Self-Monitoring Abilities of Two Adults With Traumatic Brain Injury During Verbal Learning

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Adult survivors of traumatic brain injury (TBI) often display learning and executive function deficits. In this study, two adults with TBI and two control subjects were required to self-monitor their learning by making "judgment-of-learning" (JOL) predictions about future recall. Control subjects were highly accurate when predictions were delayed from the learning episode, but not as accurate when predictions were made immediately following learning. Delayed monitoring accuracy of subjects with TBI was the same as their immediate monitoring accuracy. One subject overpredicted his recall ability, whereas the other displayed poor relative predictive accuracy. Proportions of recall, predictions of recall, and correlations between recall and predictions were necessary in order to identify the different types of monitoring difficulty demonstrated by these subjects with TBI.

Memory and learning impairments are commonly associated with adult survivors of traumatic brain injury (TBI) (Haut & Shutty, 1992; Levin & Goldstein, 1986). Metamemory, or knowledge about memory during learning, has not been quantitatively documented in the research literature, although some studies have identified "awareness of deficit" impairment after TBI (Allen & Ruff, 1990; Prigatano & Altman, 1990). No studies have substantiated the presence of impaired monitoring while learning, i.e., "on-line," although poor self-monitoring is included in "laundry lists" of deficits (Ylvisaker & Szekeres, 1989). If individuals do not accurately monitor their own learning, then the foundation on which decisions for strategy selection are made is faulty. It is the intent of this study to describe the "on-line" monitoring ability of two adults with TBI and two matched control subjects, using methodology common in metamemory research.

Thirty years of research in metacognition has provided a wealth of information describing the monitoring and control strategy processes of neurologically intact and impaired adults. Results of metamemory research indicate that unimpaired populations have profound ability to monitor their own learning under certain conditions (Dunlosky & Nelson, 1994; Nelson & Narens, 1990), whereas individuals with frontal-lobe damage experience difficulty monitoring their own learning and predicting recall (Janowsky, Shimamura, & Squire, 1989). Self-ratings, including predictions of performance, are the techniques traditionally used for examining monitoring accuracy. Presumably, individuals make predictions about performance based on the monitoring and assessment of the item learned, and these predictions are treated as behavioral data (Ericsson & Simon, 1980).

"Judgments-of-learning" (JOLs) were the monitoring techniques selected for this study and are predictions of the likelihood of being able to recall information in the future. JOLs are made during learning acquisition or maintenance. They are highly accurate when made in reference to future recall, but are not reflective of recall performance. Furthermore, JOLs drive decisions about self-directed study strategies (Nelson, Dunlosky, Graf, & Narens, 1994). Two types of JOL predictions are reported in the research literature. Immediate JOL predictions are those made immediately after the item has been studied, whereas delayed JOL predictions are made at least 30 seconds later. Results of several studies have shown that college students' predictive accuracy is extremely high when predictions are slightly delayed, whereas immediate predictive accuracy is significantly lower (Dunlosky & Nelson, 1994; Nelson & Dunlosky, 1991). Although some adults with TBI over- or underestimate their recall performance in general (Prigatano & Altman, 1990), others may be unable to differentiate, during the learning task, between items they will or will not recall later.

The research questions in this study were:

1. Do these two adult survivors of TBI demonstrate similar monitoring accuracy as controls when making immediate and delayed predictions during verbal learning?
2. What is the relationship between recall and monitoring accuracy within single subjects?
3. What is the utility of "judgment-of-learning" methodology for providing evidence of monitoring deficits following TBI?

Methods

Subjects

Two subjects with TBI volunteered to participate in the study and were selected on the basis of a single closed head injury medical diagnosis. At the time of the injury, TBI 1 had been unconscious for 30 minutes, and TBI 2 was unconscious for several days. At the time of this study, both TBI subjects were fully oriented, had recovered from post-traumatic amnesia as reported by the rehabilitation team, and neither had aphasia as determined by the Western Aphasia Battery (WAB; Kertesz, 1982) (see Table 1). Reading comprehension was screened using the Reading Comprehension for Sentences subtest from the WAB, on which both subjects received the maximum score of 40. Before their injury, both subjects had been employed in business. TBI 1 was receiving vocational rehabilitation services; TBI 2 had recently returned to work at the time of this study.

Both subjects were receiving additional outpatient rehabilitation services. Control subjects were matched with TBI subjects based on age, education, and gender, and all subjects were native speakers of English. Control 1 was a businessman; Control 2 was a schoolteacher. No subjects had a prior history of neurological disease, psychiatric illness, learning disabilities, or drug and/or alcohol abuse.

Instructions and Task Description

Subjects were instructed to study a list of word pairs and make predictions about their recall ability on a later cued recall test. All instructions were presented on a computer screen, with the experimenter reading them aloud. For studying, word pairs were presented at a 13-second rate. JOL predictions were made for every item, using the same cue as would be used for the recall test (Dunlosky & Nelson, 1994). Subjects provided verbal predictions, and the experimenter typed in the answer. The query used to elicit the JOL prediction was:

ocean - __?__

How confident are you that in about 8 minutes you will be able to recall the second word that went with this first word, when you see it appear on the screen?

0 = definitely won't
20 = 20% sure
40 = 40% sure
60 = 60% sure
80 = 80% sure
100 = definitely will recall

Subjects practiced making JOL predictions for two items, without difficulty.

A cued recall test immediately followed studying and all JOL predictions (e.g., ocean - __?__). Test order of presentation was randomized in thirds within the two blocks described in the next section. Verbal responses were self-paced, and subjects were required to provide a response, even if they had to guess (i.e., omission errors were not allowed).

Stimuli, Design, and List Construction

Forty unrelated English noun word pairs were presented for study, of which 4 items were used as a primacy buffer only (e.g., *lake–harp* and *foam–meadow*). Item selection was based on concreteness and imagery. Rankings within word pairs ranged from 5.1 to 6.9 in imagery and 6.08 to 7.0 in concreteness (Nelson & Dunlosky, 1991; Paivio, Yuille, & Madigan, 1968). Words receiving the highest rankings were not paired together. Bolded word pairs were a half inch in size.

The experimental tasks included one study trial, in which a within-subjects manipulation of immediate and delayed JOL predictions was followed by a cued recall test. The computer randomly divided items into two blocks, after identifying 4 items used as the primacy buffer. Within each block, half of the items were slated for immediate JOL predictions, and the other half were slated for delayed JOL predictions (Dunlosky & Nelson, 1992). All items within a block were studied and immediate JOL predictions made, before making delayed JOL predictions. Immediate JOL predictions were generated by having subjects provide a JOL prediction immediately after the item was studied. Delayed JOL predictions were made by imposing time between studying and making JOL predictions. This delay was created by mixing the studying of all items (slated for immediate and delayed JOL predictions), and by making immediate JOL predictions for those items slated as such. The amount of time between studying and making delayed JOL predictions ranged from approximately 2 to 4 minutes, depending on the location of the item in the randomly generated block of 18 items. All items in Block 1 were studied and JOL predictions made before the studying of items in Block 2. The actual delay between predictions and recall ranged from 8 to 10-1/2 minutes.

TABLE 1. Characteristics of TBI and control subjects.

Subjects	Age/Sex	Time Post-injury	Education	AQ[a]	Verbal IQ[b]	Logical Memory[c]
TBI 1	46/M	6 mos	19 yrs	98	108	16th%
TBI 2	27/F	3 mos	16 yrs	98.8	100	55th%
Control 1	46/M	na	18 yrs	na	130	86th%
Control 2	29/F	na	16 yrs	na	110	95th%

[a]Aphasia quotient (AQ) from the *Western Aphasia Battery* (Kertesz, 1982).
[b]From the *Quick Test* (Ammons & Ammons, 1962).
[c]Percentile rankings from *Wechsler Memory Scale–Revised* (Wechsler, 1987).

Dependent Variables

The proportion of recall and absolute JOL predictive ratings provide an indication of overall predictive accuracy when considered together. For example, if the mean JOL rating was 85, while overall recall was 10%, then the individual overestimated recall performance. However, this does not measure the individual's ability to predict recall by differentiating between individually studied items, i.e., relative predictive accuracy. The Goodman-Kruskal *gamma correlation* (G) is considered the most appropriate statistic for determining relative predictive accuracy for mixed types of data (Nelson, 1984). The gamma involves the yoking of the JOL rating with recall for each item and is generated by subtracting all discordances from concordances, and dividing by the total number of discordances and concordances. All ties in ratings or recall are excluded from the equation. The gamma correlation provides an indication of whether the individual can predict recallability of one particular item when compared to another item, providing a relative comparison of predictive accuracy.

Results

Recall

Recall of word pairs varied across all subjects. Figure 1 illustrates the proportion of recalled items in each JOL condition. A review of these data confirms that recall of immediate JOL items was similar to that of delayed JOL items for all subjects.

Monitoring Accuracy

Mean immediate JOL predictions for recalled and nonrecalled items were similar within subjects (Figure 2). As expected, the differences in mean ratings between the two item types were small. JOL ratings of three subjects (Control 1, TBI 2, Control 2) were in the middle range of rating scale, whereas TBI 1's ratings were in the top range. This information, in combination with TBI 1's extremely impaired recall, suggests that he was overestimating his recall ability.

Large differences in the mean delayed JOL predictions for items recalled and items not recalled were present across subjects (Figure 2). All subjects assigned lower predictive ratings for items not recalled than for items recalled. However,

FIGURE 1. Proportion of recalled items across subjects for items in the immediate and delayed JOL conditions.

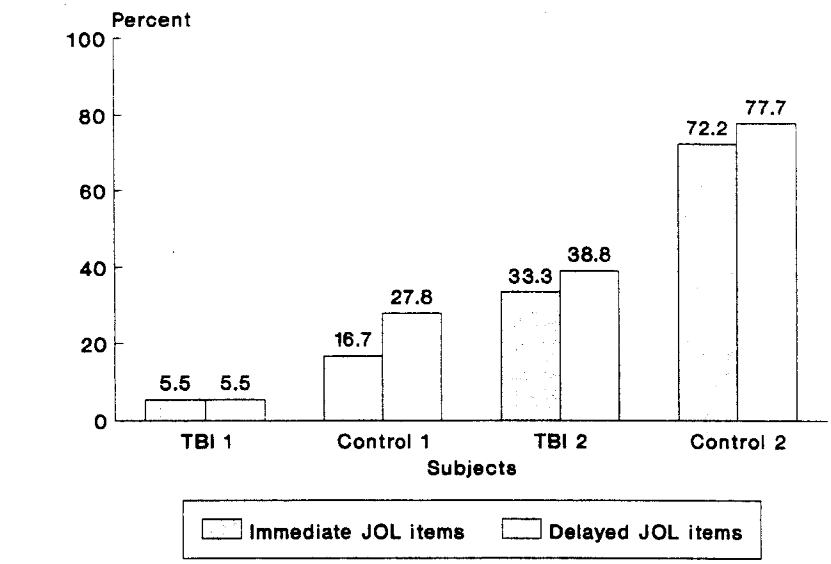
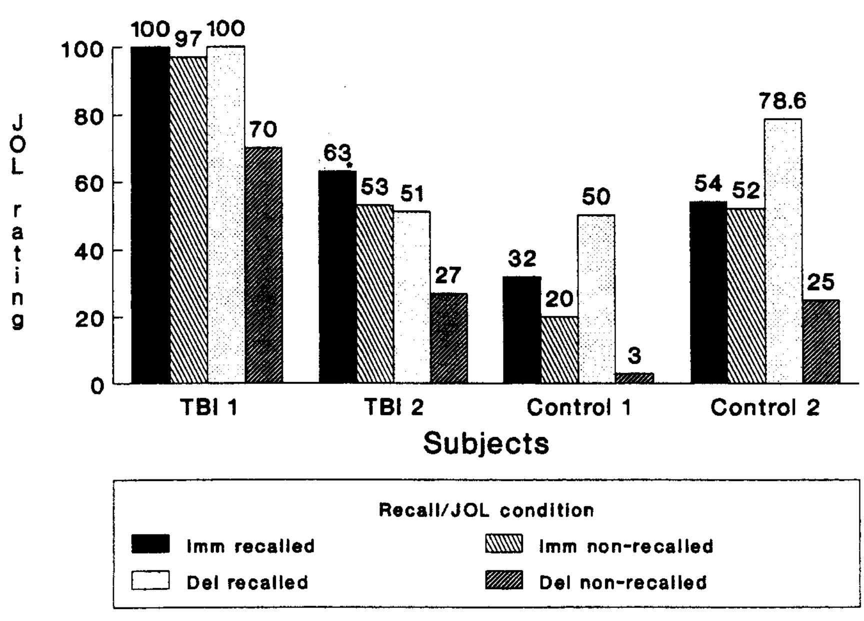


TABLE 2. Standard deviations for JOL predictions of recall.

Subjects	Immediate JOL Predictions	Delayed JOL Predictions
TBI 1	13.74	29.98
TBI 2	17.95	35.43
Control 1	9.43	24.9
Control 2	13.33	25.82

FIGURE 2. Mean absolute JOL ratings across subjects for items recalled and not recalled for immediate and delayed JOL conditions.



the differences in the mean scores between recalled and nonrecalled items for TBI subjects were 30 and 34 respectively, while the difference scores for control subjects were 47 and 56. This suggests that control subjects used the rating scale in a dichotomous manner, providing evidence that predictions were based on their internal attempts at actually recalling the missing item (Nelson & Dunlosky, 1991). TBI 1's predictions for nonrecalled items were again very high, revealing a substantial overestimation of recall ability. TBI 2's delayed JOL ratings for recalled items were within the middle range of the scale, with low ratings assigned to nonrecalled items.

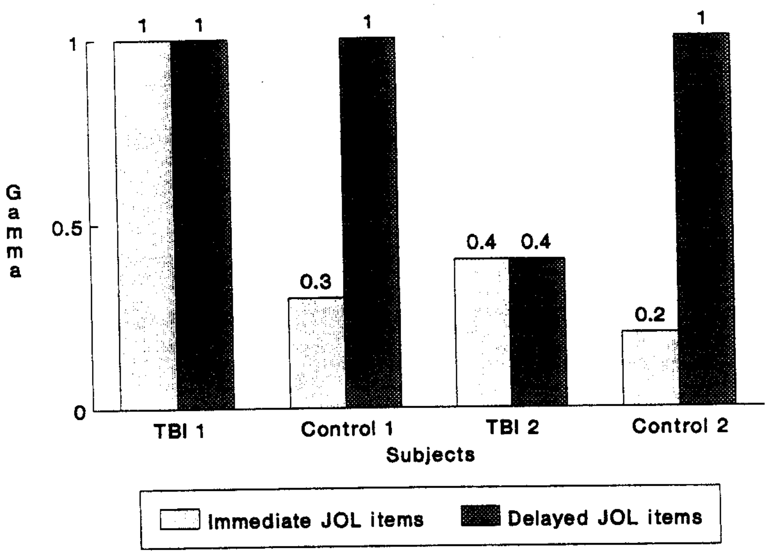
Variability of immediate and delayed JOL ratings was examined across subjects using standard deviations (Table 2). TBI subject 2's immediate and delayed predictions were slightly more variable than those of the other three subjects.

Gamma correlations, which provide an indication of relative predictive accuracy, are displayed in Figure 3. Control subjects' correlations of recall with immediate and delayed predictions were as expected; predictions were more accurate when delayed from the learning event than when made immediately after. However, for the TBI subjects, relative predictive accuracy was the same within subjects regardless of the JOL condition. TBI 1 appears to have had excellent immediate and delayed relative predictive accuracy (1.0 and 1.0), while TBI 2's predictions were much less accurate (.4 and .4). Interestingly, both TBI subjects displayed higher immediate predictive accuracy than the controls did.

Discussion and Clinical Implications

Two TBI subjects differing in recall performance had difficulty monitoring their learning "on-line" as measured by predicting future recall. One subject (TBI 1), whose memory was extremely impaired, substantially overestimated his recall. However, because he recalled only one item in each JOL condition and because the JOL rating for that item was 100 and the ratings for other nonrecalled items were 80 or 100, his gamma correlation was disproportionately high. Use of the gamma statistic should be questioned when recall is near the floor or the ceiling. The other TBI subject (TBI 2), whose recall was within the middle range, did not over- or underestimate her recall ability, demonstrated by predictive ratings that were close to those of controls. However, she had difficulty making relative predictions about recallability between items, evidenced by the low gamma correlation in the delayed JOL condition, despite the acceptable absolute JOL ratings. Additionally, TBI 2's use of the rating scale was more variable than that of the other subjects. This variability may have

FIGURE 3. Gamma correlations providing an indication of relative predictive accuracy across subjects for immediate and delayed JOL conditions.



affected the gamma correlation.

These findings may have separate clinical implications. A person who overpredicts recall performance (TBI 1) may need further education about his memory deficits. However, for the person who cannot make accurate delayed predictions, explanations and clinical implications are less clear. One possible explanation is that the individual is not making active attempts at retrieving the missing words before making a delayed prediction. It is well established that non-brain-damaged individuals use this strategy during delayed JOL predictions (Nelson et al., 1994). Some researchers have hypothesized that TBI survivors assume a "passive" role during learning, failing to select and implement learning strategies (Levin & Goldstein, 1986; Paniak, Shore, & Rourke, 1989). If this is true, having persons make active attempts at recalling the missing word and using the "information" about the recall attempt to assist in making the prediction might improve delayed accuracy. Determining the person's monitoring accuracy is the first necessary step in differentiating monitoring difficulty from impaired strategy selection.

Two explanations are possible for the finding that the relative immediate predictive accuracy of the two subjects with TBI was higher than that of controls. Nelson and Dunlosky (1991) proposed "monitoring-dual-memories" as an explanation for poor immediate predictive accuracy in college students. They suggested that individuals must monitor both short- and long-term memory when making immediate predictions and that this dual monitoring interferes with predictive accuracy. This would suggest that individuals with short-term memory impairment would experience less interference, resulting in higher immediate JOL predictive accuracy. As in this study, both TBI subjects had poor short-term memory of varying severity and immediate predictive accuracy that exceeded that of controls.

Another explanation for the TBI subjects' elevated immediate predictive accuracy is the possibility that individuals base their immediate predictions on what they believe they should be able to remember, rather than on what they actually recall at the time the prediction is made (i.e., as with delayed JOL predictions) (Nelson & Narens, 1990). The two TBI subjects in this study had received education about their memory deficits, and both made statements about their "poor memory" during the study. Perhaps their immediate predictions were more accurate than those of controls because they believed their memory was impaired and, therefore, made relatively lower JOL ratings. Both of these speculative explanations about the accuracy of the TBI subjects' immediate predictions require further investigation.

Conclusions and Future Research

The results from this study suggest that some adult survivors of TBI may exhibit difficulty self-monitoring "on-line" during learning. Differences between the two case presentations here lead us to conclude that the multidimensional aspect of metamemory must be understood if appropriate intervention approaches are to be developed. Without measures of recall and predictive ratings, and correlations between the two, it would not have been possible to identify the various types of monitoring difficulty these persons demonstrated. This technique of "on-line" predicting may be useful in identifying a part of metamemory typically described within the complex of "executive dysfunction" following TBI.

Control subjects' predictions of future recall were very accurate when slightly delayed, despite differences in recall ability. The ability to monitor recall was not related to recall performance. This finding supports previous results from studies investigating metamemory abilities of patients with amnesia, Korsakoff's disease, and frontal lobe damage, that indicate that memory performance is separate from the metacognitive monitoring of memory (Janowsky et al., 1989; Shimamura & Squire, 1986). Likewise, the TBI subjects' recall performance appears to be separate from the monitoring of recall, operationalized in this study using "judgment-of-learning" predictions.

Further research is needed if we are to understand fully the metamemory abilities of survivors of TBI. Group studies involving tasks over several trials could examine the effect of practice. Studies that include an instructional component might provide further explanations for low monitoring accuracy. Longitudinal research could follow the recovery of these abilities as other cognitive processes improve. Investigations about the relationship between predictions about cued recall performance and predictions about other types of learning are needed. Finally, relating JOLs and other metamemory monitoring judgments to functional outcomes would have clinical importance.

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