Neuropsychiatry, Neuropsychology, and Behavioral Neurology
Vol. 9, No. 3, pp. 176–181

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Direct and Indirect Measures of Contextual Information in Brain-Injured Patients

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Summary: Several investigators have suggested that amnesics fail to encode contextual information. Support for this approach was derived from studies that tested the recall or recognition of different aspects of contextual information. In the present study, we tested the possibility that contextual information is encoded by patients with memory impairment but cannot be retrieved by direct methods. The distinction between direct and indirect recall of context is an important one that has not been sufficiently addressed with regard to brain-injured patients. Fifteen brain-injured (BI) patients and 19 non–brain-injured (NBI) subjects participated in this study. The results show that when contextual information was tested directly the NBI group outperformed the BI group. However, both groups benefited from the contextual cues (i.e., indirect measure). Results are interpreted in terms of the theoretical distinction between implicit and explicit memory regarding contextual information; implicit memory is shown to be preserved in patients with memory impairment. **Key Words:** Brain injury—Amnesia—Contextual information—Indirect memory. **NNBN 9:176–181, 1996**

Memory disturbance is the most prominent residual deficit following brain injury (1,2). In reviewing the literature, Baddeley and co-workers (1) concluded that the pattern of memory deficit shown by brain-injured (BI) patients is similar to that of classic amnesic patients. The medial temporal lobe (3) and the basal forebrain (4) have been linked to memory functions, and both are vulnerable to traumatic brain injury (5).

Several investigators have suggested the "context theory" as an explanation for the underlying impaired cognitive mechanism in amnesia (6–8). They posit that amnesics fail to encode contextual information that normally serves as cues in the retrieval stage. Thus, poor target memory is a consequence of poor contextual memory. Different versions of this approach have been offered in the literature (9).

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Received November 20, 1995; revised January 26, 1996; accepted February 20, 1996.

Investigators disagree regarding involvement of effortful or automatic mechanisms in processing contextual information. Kinsbourne and Wood (10) claim that amnesics have an attentional deficit that disrupts encoding and retrieval of contextual information requiring attentional effort. Among the studies supporting this approach are Smith and Glenberg (11), Smith (12), and Winocur and Kinsbourne (13). In these studies, different information (e.g., lists of words) was learned in *very distinct* contextual environments (e.g., different rooms or different physical conditions). Only under these circumstances did amnesics show improved memory, expressed either by reduction of negative transference from one list to the other or by improved recognition when the test was performed in the original learning environment. That normal subjects functioned effectively with minimal cueing was interpreted as reflecting the amnesics' deficit in attentional encoding and retrieval of contextual information.

A different version of the contextual hypothesis was suggested by Hirst and Volpe (6), who argued that contextual information is normally encoded automatically, since "target" and "context" cannot be simultaneously encoded effortfully. Thus, the target, which is the focus of attention, is encoded effortfully while the context is encoded automatically. According to this approach, amnesics fail to encode contextual information due to the breakdown of automatic processes. In support of their view, Hirst and Volpe (6) cite many studies in which amnesics were impaired in their recall and recognition of contextual information. Similar studies were conducted with other memory-impaired populations, such as the elderly (14) and BI patients (15). Most of these studies tested direct recall or recognition of different aspects of contextual information, such as temporal order or spatial location of items (7,16,17). Impaired recall or recognition of this information by memory-impaired patients was interpreted as supporting the contextual theory.

On the other hand, the contextual theory presents difficulty in interpreting some findings with amnesics (9). For example, Squire (18) showed that even when target item memory is matched to that of non–brain-injured (NBI) subjects, patients still evidence poorer memory for contextual information (i.e., temporal judgment). However, frontal lobe-lesioned patients who normally recognize target items are impaired in temporal order judgment (19). Furthermore, the severity of amnesia did not correlate with the severity of temporal judgment impairment (18). These studies tested temporal order as an aspect of contextual information, whereas temporal order might be a special feature of context that differs from other aspects of context (20,21).

Mayes and colleagues (22) reported two experiments in which they showed that amnesics, unlike normal subjects, did not benefit from interactive context (when words meaningfully related to target words are presented simultaneously with the target words). Furthermore, patients showed poorer recognition of the interactive context words. A more recent study by Priestley and Mayes (23) showed that priming for interactive context was preserved in amnesics.

In the present study, we tested the possibility that contextual information, though not accessible through intentional retrieval processes, may be encoded and serve as retrieval cues. The distinction between direct and indirect measures of contextual information is an important one that has not been sufficiently addressed with regard to BI patients. Vakil et al. (15) showed that when intentional retrieval (i.e., direct) of temporal order of a word list was required, BI patients were impaired as compared with NBI subjects. However, with regard to incidental retrieval (i.e., indirect) of temporal order of a word list, the two groups did not differ significantly. A similar pattern of results was obtained in a study by Vakil et al. (15) in which BI patients were impaired as compared with controls when direct frequency judgment of words was required. However, when frequency was assessed indirectly by a word-stem priming task, the groups did not differ from each other. It is argued that the fact that many studies have shown that memory-impaired patients failed to recall or recognize contextual information directly does not necessarily indicate that this information was not encoded and was not used indirectly. Therefore, it is hypothesized that memory for context should manifest itself through its *indirect* effect on target memories after changes in background context. By contrast with contextual theory prediction, we expect a similar effect for the BI group and the NBI group under this condition. However, memory for context is assessed *directly* by testing recognition for items previously shown as context for other information. In accordance with the contextual theory, the BI patient group is expected to be inferior to the NBI group on this task.

METHOD

Subjects

Two groups of subjects participated in the present study: A sample of NBI subjects was the comparison group for the BI patient group. The NBI group consisted of 19 volunteers aged 20–31 years (mean 25.84 years) with 12–14 years (mean 12.26 years) of schooling. The BI group was composed of 15 patients aged 16–44 years (mean 29.47 year) with 10–19 years (mean 12.40 years) of schooling. The groups were not significantly different either with regard to age ($t(32) = .10$, $p > .05$) or on educational level ($t(32) = .81$, $p > .05$). Table 1 provides a more detailed description of the patient group. The BI patients were recruited for the study from a population of patients hospitalized in the Loewenstein Hospital (Israel) for rehabilitation after a brain injury. All subjects were at least 10 weeks postinjury (Table 1). All patients selected for the study passed a screening battery administered by the occupational therapist and the speech pathologist in the hospital department. The Loewenstein Occupational Therapy Assessment (LOTCA) battery was administered (24). This battery included tests of orientation, visual and spatial perception, visuomotor organization, and thinking operations. Furthermore, patients referred to the study had been evaluated at least 1 month earlier by an interdisciplinary team in the department as no longer having posttraumatic

TABLE 1. *Demographics of the brain-injured patient group*

Patient/age (yr)/sex	H	Education (yr)	Time after onset (wk)	Coma (days)	GCS
1/16/F	R	10	27	35	5
2/25/F	R	12	11	21	5
3/37/M	L	15	13	2	7
4/40/M	R	15	42	7	7
5/32/M	R	11	25	24	7
6/38/M	R	19	27	17	6
7/42/M	R	11	11	—	—
8/24/M	R	12	19	2	6
9/21/F	L	12	26	6	5
10/44/M	R	11	24	5 h	—[a]
11/26/M	R	12	40	45	4
12/21/M	R	12	31	6 h	9
13/32/M	R	10	19	15	8
14/22/M	R	12	20	6	—[a]
15/22/M	R	12	30	14	6

H, Handedness; GCS, Glasgow Coma Scale, on admission to hospital.
[a] Information not found in medical records.

amnesia (PTA). Therefore, the patients' intellectual and linguistic functioning was at a level enabling adequate responsiveness to the task requirements based on the tests conducted. None of the participants had a history of alcohol, drug abuse, or psychiatric illness.

Testing Material

Three sets of slides were used in the present study.

I. Learning set. The learning set consisted of 21 slides with pictures of a common object (i.e., target) placed on top of another common object (i.e., context), such as a book placed on a chair. Objects were chosen so that there was no natural relation between the target and context items; e.g., we did not present a picture of a book on a bookshelf.

II. Testing set. The testing set consisted of 42 slides like those in the learning set. The 21 target objects used in the learning set were presented again, but one third (7) were in the "same context," one-third had a "plain context" (white background), and one third were in a "different context" consisting of new items. In addition, there were 21 slides of new objects, one third (7) presented with a context used before with a different object, one third presented with a new context, and one third presented in the plain context. Slides were presented in random order.

III. Context set. The context set consisted of 14 slides, including seven slides with pictures of objects used in the learning set as context and seven slides of completely new objects. Slides were presented in random order.

Procedure

Each subject was tested individually. The 21 slides of the learning set were projected from a slide projector, from a distance of ~2 m, at the rate of one picture every 5 s. Subjects were told: "You will be presented with a series of slides in which one object is placed on top of another object. You are asked to pay close attention to the object *on top* since your memory for *these* objects will be tested." After presentation of the learning set, free recall of the target objects was tested. Subjects were asked to recall as many target items as they could remember. After the free recall task, the testing set slides were projected. With each slide, subjects were asked to decide whether the object presented had appeared in the learning set. Finally, the context set was presented, in which half of the objects had appeared in the learning set as context and half were completely new objects. Subjects were asked to identify the context objects that had appeared in the learning set. All answers were recorded by the experimenter.

RESULTS

Three aspects of measures were analyzed in this experiment: free recall and recognition of target items and recognition of context items.

Free Recall of Target Items

The number of target items correctly recalled by the two groups was subjected to the t test. The results showed a significant advantage of the NBI group (mean 9.47) over the BI group (mean 4.47): $t(1, 32) = 5.27, p < .001$.

Recognition of Target Items

For the recognition of target items, the hit rate and false alarm rate were obtained for each subject. Tables

TABLE 2. *Mean hit rate (and SD) for the BI and NBI groups as a function of the different testing context*

Group	Context		
	Different	Neutral	Same
NBI (n = 19)	6.16 (0.90)	6.21 (1.18)	6.74 (0.45)
BI (n = 15)	4.73 (2.15)	5.20 (1.90)	5.73 (1.62)

BI, brain-injured; NBI, non-brain-injured.

2 and 3 show the hit rate and false alarm rate for the BI and NBI groups as a function of the different context. Both recognition measured were submitted separately to a mixed-design analysis of variance to assess the effect of group (BI vs. NBI) by context (same context as in the learning condition, plain context, and different context); the former is a between-subjects factor, and the latter is a within-subjects factor.

Hit Rate Analysis

Both main effects were significant: group $F(1, 32) = 6.79$, $p < .01$. The NBI group recognized more target items than the BI group; context $F(2, 64) = 8.70$, $p < .001$. Both groups recognized the objects best when they were presented in the same context as in the learning set and recognized them least under the different context condition. The lack of significant interaction between the two main effects indicates that both groups were affected similarly by the different context. Follow-up analysis was conducted to identify the source of significance in the context main effect. Results indicate that the only conditions significantly different from each other were same versus different context situations for both groups.

False Alarm Rate Analysis

As, in hit rate analysis, above, both main effects but not the interaction between them reached significance. The NBI group made fewer false alarms than the BI group [$F(1, 32) = 4.78$, $p < .04$], and more false alarms were made when objects were presented in the same context as compared with the other two conditions, $F(2, 64) = 4.66$, $p < .02$.

Recognition of Context Items

The number of context objects correctly recognized by the two groups was subjected to the t test. The results show a significant advantage of the NBI group (mean 5.53) over the BI group (mean 4.53): $t(1, 32) = 2.13$, $p < .04$.

Pearson product-moment correlations were calculated between the measures of severity of injury (i.e., length of coma, Glasgow Coma Scale on admission to hospital, and time after onset) and the different memory measures. The only significant correlation was that between Glasgow Coma Scale score and the number of context items recognized correctly, $r(12) = .64$, $p < .03$. Two other scores reached near-significance; the correlation between length of coma and the number of context items recognized correctly [$r(14) = -.50$, $p < .07$] and between time after onset and the number of false alarms in target recognition [$r(15) = .50$, $p < .06$].

DISCUSSION

The major advantage of the paradigm we used is that it enabled us to measure direct and indirect aspects of memory for contextual and target information within the same task. In accordance with the results of Baddeley and associates (1) and Levin (2), survivors of brain injury showed impaired memory when measured explicitly. The NBI group recalled and recognized significantly more target as well as more context items than the BI group. This result confirms our assumption that BI patients have impaired memory. Few memory measures were associated with the severity of injury as measured by length of coma and Glasgow Coma Scale, possibly because the severity measures are primarily related to brainstem injury rather than to injury to the regions associated with memory such as the temporal and frontal lobes (25).

The BI patients used and NBI subjects used contextual cues to the same degree. This finding requires more careful analysis. That we used only 21 pictures in the learning set and that on the average NBI subjects recognized more than six of seven pictures raises the possibility of a ceiling effect for the NBI group. Therefore, if controls performed well below ceiling, they may well have manifested a disproportionate tendency to be *more* affected by context manipulation than the BI group. Theoretically, the most telling finding is that the BI group benefited in-

TABLE 3. *Mean false alarm rate (and SD) for the BI and NBI groups as a function of the different testing context*

Group	Context		
	Different	Neutral	Same
NBI (n = 19)	0.11 (0.32)	0.16 (1.38)	0.58 (0.61)
BI (n = 15)	0.87 (1.19)	0.53 (0.83)	1.00 (1.46)

BI, brain-injured; NBI, non-brain-injured.

directly from the contextual information, although this information was not accessible directly. As reported in the Results section, the pattern of performance of the BI group was similar to that of the NBI group. Both groups performed significantly better under the same context condition. The question of whether the NBI subjects might have benefited *more* than the BI subjects under a more demanding memory task remains unresolved.

Even without use of exaggerated contextual cues, our BI patients benefited from contextual cues, unlike the patients of Winocur and Kinsbourne (13), the discrepancy might be explained by the fact our patients had impaired memory, whereas those of Winocur and Kinsbourne were global amnesics. Further investigation is required to determine whether this difference reflects a qualitative or only a quantitative difference between the two patient groups.

Our findings replicate previous findings of Hirst and associates (16,17) indicating that direct measures of contextual information show an impairment in different amnesic groups. However, our findings that both groups benefited from the contextual cues suggests that not only was this information encoded, but it even contributed to retrieval of the information. That the NBI group benefited from contextual cues is in accord with Tulving and Thomson's principle of "encoding specificity" (26) and with a more recent version of this theory: Transfer Appropriate Processing (TAP) (27). These theories emphasize the advantage of testing memory under conditions similar to those that existed during learning. The finding that the BI group benefited from contextual cues can be explained in terms of the distinction between implicit and explicit memory (28). Implicit memory is preserved in amnesics since it does not require intentional retrieval of information, but instead is expressed indirectly through facilitation of test performance without conscious recollection. These findings imply that contextual information is registered and stored but is unavailable through direct-intentional retrieval mechanisms. This does not prevent the information from being available and useful as retrieval cues through indirect-unintentional retrieval mechanisms.

Our findings agree in part with those obtained in a series of studies by Mayes and colleagues (21–23). These studies confirm the distinction between the encoding and retrieval of contextual information. As in the present study, patients with memory impairment exhibited a dissociation between their ability to encode and retrieve the information: Although encoding is preserved, retrieval is impaired. However, another study showed that memory-impaired patients did not benefit from contextual information despite indications that it was encoded (22). There are several possible explanations for this discrepancy. First, Mayes and colleagues (22) studied global amnesics, whereas participants in our study were BI patients with possibly less severe memory impairment. Second, in their study, the target and context were words, but we used pictures of common objects. Therefore, in our study, memory may have depended more on perceptual processing, whereas in the study of Mayes and co-workers (22), memory may have depended more on verbal or semantic processing. Third, in the study of Mayes and co-workers, the context word was presented under the target word, whereas in our study the target object was on top of the context object so that it did not require additional effort to be perceived. Further research is required to evaluate the contribution of each of these possibilities to the discrepancy between the studies.

Finally, our findings argue against the context-memory deficit hypothesis in its general form. A more restricted version of this theory is required, focusing particularly on impairment of retrieval rather than on encoding of contextual information, while taking into account direct as well as indirect effects of contextual information.

Acknowledgment: This work was supported by the Schnitzer Foundation for research on the Israeli economy and society.

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