it seems to occur more frequently in unilateral hemispatial neglect. Anosognosia can give rise to some bizarre clinical phenomen. However, for reasons of scope and length it will not be covered further in this piece. Suffice it to say that a constellation of clinical signs and symptoms in neglect which includes apparent problems in explicit attention combined with denial of the impairment and relative preservation of at least some elements of implicit visuospatial processing represents a fascinating combination of syndrome characteristics, with potentially very significant implications for our theorizing about the neural basis of consciousness.

5. Agnosia

Visual agnosia refers to the inability to identify familiar objects by sight in the absence of a fundamental visual sensory impairment, such as complete or partial blindness. However, in visual agnosia objects may well be identifiable through other sensory modalities, for example through touch or hearing. Two categories of visual agnosia were identified by Lissauer: in apperceptive agnosia, the individual is thought to fail to form an integrated percept of an object, whereas in associative agnosia, an adequate percept seems to be formed, but it fails to be associated with meaning (Lissauer, 1890, cited in Walsh and Darby, 1999).

Goodale, Milner, Jokobson, and Carey (1991) found evidence for spared implicit visual processing of object orientation in a patient with apperceptive visual agnosia (DF). When DF was required to indicate the orientation of a slot (either verbally, or by matching the orientation of the slot to the correct depiction on a card), her performance was greatly impaired. However, when she was asked physically to "post a card" through the slot, her performance (measured as the orientation of the card just before contact with the slot) was nearly perfect. A second dissociation between explicit and implicit processing was observed in DF using a size-estimation task. When DF was required to indicate explicitly the width of an object, she did so at chance levels (the estimated width of different sized objects that she produced did not vary systematically with the actual size of the objects). However, when she was asked to reach out and pick up the objects, DF's performance was similar to controls: maximum grip aperture increased linearly with object width. On the basis of these findings, Goodale et al. (1991) proposed that the neural substrates for the "automatic" guidance of visuomotor skilled actions must be separate from those responsible for conscious perception of those objects.

In prosopagnosia, the agnosic impairment is considered to be limited specifically to the identification of previously familiar faces. Tranel and Damasio (1985) found evidence for a dissociation between explicit and implicit face processing in two patients with prosopagnosia. These participants were asked to rate the familiarity of faces: some of the faces were of people that were personally very familiar to the participants, some were of famous people, and some of the faces were unknown to the participants. One participant reportedly failed to recognize any of the familiar or famous faces, yet had large skin conductance responses (SCRs) to both these sets of faces (but not to unfamiliar faces). The second participant could consciously recognise familiar faces if they were of people known to her since before the onset of the illness. In addition, SCRs in this patient were larger for familiar faces compared to unfamiliar faces. This participant was also tested on an additional set of faces, made up of people whom she had met since the onset of the illness. Although she was not able to recognise these faces at a conscious level, she produced large SCRs to them. Tranel and Damasio interpreted the preserved SCRs for familiar faces in these two patients as evidence that an early step in the face identification process was taking place, but that - on some occasions - the results of this identification process had failed to reach conscious awareness. These findings were replicated in four other patients with face agnosia (Tranel and Damasio, 1988). The dissociation between explicit and implicit face identification observed in these cases was proposed by Tranel and Damasio (1988) to be the result of a neural disruption to the linkage between face "records" (which - the authors argue -- are automatically activated by the presentation of a familiar face, even in prosopagnosia) and information associated with these face records, including the identity of the people associated with the faces. The representation of this latter type of conscious identity-related face information is -- according to Tranel and Damasio (1988) - represented via face identity "records". According to this model, since face records typically become available to conscious awareness via these identity records, the proposed disruption of the latter in prosopagnosia means that the identity of the face fails to reach conscious awareness, and the face fails to be recognized as familiar and subsequently identified. According to Tranel and Damasio, the activation of the face records alone is deemed sufficient to trigger the autonomic SCR, at a non-conscious level.

In addition to this kind of indirect electrophysiological evidence for implicit face processing in prosopagnosia, implicit face identification has been observed using behavioural tests. De Haan, Young, and Newcomb (1987) asked a prosopagnosic patient (PH) to judge whether pairs of faces were of the same person, or of different people. This task was found to be easier for normal participants (indicated by a faster reaction time) if the faces were of familiar people. PH's reaction times were much slower than controls overall. However, a similar pattern of shorter reaction times to familiar faces than to unfamiliar faces was observed in PH as in controls. In another "bubble" task, participants were required to classify the written names of famous people (accompanied by a face) as entertainers or politicians. Controls were typically quicker to identify the occupations of written names of famous people a) if the name was presented without face, b) if it was associated with the face of the same person, or c) if it was associated with a face from the same face category (pop star or politician) compared to the experimental condition d) where the name was associated with an unrelated face. Again, despite slower reaction times overall, the pattern of PH's responses was similar to those of the controls. For PH, the reaction times for name identification when the name was presented alone, with the face of the same person, or with the face of a related person were not different. However, PH's reaction times when the name was presented with the face of an unrelated person were significantly slower than when the name was presented with the face of the same person. In another behavioural task, PH was better able to learn to associate the face of a famous person with the true occupation of that person than with a made-up occupation. However, it is important to reiterate that PH was unable to explicitly recognize any of the familiar faces used in these experiments. From their findings, De Haan et al. (1987) concluded that recognition of face identification was occurring at an unconscious level in PH, but that this recognition failed to reach conscious awareness.

A final point here is that there has been some suggestion that the Capgras syndrome, which involves a delusional misidentification of individuals (and -- typically -- the bizarre conviction that one's relative have been replaced by impostors), may be conceptualized as a kind of mirror-image of prosopagnosia (Ellis & de Pauw, 1994). However, this is quite a controversial issue, and the implications of this position for the issues considered in this essay are not clear.

Within the general domain of agnosia, the majority of evidence of preserved implicit processing in the face of impaired explicit processing has been collected in studies of prosopagnosia, that is agnosia for faces. There is relatively sparse evidence for selectively preserved implicit processing of objects after cortical brain injury. However, taken together, the findings reported in this section from the fields of object agnosia and prosopagnosia indicate that there is significant evidence from the study of neuropsychological patients for the preservation of implicit "recognition" of faces and objects in the absence of explicit identification of these same materials. There has been scant discussion in the neuropsychology literature regarding the neural basis of these observations, which may be mediated via a combination of preserved cortical and possible subcortical (in the case of SCR) mechanisms. Furthermore, as far as we are aware, there are no reported studies of preserved explicit identification of faces and objects in the absence of implicitly mediated recognition of these same materials. In other words, as in the field of hemi spatial neglect, double dissociations have not been demonstrated in the fields of agnosia and prosopagnosia with respect to the implicit and explicit processing of objects and faces. Therefore, we cannot draw strong conclusions at this time as to whether the pattern of preserved implicit processing of faces and objects in the absence of explicit processing of these same materials in fact reflects distinct "modular" processing or is instead mediated via different levels of task difficulty across a common functional continuum.

6. Aphasia

Aphasias are disorders of impaired expression or understanding of language, excluding deficits in language due to perceptual or memory problems. Aphasias generally develop after damage to the language "dominant" cerebral hemisphere, which is usually on the left side. For example, lesions in the left inferior frontal lobe (in Broca's area) are often associated with impairments in language production, while a lesion in the left temporal lobe (in Wernicke's area) is often associated with impairments in language comprehension (Walsh and Darby, 1999). However, these impairments are not completely dissociated in aphasic patients. Thus, a lesion confined to Broca's area can sometimes be associated with impaired language comprehension as well as impaired language production, and damage to Wernicke's area can cause problems in language output as well as impairments in language comprehension.

Preserved implicit language comprehension has been demonstrated in patients with severely impaired explicit language comprehension. Evidence for preserved implicit processing in an aphasic patient was reported by Schacter, McGlynn, Milberg and Church (1993), who found normal auditory priming in a patient with severely impaired auditory comprehension. The participant, JP, became aphasic following a stroke, which left him with word-meaning deafness. In this study, JP and four control participants initially heard a list of words, then - following a distracter task - they where asked to identify words masked by white noise. Although JP had more difficulty identifying non-studied words in the white-noise task than control participants, he showed a similar level of priming for previously studied words as the control participants. A subsequent test of word recognition showed that JP recognized none of the previously studied words, and a comprehension test indicated severely impaired comprehension of the studied words. Schacter et al. (1993) concluded that the auditory priming exhibited by JP was probably operating at a presemantic level, since it did not correspond to explicit comprehension of spoken words.

Revonsuo (1995) demonstrated implicit access to semantic knowledge in a globally aphasic participant, PM, using a Stroop-like task. In a test of PM's explicit processing of the meaning of "colour words" (for example, the word "red"), he was found to be severely impaired in matching colour words to the appropriate colour. However, in the Stroop-like task, his reaction times to identify the colours of words were longer if the word and the colour were incongruent (for example, the word "red" depicted in blue letters) than if they were congruent (for example, the word "red" depicted in red letters). These results indicate that semantic processing can occur in aphasia, without conscious awareness of the meanings of the stimuli presented.

Mimura, Goodglass, and Milberg (1996) also found evidence for preserved semantic processing in a patient with aphasia resulting from a left-hemispheric cerebral infarct. Picture primes were presented to this participant (BH) followed by related or unrelated words or non-word letter strings. BH was then required to decide whether the target stimuli were real words or non-words. The number of errors made for words preceded by an unrelated prime was significantly higher than the number of errors for words preceded by a related prime. In addition, reaction times were longer for words preceded by an unrelated prime than for words preceded by a related prime. Following the initial experiment, BH was asked to match the target words to the prime pictures. BH was impaired on this explicit matching task, scoring only 42 percent correct. BH therefore demonstrated impaired explicit access to semantic information but with preserved implicit semantic processing on the primed lexical decision task. The authors suggested that right hemispheric language capacities may be mediating the implicit access to semantic information in BH, although they also point out that BH was left-handed, which can be associated with a different distribution of language functions between the left and right hemispheres relative to that of right-handers.

An electrophysiological study also revealed intact implicit semantic processing in a globally aphasic participant, KK, who was severely impaired in reading, recognizing letters and matching spoken words to pictures (Revonsuo and Lainne, 1996). Auditory event-related potentials to congruent and incongruent words were recorded in spoken sentences in KK and in control participants. KK was not able to state explicitly which sentences contained congruent words and which were incongruent. However, in KK several event-related potential components were identical to those of control participants in the incongruent condition relative to the congruent condition, including a negative peak at around 400 ms, and a positive peak at around 800 ms. These findings indicate that the incongruity was being processed in KK. Overall, these results indicate that implicit semantic processing of verbal information can occur in the absence of explicit comprehension of the spoken word.

Tyler, Moss, Patterson and Hodges (1997) studied a participant (FM) with progressive aphasia over a period of four years, and monitored both implicit and explicit language comprehension in this individual. On a lexical decision task, FM was presented with prime-target pairs, and asked to decide if the target was a real word or a non-word. Her reaction times to targets following related primes was significantly shorter compared to targets following unrelated primes. This priming effect was of a similar magnitude to that in control participants. The pattern of semantic priming observed in FM was preserved across the four years of the study. However, when FM was required to make explicit judgements about the relatedness of words, or to combine the meanings of words, she was severely impaired, and her performance on these explicit tests of language comprehension deteriorated over the four years of study.

Support for the involvement of the right hemisphere in the processing of the spoken word comes from a functional neuroimaging study with both controls and aphasic patients. Mummery, Ashburner, Scott and Wise (1999) showed increased activation in both the left and right superior temporal sulci with the presentation of speech stimuli (compared to the presentation of noise equivalents of speech) in healthy participants, but activity in only the right superior temporal sulcus with speech stimuli in two partially recovered aphasic patients who could comprehend only single spoken words. Based on these findings, Mummery et al. (1999) suggested that the right and left temporal lobes may be involved in the normal prelexical processing of speech. This study provides some (indirect) support for the proposition that the spared right hemisphere is responsible for preserved implicit processing of semantic verbal information in individuals with aphasia.

Therefore, there is a range of studies in the relevant literature indicating that implicit semantic processing can be preserved in at least some aphasic participants, despite an impairment in explicit semantic processing. In terms of the neural basis for this set of observations, it has been suggested that these findings are mediated via the preserved functioning of the right cerebral hemisphere after left-sided cortical damage. As with the other cognitive domains that have been considered in his piece, there is an important conceptual issue with respect to the question of whether the findings reported in this section represent real or only apparent functional dissociations. Although -- for reasons of length -- this literature will not be considered extensively here, there is another set of findings indicating that damage to the right cerebral hemisphere can affect processing of complementary aspects of language, such as prosody, metaphor, humour and emotion, while leaving other aspects of language more or less intact (Heilman, Scholes & Watson, 1975; Ross & Mesulam, 1979; Ross, 1981; Sperry, 1984; Winner & Gardner, 1977). Therefore, there would appear to be at least tentative evidence of a double dissociation in the field of aphasia, whereby implicit aspects of semantic processing of language in left cortically damaged aphasic patients may be mediated via the right hemisphere, which itself appears to mediate other complementary aspects of language.

7. Discussion

> How is it that anything so remarkable as a state of consciousness comes about as a result of irritating nervous tissue, is just as unaccountable as the appearance of Dijin when Aladdin rubbed his lamp. T.H. Huxley, (1866, cited in Young and Block, 1996, p. 149).

From the selective but illustrative review presented above, it is apparent that evidence for the preservation of unconscious knowledge in the absence of conscious awareness of this knowledge can be shown in various cognitive domains following cortical brain injury. Extrapolating from these observations, it can be argued that this distinction may well be usefully applied to a majority (and possibly all) neuropsychological disorders, even extending to those disorders in which the implicit/explicit distinction is not usually employed. For example, in a condition known as ideomotor apraxia, patients have been noted who may be unable to demonstrate an action in a clinical setting, and yet may have no problem with the execution of the movement in the context of their everyday life (Leiguarda & Marsden, 2000). This distinction between performance in the clinical setting and ability in everyday life could be reformulated as a distinction between an inability to perform "on command" (or explicitly) and an ability to perform automatically (or implicitly). In this way, the distinction is much like that discussed in the context of other neuropsychological disorders - such as those mentioned previously in this piece - in which a direct test (i.e. requesting performance "on command") often reveals a deficit in explicit cognition in cortically damaged patients, while an indirect test (i.e. assessing automatic influences on cognition) frequently reveals a relative or absolute sparing of implicit cognitive functioning. In achromatopsia, the patient's colour perception is impaired such that s/he typically experiences the world in shades of grey and colour can appear to be very washed out (Meadows, 1974). However, there is evidence that some forms of colour processing mechanisms continue to work in at least some cases of achromatopsia. In these cases, some of the cortical mechanisms that show sensitivity to different wavelengths of light still operate, but there is apparently no subjective experience of colour (Heywood, Cowey & Newcombe, 1991). A further example comes from the phenomenon of Balint's syndrome, in which a single object can be perceived despite the person affected being apparently unaware of its location. Kim and Robertson (2001) have argued that in Balint's syndrome spatial information for visual features that cannot be explicitly located is nevertheless represented normally below the level of spatial awareness, even after large occipito-parietal lesions. In addition, there is also evidence of problems in self-consciousness (which may also be justifiably be conceptualized as a problem with awareness) after frontal lobe lesions (Damasio et al., 1990; Stuss, 1991), and to unawareness of impairment (i.e. anosognosia) after different types of brain injury (McGlynn & Schacter 1989). Indeed, Marcel (1993) has suggested that the types of dissociations between implicit and explicit processing that we have considered in this piece are somewhat reminiscent of the effects of hypnosis and other dissociative states.

These further points notwithstanding, the question remains as to whether the implicit/explicit distinction is a valid and useful distinction across a range of different situations and participant populations. This issue will now be examined. The implications of the findings reviewed in the previous sections for our understanding of the parameters of different neuropsychological disorders, for our conceptualization of normal cognitive functioning, and for the neural basis of consciousness are also considered. It is clear from the brief review presented here that there is significant evidence for preserved implicit functioning across a range of cognitive domains. But does this truly reflect preservation of specific qualitatively distinct implicit or non-conscious brain "modules" (as would be indicated by the demonstration of an implicit/explicit double dissociation) or - rather -- is it more likely that this represents the preservation of merely simpler and less resource-demanding forms of processing after brain injury? In other words, does the evidence cited above imply that implicit and explicit processing are qualitatively distinct or merely quantitatively different? As noted earlier, there is strong evidence for double dissociations of function within the domains of long-term memory and - to a lesser extent -- in blindsight and aphasia. However, there is little if any evidence for double dissociations of function in the domains of agnosia and neglect. Indeed, in the latter -- as pointed out earlier -- it is hard to conceive of meaningful evidence that would support a double dissociation. Nevertheless, there are other informative examples which impact on this question from outside the domains that we have considered directly in this piece. For example, Bisiach and Geminiani (1991) and Marcel (1993) have noted inconsistencies between denial after brain injury as evidenced by actions and verbal reports. For example, a patient with left-sided paralysis following a right hemisphere stroke may complain bitterly about his or her problem but still try to get out of bed and walk, whereas another patient may deny having any deficits on verbal questioning but makes no attempt to get out of bed. In each case, words and actions are inconsistent with each other, but in directly complementary ways. Taken together, there is therefore some evidence that implicit and explicit modes of processing rely on separate neurally-encapsulated modules, although at the present time it cannot be ruled out unequivocally that this distinction merely reflects a difference in level of difficulty of so-called implicit and explicit tasks, especially within certain cognitive domains.

Is there any evidence that the implicit/explicit distinction is valid in controls as well as brain-injured individuals, and what does it tell us - if anything - about the nature of consciousness and its neural basis? Dissociations between implicit and explicit cognition have been demonstrated in various modalities in healthy participants. Over 30 years ago, Zajonc (1968) demonstrated the mere exposure effect, whereby the more often participants viewed particular items, the more favourably they rated those items. Furthermore, Zajonc (1980) demonstrated that this effect was not dependent on conscious memory of these items, as indicated by chance performance on a forced choice recognition test. The dissociation between implicit and explicit memory has also been widely studied in controls using visual priming studies (e.g., Jacoby et al., 1993). Implicit processing of auditory information has been observed in healthy individuals in experiments such as those which require the identification of words masked by white noise (Schacter et al., 1993). A dissociation between perception and action has been found in non brain-damaged individuals (Haffenden and Goodale, 1998). The findings of Haffenden and Goodale (1998) in non brain-damaged individuals were somewhat analogous to the preserved covert judgements of object size which Goodale and co-workers had previously reported in brain-injured visual agnosic participants, despite errors in overt judgements (Goodale et al., 1991). Haffenden and Goodale (1998) found that when control participants were required to judge the size of a central disk in a three-dimensional version of the Titchener Circles Illusion, they made errors consistent with the illusion. However, despite the presence of this visual illusion, when asked to reach out and pick the central disk up, participants' grip apertures were appropriate for the size of the disk. From these findings, the authors suggested separate neural pathways guiding prehension and perception. A similar dissociation was demonstrated in unimpaired individuals using the "size-weight" illusion (Flanagan and Beltzner, 2000). When objects of equal weight - but unequal size - are lifted, the smaller is judged to be heavier. However, when participants were required to lift these weights repeatedly, they scaled their fingertip forces to be appropriate for the true weight of the objects, despite the persistence of the "size-weight" illusion.

Taken together with the findings in non brain-damaged individuals, the findings of dissociations between explicit and implicit processing in brain-damaged individuals significantly inform our conceptualisation of the cognitive architecture of the mind-brain. Furthermore, these demonstrations of the implicit/explicit distinction in healthy as well as brain-damaged individuals imply that there is distinct neural underpinning for conscious versus nonconscious cognitive processing.

So what is the possible neural basis of this distinction? Following cortical brain injury, behavioural neurologists conducting a clinical examination typically investigate whether there has been any release of more primitive, subcortically-mediated reflexes. Is there any evidence for similar mechanisms underlying the release of implicit cognitive processes following brain injury? The answer to this question would appear to be both "yes" and "no". For example, with respect to more primary perceptual capacities for example, in blindsight -- there is some suggestive evidence for mediation of some implicit phenomena via non-cortical pathways, although clear involvement of extrastriate cortical regions has also been demonstrated in blindsight (Cowey & Stoerig, 1991). With respect to other cognitive capacities (such as, for example, language or memory), there is evidence for mediation of implicit phenomena via complementary cortically-mediated mechanisms. It may well be the case that preserved implicit phenomena in neglect are also mediated by complementary components of a cortical "attention" network. However, in the domains of agnosia and prosopagnosia, there appears to be little clear evidence for either cortical or subcortical mediation of reported implicit phenomena at present.

And is the implicit/explicit distinction a clinically informative distinction? In other words, should the apparent preservation of implicit processes and impairment of explicit processes have implications for the kinds of rehabilitation regimes that are used in clinical practice? The implicit/explicit distinction in memory may certainly have implications for learning strategies in patients with amnesia, and this may also be relevant for other cognitive domains. For example, Wilson, Baddeley, Evans and Shiel (1994) found that errorless learning in amnesic patients was more successful than errorful learning when it was used as a training regime for the purposes of rehabilitation. In the initial phase of this study, amnesic and control participants were presented with lists of word stems and they were required either to guess the word (which permitted incorrect responses) or were provided with the whole word (preventing incorrect responses). At the end of the study phase, participants were asked to recall the words which had been presented to them using an explicit cued recall task (stem completion). The amnesic participants' performance was poorer than that of controls. However, amnesic individuals performed significantly better in the errorless learning condition than in the errorful learning condition. The authors argued that implicit learning - on which amnesic patients are thought to be heavily reliant - is particularly susceptible to interference, and is therefore not well equipped to deal with errors. The implications of these findings for rehabilitation is that if new information is to be learned as effectively as possible by amnesic individuals, contamination of implicit memory should be prevented. Wilson et al. (1994) also tested the effectiveness of errorless learning with amnesic individuals in real-life situations, and found that this was superior to errorful learning.

The dissociation of implicit and explicit processing in neuropsychological conditions may - therefore - have implications for the attempted rehabilitation of at least some of these clinical disorders. However, is the distinction useful for the everyday functioning of an individual patient? Ultimately, for an individual with any clinical impairment, the most important information concerns the nature of the deficit, what improvement they can expect, and the nature of the spared functions. It seems questionable whether in many everyday situations relatively preserved implicit processing would be of significant self-directed benefit for brain-injured patients because of the very nature of this processing; by definition, implicit processing is not governed by conscious control. Therefore, the implicit/explicit distinction is probably not so useful for the personal insight of an individual patient, except insofar as it may usefully guide possible rehabilitation directives (as in the possible case of amnesia, noted above). Furthermore, although there has been considerable reference in the neuropsychology literature to the preservation of implicit processes, future work should perhaps focus on whether there is absolute (rather than simply relative) preservation of implicit processes in patients compared with controls. The findings of these investigations will have significant clinical as well as theoretical implications.

Nevertheless, the implicit/explicit distinction has revealed valuable information about the underlying nature of neuropsychological disorders, as well as enhancing our understanding of normal cognitive processing and human consciousness. In inferring normal processing from neuropsychological evidence one, of course, needs to be mindful of a number of assumptions. One is the assumption that a focal lesion to one part of the brain results in damage to one "system" or "module", and the rest of the brain (other "modules") continue to function (more or less) normally in the absence of this lesioned part. This is sometimes known as the subtractivity assumption. Another assumption is related to the reorganization of the central nervous system following brain lesions. This reorganization has been shown to occur both at brain sites close to the damage and at sites distant from the damage (Weiller, 1998). Performance on a given cognitive task in a brain-injured individual may therefore reflect this neurocognitive reorganization, and may not have any significant relevance for normal processing. Given these caveats, however, neuropsychological data can improve our understanding of normal functioning of the mind-brain, given that these data are not studied in isolation. In other words, theories of normal functioning should not be based solely on the performance of brain-damaged patients. Instead, the findings of cognitive studies of brain-injured individuals should be inter-related with findings obtained from the study of healthy individuals. From the findings reviewed in this article, it seems that the implicit/explicit distinction applies to normal cognitive functioning in addition to cases of neuropsychological disorders. Furthermore, as indicated in the previous sections of this piece, by studying impaired individuals, we are able -- to some degree - to "carve cognition at its joints". In the process, important functional elements of cognition are revealed. As stated by Kohler and Moscovitch (1997), "brain damage and other extreme conditions only reveal starkly what otherwise would be difficult to detect" (pp. 361).

The distinction between implicit and explicit processing is - of course - intimately related to the nature of conscious awareness. From this perspective, in future a "more detailed examination of such parallels and divergences between different types of clinical conditions involving covert processing of visual information may have great promise for elucidating the nature of the mechanisms involved in sustaining awareness" (De Haan et al., 1987, p. 412). With respect to the subtypes of conscious awareness that have been proposed by some authors in the literature (for example, Young & Block, 1996), we have largely been dealing with instances of "access consciousness" in this piece, although blindsight has been considered by Young and Block (1996) as the prototypical example of "phenomenal consciousness". From the selected review of the neuropsychology literature presented in this article, we have already seen that there is good evidence for a neurally grounded decoupling between (in broad terms) conscious and unconscious aspects of mental life and behaviour (at least in certain cognitive domains). Researchers should now start to consider how different proposed elements of consciousness (see, for example, Young & Block, 1996) are mediated by the brain, and how these proposed elements may manifest themselves across the range of neuropsychological disorders. A thorough consideration of the neuropsychology literature from this perspective should have significant implications. Such a consideration will provide further, more detailed insight into the architecture of normal cognitive processes, the nature and neural basis of consciousness, the conceptualisation of the conscious versus unconscious mind and the ways in which the relevant findings can potentially be harnessed in the clinic.

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