Implicit learning in Closed Head Injured subjects: Evidence from an event sequence learning task.

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A group of 20 closed head injured (CHI) subjects and 20 neurologically intact controls were tested on an event sequence learning task (Nissen & Bullemer, 1987) designed to assess implicit learning. Despite severe explicit memory and learning deficits as measured by the California Verbal Learning Test, CHI subjects showed intact implicit learning and this learning was retained over a 20 minute delay. The results support the view that implicit memory and learning processes are relatively robust in the presence of severe neurological damage.

In recent years a distinction has been made between memory and learning processes that require conscious awareness and those that do not (Graf & Schacter, 1985). In the memory domain, explicit memory requires a conscious recollection on behalf of the individual and is typically measured by free recall and recognition tests. Implicit memory on the other hand, may be defined as "memory for information that was acquired during a specific episode and that is expressed on tests in which subjects are not required, and are frequently unable, to deliberately or consciously recollect the previously studied information or episode itself" (Schacter, 1990, p. 338). Typically, a dissociation exists between explicit and implicit memory performance. This is most marked in amnesic groups where the typical finding is one of a relatively intact implicit memory in the presence of severely impaired explicit performance (Graf & Schacter, 1985; Graf, Squire, & Mandler, 1984; Schacter & Graf, 1986).

In the field of learning, there is also increasing evidence that subjects can learn new information over time without being aware that they are engaged in a learning process, or being aware that there is anything to learn. Such learning without awareness has been termed implicit learning (see Reber, 1992). A number of experimental procedures have been used to demonstrate implicit learning including the manipulation of social information (Hill, Lewicki, & Neubauer, 1991; Lewicki, 1986), artificial grammar learning (Reber, 1967, 1989) and event sequence learning (Hartman, Knopman, & Nissen, 1989; Nissen & Bullemer, 1987).

In keeping with the findings within the memory literature, implicit learning appears to be preserved under conditions which impair explicit learning processes, and within certain groups of individuals who display severe deficits in explicit learning. Thus, implicit learning has been found to be preserved in Korsakoff patients (Nissen & Bullemer, 1987), normal aged adults (Howard & Howard, 1989), patients suffering from Alzheimer's disease (Knopman & Nissen, 1987), and subjects under the influence of scopolomine (Nissen, Knopman, & Schacter, 1987). In summing up numerous studies demonstrating implicit learning and memory, Reber, Walkenfeld, and Hernstadt (1991) concluded that implicit processes typically survive neurological and psychological damage whereas explicit processes are severely compromised.

Some groups however appear to show impaired implicit learning, for example Huntington's patients (Knopman & Nissen, 1991) and those under the influence of Lorazepam (Knopman, 1991). The aim of the present study is to examine implicit learning in closed head injured (CHI) subjects. Much of the neuropsychological work with this group has focussed on elucidating the specific nature of the memory deficits such as recognition memory, auditory versus visual processing, short term versus long term memory, attentional deficits, and automatic versus effortful processing (Crossan, Novack, Trennery, & Craig, 1988; Haut, Petros, Frank, & Lamberty, 1990; Levin & Goldstein, 1986; Parkin, 1982; Shum, McFarlane, Bain, & Humphreys, 1990; Vakil, Blanchstein, & Hoofien, 1991; van Zomeren, Brouwer & Deelman, 1984). From this work it is clear that CHI subjects have severe explicit memory and learning deficits, but less is known of their abilities when tested with tasks designed to measure implicit learning. Ewart, Levin, Watson, and Kalisky (1989) used mirror reading, mazes, and a pursuit motor task to investigate the possibility that the learning of skills is preserved during the Post Traumatic Amnesia (PTA) phase of 16 severe CHI subjects. Their findings showed that despite maintained impairment of explicit memory during

PTA, the performance of the CHI subjects improved across sessions on all procedural tasks.

Based on the finding by Levin, Goldstein, High, and Eisenberg (1988) that about one quarter of long term survivors of CHI have impaired explicit memory relative to their normal intellectual functioning, further investigation into those cognitive aspects which may be preserved seems warranted. In the present study, implicit learning by CHI subjects was assessed using the event sequence learning procedure devised by Nissen and Bullemer (1987). In this procedure, subjects sit in front of a computer screen and are shown an asterisk which appears in one of four locations along the bottom of the monitor. Subjects are instructed to react to the presentation of the stimulus by pressing, as quickly as possible, the one of four allocated keys that is positioned below the stimulus. A correct response erases the stimulus and another appears 500ms later in one of the other three positions. Unbeknown to the subject the location of stimuli is not determined randomly but follows a pattern whereby the stimuli follow a 10 trial sequence which is then repeated. The beginning and end of the sequence is not marked in any way. Each subject typically receives 10 repetitions of the sequence (100 trials) which makes up a block and typically 4 blocks are presented overall. At the end of the fourth block a fifth block is presented whereby the position of the stimuli is determined randomly. The dependent variable is reaction time (RT) and learning of the sequence is inferred from a reduction in RT over the 4 learning blocks as well as an increase in RT when the switch is made to a random presentation on the fifth block. Of interest is that subjects can learn the sequence over time even when they are unaware of the sequential nature of the stimuli (Nissen & Bullemer, 1987).

In the present study the performance of CHI subjects was examined using the Nissen and Bullemer procedure. Subjects were presented with 4 blocks of sequentially presented stimuli followed by a fifth block in which the stimuli were presented in random order. In order to assess the ability of subjects to retain any learned information, a sixth block of sequential stimuli was presented after an interval of 20 minutes. The performance of subjects in the SRT task was compared with their performance on the California Verbal Learning Test (CVLT: Delis, Kramer, Kaplan, Ober, & Fridlund, 1987), a test of explicit memory and learning functioning.

Method

Subjects

Head injured subjects were recruited either through an advertisement in the newsletter of the Wellington Branch of the Head Injury Society or through being approached by members of the Society. To be selected subjects had to have sustained a closed head injury which had occurred a minimum of 6 months prior to testing. Those with a prior history of psychiatric illness, or drug or alcohol abuse were eliminated. Finally, evidence of having undergone a period of unconsciousness immediately following the injury was necessary. Twenty subjects (twelve men) met these criteria. Their mean age was 34.55 years (SD=10.73). Eleven subjects had sustained their injuries in motor vehicle accidents, and the rest by various other means. Reliable estimates of coma length were established for all subjects. Estimates were based on medical reports, family member information and/or self report. All subjects were reportedly unconscious for at least 48 hours and were, therefore, considered to have suffered severe to very severe closed head injuries (Jennet & Teasdale, 1981). A control group of 20 neurologically intact volunteers (12 men) was recruited. All were screened for a history of CNS disorders, alcohol and drug use, and CHI. Controls were closely matched with the CHI group for age (mean age = 33.65, SD = 10.55).

All subjects were assessed on the National Adult Reading Test (NART). The NART (Nelson, 1982) is a 50 word reading list designed to provide an estimated premorbid intelligence level for adults suspected of intellectual impairment. It was used to assess general intellectual level across the two groups. The NART provided an error score for each subject calculated from the number of correct pronounciations subtracted from the maximum total of 50 words. The subjects error score was then converted into a predicted WAIS Full Scale IQ score. The mean error score for the CHI group was 23.3 words (SD = 8.81), and for the control group 20.1 words, (SD= 7.97). This difference was not significant.

Measures

California Verbal Learning Test

The CVLT (Delis, et al., 1987) consists of 2 lists, A and B, each comprising the names of 16 shopping items from 4 different categories. Subjects are read all of the List A items and are tested by free recall. Five trials of List A are completed. The number of correct responses as well as intrusions and perseverations is scored for each trial. Immediately after the five List A trials, an interference list, (List B) is presented and recall is tested on this list. Finally List A items are tested without further presentation.This is followed by a cued-recall procedure whereby the subject is provided with the category names and asked to recall the exemplars within them. After a 20 minute interval a delay trial begins consisting of one free recall, one cued recall, and a recognition testing of List A. The CVLT has been reported to distinguish between long term survivors of severe CHI and normal controls (Crosson, et al., 1988) and clinically distinct types of memory disfunction (Crosson, Novak, Trenerry & Craig, 1989).

Serial Reaction Time Task (SRT)

The SRT task was similar to that used by Nissen and Bullemer (1987). The stimulus consisted of an asterisk 0.35cm in diameter that appeared in one of four locations, each of them 2.5cm from the bottom of a computer monitor. Each position was separated horizontally by 2.9cm. At a viewing distance of approximately 60cm the four locations were separated by a visual angle of 2.90 degrees. Responses were made by pressing the one of four keys along the top of the keyboard that was most closely alligned with the 4 stimulus locations. A correct response erased the stimulus and a new one appeared in a different location after an interval of 400ms. To assess the effects of task difficulty on performance, two separate versions of the task were devised. The first comprised stimuli which followed a repeating 10 trial sequence (Short sequence) while a second was made up of a repeating 15 trial sequence (Long sequence). For the 10 trial sequence the pattern used by Nissen and Bullemer (1987) was used. An additional 5 locations were determined randomly and added on to the 10 trial sequence to make up the 15 trial sequence. For both sequence conditions no two consecutive stimuli appeared in the same location. Each block of trials consisted of 10 repetitions of the sequence. The end of one sequence and the beginning of another was not marked in any way and subjects were not informed of the presence of any pattern. For the random condition each location was determined randomly with the constraint that no two stimuli appeared in the same location consecutively.

Procedure

All subjects were tested individually in their homes or, in a few instances, in their work place. All CHI subjects were tested first following a set procedure: Subjects were randomly assigned to either the short sequence group (10 element) or the long sequence group (15 element). All subjects were then administered the initial trials of the CVLT. During the 20 minute delay on this test subjects completed the first 5 blocks of the SRT task.They were instructed to rest their middle and index fingers of both hands over the 4 marked keys on the computer keyboard and were told that upon seeing the stimulus they should press the key directely below it as quickly as possible whilst at the same time maintaining accuracy. Each block was separated by a 3 minute rest period. The first 4 blocks consisted of the repeating sequences and on the fifth block the location of the stimuli was random. At the completion of Block 5 subjects then completed the delay and recognition trials of the CVLT. The NART was administered and finally subjects gave details of their injury. At the completion of this, (or after 20 minutes which ever came first) subjects completed Block 6 of the SRT task, which contained the repeating sequence. The testing procedure varied slightly for the control group. The NART was administered first to establish eligibilty for inclusion. For this reason the time normally filled at this point was taken up with conversation.

Results

CVLT All subject's raw scores were converted to standard (T) scores for trials 1 to 5. The overall mean T scores and those of the primary scores are shown in Table 1. Significant differences were obtained for all 9 measures.

Table 1. Comparison of CVLT performance of CHI and control subjects

	CHI		Controls		
CVLT	*M*	*SD*	*M*	*SD*	*t*
List A Total:					
Trials 1-5	41.15	11.93	67.85	5.09	9.21**
Trial 1	6.00	1.81	9.65	2.03	6.00**
Trial 5	9.65	3.01	15.45	0.83	8.31**
List B	5.05	2.74	8.40	1.35	4.90**
List A Short Delay:					
Free Recall	8.10	3.81	13.80	2.26	5.75**
Cued Recall	9.15	3.28	14.50	1.47	6.66**
List A Long Delay:					
Free Recall	7.65	4.02	14.25	1.80	6.70**
Cued Recall	8.80	4.29	14.35	1.73	5.37**
Recognition (Hits)	13.85	2.62	15.45	0.83	2.60*

* p < .05
* * p<.001 **

SRT task

The median reaction time (RT) of correct responses in each set of 10 or 15 trials within a block was determined and the mean of these medians was computed. A 2(Group) X 2 (Sequence Length) X 6(Block) revealed a significant main effect of Group, $F(1,32) = 39.31$, p <001, and a significant main effect of Block, $F(5,180) = 32.90$, $p<.001$. Sequence Length was not significant neither did it interact with any other factor. There were no other interactions. The means of the median response times for CHI and control subjects collapsed across sequence length are shown in Figure 1.

To examine the extent of sequence learning, the procedure adopted by Howard and Howard (1989) was followed. Sequence learning was calculated for each subject by subtracting Block 4 response times from those of Block 5, and was considered to have occurred if RT increased at Block 5. For the CHI group there was a 60ms increase in RT from Block 4 to Block 5, a score which was significantly different from zero, $t(19) = 5.74$, $p<.01$. For the control group, there was a 110 ms increase in RT from Block 4 to Block 5, this score also being significantly different from zero, $t(19) = 6.21$, $p<.01$.

To examine retention of sequence learning, a score for each subject was calculated by subtracting Block 6 response times from those of Block 4. Retention of sequence learning was considered to have occurred if RT for Block 6 did not significantly increase from RT performance on Block 4. For the CHI group, Block 6 scores were on average 52ms faster than Block 4 scores. For the control group Block 6 scores were 22ms faster.

Discussion

The CHI group in this study clearly demonstrated impaired functioning on the CVLT. In this regard the findings are consistent with a number of studies that have examined performance on the CVLT with various neurologically impaired groups. Thus patients with Alzheimer's disease (Kramer, Levin, Brandt, & Delis 1989); multiple sclerosis (Kessler, Lauer, & Kausch's study as cited in Delis, Massman, Butters, Salmon, Cermak, & Kramer, 1991); Parkinson's disease (Massman, Delis, Butters, Levin, & Salmon 1990); Huntington's disease (Strauss, Brandt, Hale, & Folstein's study as cited in Delis et al.,1991); Korsakoffs syndrome (Delis, et al., 1991); temporal lobe epilepsy, (Hermann,

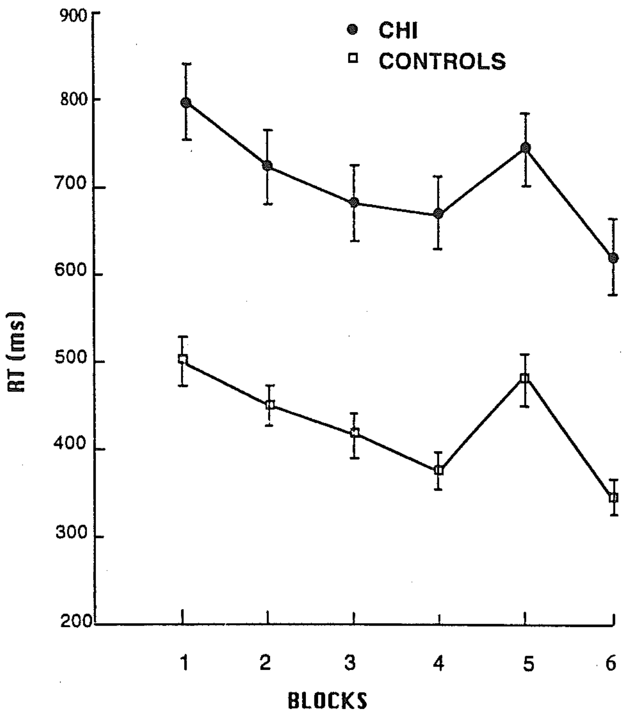

Figure 1. Mean RT over blocks for closed head injured (CHI) subjects and controls. Bars are standard errors.

Wyler, Richey, & Rea, 1987); and head trauma (Crosson, et al., 1988), have all demonstrated clear impairment on the CVLT.

Despite this significant impairment of explicit recall and learning, the CHI group demonstrated relatively preserved implicit learning on the SRT task as indicated by the significantly longer RT on Block 5, as well as the lack of interaction with Group and Block. This overall finding mirrors other studies of neurologically disordered groups using the same task. These include most patients with Alzheimer's disease (Knopman, 1991; Knopman & Nissen, 1987); ECT patients (Nissen & MacKenzie's study as cited in Nissen, 1992); Korsakoff patients (Nissen & Bullemer, 1987; Nissen, Willingham & Hartman, 1989); and healthy adults given scopolamine (Nissen, Knopman, & Schacter, 1987).

Apart from demonstrating learning across Blocks 1 to 4 as shown by a large transfer effect in Block 5, CHI subjects also retained their learning over a 20 minute activity filled period. This finding is consistent with the results found by Howard & Howard (1989) who demonstrated retention over a 30 minute period with young and old subjects. The same retention interval was used with drug induced amnesic subjects with similar results (Nissen, et al.,1987). Korsakoff subjects also demonstrated learning on the SRT task across a one week interval (Nissen, et al.,1989), and some Alzheimer's subjects retained learning over a 1-2 week interval (Knopman, 1991).

Unlike the finding by Howard and Howard (1989) the present study found no significant difference in learning as a function of sequence length with either the CHI or control groups. Howard and Howard (1989) found with aged subjects that sequence length did influence performance with poorer learning occurring in the long pattern.

It is not clear why this finding was not replicated in the present study, and further research is needed to explore the extent to which sequence length interacts with performance in CHI subjects.

Although implicit learning was shown to be relatively preserved in the CHI group, they were slower in their overall RT than the control subjects. Similar findings have been obtained in the previously cited studies which have all demonstrated an overall slower RT in impaired groups relative to their equivalent controls. The attentional requirements of the task may play a critical part in this result and there is evidence that CHI subjects typically display reduced attentional resources (van Zomeren, 1981). Indeed this slowing of overall performance in the presence of preserved sequence learning has been found in normal subjects where the SRT task has been practiced in the presence of a secondary task, designed to reduce attentional allocation (Cohen, Ivry, & Keele, 1990; Curran & Keele, 1993; McDowall, Lustig, & Parkin, 1995).

Nissen et al., (1989) have suggested that a common property of those implicit learning tasks which amnesic groups do learn (e.g. SRT task), is that "the stimulus environment provides strong constaints on response selection" (p.350). In the SRT task the stimulus presented on each trial specifies which response is to be made without the subject having to generate incorrect responses. The impaired response selection ability of CHI subjects which has been demonstrated in other tasks (Shum, McFarlane, Bain, & Humphreys, 1990), may have been assisted by this property of the SRT task.

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