Pilot Study to Examine the Use of Self-Generation to Improve Learning and Memory in People With Traumatic Brain Injury

Yael Goverover, Nancy Chiaravalloti, John DeLuca

KEY WORDS
- activities of daily living
- brain injuries
- executive function
- learning
- memory
- retention (psychology)

People with traumatic brain injury (TBI) experience memory and learning difficulties. Difficulty in the initial acquisition of information is a primary reason people with TBI experience difficulties in learning and memory. Treatment focusing on improving the acquisition of information will likely improve both recall and recognition performance. In the “generation effect,” items self-generated are remembered better than items read or otherwise provided. The purpose of this study was to examine the application of the generation effect in improving memory for functional activities. The study used a within-subjects design and included 10 participants with TBI and 15 healthy control participants. Results demonstrated that material learned under the generated learning conditions was recalled better than when generated under provided learning conditions. This finding was true in both the TBI and the control groups. These results provide initial evidence supporting the use of self-generation to improve new learning of functional tasks for people with TBI.


The generation effect is a phenomenon whereby items that are self-generated by people are remembered better than items provided to them (Slamecka & Graf, 1978). Over the past 2 to 3 decades, self-generated learning has been shown to be robust in improving memory performance across a variety of conditions in samples of healthy people (McElroy & Slamecka, 1982; Slamecka & Ferveiski, 1983; Slamecka & Graf, 1978). Although this strategy has been widely studied in healthy participants, few studies have applied the self-generation strategy to participants with neurological illnesses or injuries. Such participant populations include those with multiple sclerosis (MS; Basso, Ghormley, Lowery, Combs, & Bornstein, 2008; Basso, Lowery, Ghormley, Combs, & Johnson, 2006; Chiaravalloti & DeLuca, 2002; Goverover, Chiaravalloti, & DeLuca, 2008), epilepsy (Smith, 1996), Parkinson’s disease (Hsieh & Lee, 1999), dementia (Barrett, Crucian, Schwartz, & Heilman, 2000; Dick, Kean, & Sands, 1989; Mitchell, Hunt, & Schmitt, 1986; Multhaup & Balota, 1997), and traumatic brain injury (TBI; Lengenfelder, Chiaravalloti, & DeLuca, 2007; O’Brien, Chiaravalloti, Arango-Lasprilla, Lengenfelder, & DeLuca, 2007; Scheff, Dulay, & Fargo, 2008).

Most of the studies documented the benefits obtained by self-generation from typically used, laboratory-based stimuli such as words (e.g., Lengenfelder et al., 2007; Multhaup & Balota, 1997; Scheff et al., 2008), numbers (Crutcher & Healy, 1989), multiplication tasks (Gardiner & Rowley, 1984), or pictures (Jurica & Shimamura, 1999; Kinjo & Snodgrass, 2000). Although such studies are important to establish the effectiveness of self-generation in improving learning and memory in people with memory impairments while using laboratory-type tasks, it is unclear from these studies whether similar benefits can be obtained when attempting to improve a person’s everyday memory and life.
To our knowledge, only two studies (Basso et al., 2006; Goverover et al., 2008), both done with people with MS, have investigated the application of self-generation to learning information and tasks related to daily living. Basso et al. (2006) investigated the learning of people’s names, object locations, and appointments using self-generation, whereas Goverover et al. (2008) studied whether self-generation can improve learning and the performance of tasks such as managing finances and preparing meals. Results indicated that encoding through self-generation increased memory abilities for this information in both studies.

The primary reason for difficulties in new learning and memory in people with TBI is difficulty in the initial acquisition of information rather than the retrieval of information from long-term storage (DeLuca, Schultheis, Madigan, Christodoulou, & Averill, 2000). That is, people with TBI have difficulty learning new information but not in retrieving it from long-term memory. Specifically, DeLuca et al. (2000) determined that when participants with TBI and healthy control participants (HC) reached a predetermined learning criterion, people with TBI recalled and recognized the learned information at a level comparable to that of healthy adults. However, participants with TBI required significantly more trials to reach this learning criterion. Treatments designed to improve new learning would therefore be expected to result in improvements in recall, recognition, and performance of functional activity. Thus, self-generation can improve the learning of new information in people with TBI. Investigating the functional applicability of self-generation in improving the everyday functional activity of people with TBI was a primary goal of the current research.

The purpose of this study was to replicate results obtained by Goverover et al. (2008) in people diagnosed with MS and to examine whether similar results would be observed in people with TBI. We did so by examining the utility of self-generation to improve recall and performance of everyday tasks such as preparing meals (e.g., preparing breakfast foods) and managing finances (e.g., paying an electric bill). We wanted to examine whether participants would demonstrate better recall or performance of everyday life tasks when they were presented in the generated condition compared with tasks presented in the provided condition immediately, 30 min after, and 1 wk after initial presentation.

Method

Participants

Participants were recruited by advertisements distributed at local support groups and clinics. On initial phone contact, potential participants were screened for participation on the basis of the inclusion and exclusion criteria discussed here. Ten people with TBI who were diagnosed with moderate or severe TBI and 15 HC without reported neurological disabilities participated in this study. It was often the case that a 24-hr Glasgow Coma Scale (Teasdale & Jennett, 1974) score could not be ascertained (n = 8). Therefore, participants were included in the study only if documentation of positive computed tomography or magnetic resonance neuroimaging results was available or if a documented period of loss of consciousness of ≥24 hr had occurred. Participants were excluded from the current study if they had (1) a history of neurological illness (aside from TBI), (2) a history of major psychiatric illness, (3) a history of alcohol or drug abuse, or (4) severe visual or motor impairment that might interfere with study procedures. All participants with TBI were ≥1 yr postinjury (mean years postinjury = 8.2, SD = 6.8). The two groups did not differ significantly with regard to age (TBI = 42.5; HC = 43.3), gender (TBI: 54.5% men; HC: 45.5% men), or premorbid intelligence (measured by Wide Range Achievement Test–3, Reading Subtest; Wilkinson, 1993; M = 51.6 for both groups; the scaled score equaling 104 indicates above-average reading academic skills for both groups).

Procedures

This study received institutional review board approval, and all participants provided informed consent. Using a within-group design, all participants were asked to recall instructions for two cooking tasks and two financial management tasks. For the current study, the two meal preparation tasks had the same level of difficulty. The financial management tasks were developed specifically for the current study and were equated for level of difficulty using activity analysis conducted by two occupational therapists.

Each task was subdivided into 12 individual steps, and each step was presented individually on 9-in. × 4-in. index cards. One cooking task and one finance task were carried out in the provided condition, in which all directions explaining how to perform the task were provided to and read by the participants. The other cooking and finance tasks were presented to participants in the generated condition: A key word in each step of the task was omitted, and participants were asked to generate this key word. For example, if a participant was asked to prepare an omelet, one task step was presented as follows: “beat together______.” The participant would then have to generate the missing item (e.g., “two eggs” or “one egg”).
Tasks were counterbalanced for condition (generated vs. provided) and instrumental activity of daily living (IADL) task category (meal preparation vs. managing finances).

Task presentations were followed by immediate recall, in which participants were asked to verbally recall the task steps required to perform each of them. Thirty minutes after initial presentation of the task, participants were then required to actually perform the task. During the 30 min between initial presentation and the performance recall of the task, participants were asked to complete neuropsychological tests. Then, participants learned the two other tasks in a way similar to the procedure described previously. Finally, 1 wk after initial presentation, participants were contacted by phone and were asked to verbally recall the task steps presented for all four tasks.

The maximum score for each of the functional tasks in each of the three recall tests was 24. Scores were measured on two dimensions: (1) recall or performance of each of the 12 steps required to complete the task and (2) the sequence of recall or performance of the 12 steps. Thus, 2 points were scored for every step: 1 point for remembering the step, and 1 point for the correct sequence of the step.

**Neuropsychological Testing.** All participants enrolled in the study went through neuropsychological testing to assess their current levels of cognitive performance. During the 30 min between initial presentation and the performance recall of the task, participants were asked to complete a battery of neuropsychological tests. This battery consisted of the Digit Span subtest of the Wechsler Adult Intelligence Scale–Revised (Wechsler, 1981) to assess attention; Symbol Digit Modalities Test–Oral Version (Smith, 1982) to assess processing speed; California Verbal Learning Test (CVLT; Delis, Kramer, Kaplan, & Ober, 1987) to assess learning and memory; and three subtests of the Delis–Kaplan Executive Function System (D–KEFS; Delis, Kaplan, & Kramer, 2000): Trail Making Test, Verbal Fluency Test (Letter Fluency), and Color–Word Interference Test (Inhibition/Switching) to assess executive functions. The D–KEFS tests are valid (e.g., Baldo, Shimamura, Delis, Kramer, & Kaplan, 2001; Beatty & Monson, 1990) and reliable (Delis, Kaplan, & Kramer, 2001) tools for measuring executive functions in clinical populations.

**Data Collection and Analysis.** After enrollment, participants were then scheduled for interview and testing. The testing session lasted approximately 3 hr, during which the neuropsychological battery and the self-generation protocol were administered by Yael Goverover. All participants were paid for their participation.

Cognitive functioning was analyzed by a one-way analysis of variance (ANOVA) comparing the performance of the TBI and HC groups. Performance on the generation-effect protocol was analyzed by a 2 (Group) × 2 (Condition) × 2 (Task) × 3 (Time) mixed-design repeated-measures ANOVA; group was the between-group factor, and condition, type of task, and trial were the within-group factors. To examine effect size in the previously mentioned analyses, η² was used. Contrast tests to examine repeated effects were used when comparisons among the recall intervals were needed.

**Results**

**Cognitive Abilities**

Cognitive performance is presented in Table 1. In terms of cognitive functioning, participants with TBI performed worse than control participants on tests designed to measure executive function (D–KEFS) and learning and memory (CVLT). Specifically, the TBI group took significantly longer to perform the D–KEFS Trail Making Test–number letter switching task than the control group ($F[1, 24] = 6.2, p < .05$). On the D–KEFS Verbal Fluency Test Letter Fluency subtest, the TBI group generated significantly fewer words than healthy control participants ($F[1, 24] = 4.8, p < .05$). Finally, on the

### Table 1. Neuropsychological Test Performance

<table>
<thead>
<tr>
<th>Domain Assessed</th>
<th>Tests</th>
<th>TBI ($n = 10$)</th>
<th>HC ($n = 15$)</th>
<th>$F(1, 24)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed of processing</td>
<td>SDMT</td>
<td>42.1 ± 12.1</td>
<td>44.1 ± 13.3</td>
<td>0.14</td>
</tr>
<tr>
<td>Learning and memory</td>
<td>CVLT–sum of 5 trials (Delis et al., 1987)</td>
<td>47.3 ± 12.3</td>
<td>57.9 ± 8.6</td>
<td>6.5*</td>
</tr>
<tr>
<td></td>
<td>CVLT–Discriminability</td>
<td>84.8 ± 14.8</td>
<td>93.9 ± 5.2</td>
<td>4.8*</td>
</tr>
<tr>
<td>Working memory</td>
<td>Digit Span Total</td>
<td>18.3 ± 5.1</td>
<td>18.6 ± 4.5</td>
<td>0.43</td>
</tr>
<tr>
<td>Executive functions</td>
<td>D–KEFS Trail Making Test: Number–letter switching</td>
<td>103.2 ± 44.2</td>
<td>70.7 ± 19.8</td>
<td>6.2*</td>
</tr>
<tr>
<td></td>
<td>D–KEFS Verbal Fluency–Letter Fluency</td>
<td>31.8 ± 15.1</td>
<td>43.6 ± 11.7</td>
<td>4.8*</td>
</tr>
<tr>
<td></td>
<td>D–KEFS Color–Word: Inhibition and switching</td>
<td>75.1 ± 21.9</td>
<td>58.3 ± 14.0</td>
<td>5.1*</td>
</tr>
</tbody>
</table>

*Note. M = mean; SD = standard deviation; TBI = traumatic brain injury; HC = healthy control participants; SDMT = Symbol Digit Modalities Test; CVLT = California Verbal Learning Test; D–KEFS = Delis–Kaplan Executive Function System.

*p < .05.
D–KEFS Color–Word Interference Test inhibition and switching task, the TBI group required significantly more time for completion than the control group ($F[1, 24] = 5.1, \, p < .05$). On the CVLT, healthy participants recalled significantly more words than participants with TBI ($F[1, 24] = 6.5, \, p < .05$) and recognized significantly more words that the TBI participants ($F[1, 24] = 4.8, \, p < .05$).

**Generation Effect**

Generation-effect performance is presented in Figure 1. Tasks (i.e., managing finances and preparing a meal) learned under the generated condition were recalled at a significantly higher rate ($M = 16.4$) than tasks presented in a provided condition ($M = 14.1$) collapsed across groups and times. Thus, the main effect of the generated condition (vs. provided) was significant and demonstrated a medium effect size ($F[1, 23] = 22.9, \, p < .001, \, \eta^2 = 0.49$).

**TBI Versus HC.** The TBI and HC groups did not differ significantly in the mean number of task items recalled as collapsed across time and condition ($F[1, 23] = 0.24, \, p = .58, \, \eta^2 = 0.06$). In addition, the relative difference between the provided and generated conditions was equivalent across participant groups. The interaction of participant group (HC vs. TBI) and condition (generated vs. provided) was not significant and demonstrated a small effect size ($F[1, 23] = 1.3, \, p = .25, \, \eta^2 = 0.05$). Thus, both the HC and the TBI groups benefited from the generated condition compared with the provided condition when learning the meal preparation and finance management tasks.

**Time.** As expected, the recall of task items dropped significantly across time in both the generated and provided conditions ($F[2, 23] = 27.9, \, p < .001, \, \eta^2 = 0.54$). Contrast tests revealed a significant difference between recall after 30 min and 1 wk after task presentation ($F[1, 23] = 39.7, \, p < .001, \, \eta^2 = 0.63$). Participants in each group (HC and TBI) demonstrated a similar pattern of performance across the three time periods and the two learning conditions (see Figure 2).

**Type of Tasks (Managing Finances vs. Meal Preparation).** The main effect of task type was not significant ($F[1, 23] = 0.30, \, p = .58, \, \eta^2 = 0.013$), indicating that the meal preparation and finance management tasks did not differ in the mean number of items recalled overall. The interaction of type of task and condition (i.e., generated vs. provided) was also not significant ($F[1, 23] = 0.44, \, p = .51, \, \eta^2 = 0.019$). Thus, across the two types of tasks, participants were able to benefit from the generated condition compared with the provided condition.

**Discussion**

The results of the current study demonstrated that using self-generation during the learning of functional tasks significantly improved subsequent recall of learned information in people with TBI. People with TBI were able to significantly recall and perform more information that was self-generated than information that was provided to them. Both the HC group and people with TBI benefited from the generation effect; no significant differences in benefit were noted between the groups. The results of the current study therefore demonstrate that self-generation enhances new learning and memory of functional tasks related to IADLs in people with and without TBI. The results obtained in this study are in accordance with previous research on self-generation that found that using self-generation while learning enhanced memory for the learned items (Johnson, Raye, Foley, & Foley, 1981; Mulligan, Lozito, & Rosner, 2006). This pilot study suggests that using self-generation during the learning of functional tasks may be a useful strategy for people with TBI to improve their memory and functional skills.
extends the known benefits of self-generation to everyday life activities in people with TBI.

In contrast to findings from this pilot study, Lengenfelder and colleagues (2007) noted that the benefit of self-generation was lost in both the HC and TBI groups after a 1-wk delay when using laboratory-based tasks. In this study, however, when everyday life tasks were used, self-generation benefited learning after a 1-wk delay (similar to what was found in people with MS; Goverover et al., 2008). One possible explanation lies in the fact that information to be remembered in this study was more meaningful than that used in studies relying on laboratory types of tasks, such as simple word recall. Future research might examine whether applying the generation effect with personally meaningful or salient information would increase the strength of the effect and increase the amount of information that can be learned for people with TBI.

In summary, the results from this study suggest that self-generation may hold substantial promise for improving the lives of people with TBI. These findings should pave the way for future intervention studies attempting to increase learning abilities in people with TBI using self-generation.

Clinical Implications

The primary aim of cognitive rehabilitation in TBI is to improve the patient’s capacity to process information in hopes of improving his or her task performance and increasing independence in daily functioning (Wilson, 2002). In recent years, the focus of rehabilitative efforts has shifted to teaching compensatory strategies and optimizing residual abilities. This article has attempted to lay the groundwork for using a promising compensatory strategy, self-generation, in the cognitive rehabilitation of patients with TBI. People with TBI who have significant cognitive problems and are in need of effective cognitive rehabilitation services could benefit from a compensatory approach using the self-generation strategy. The information gained from this pilot study provides the opportunity to proceed to the next step by designing treatment plans based on individualized goals but using learning techniques that may improve long-term retention.

Limitations

The results of the current study should be interpreted with caution. First, only 10 people with TBI participated, and they may not be fully representative of the TBI population. Second, severity level was not accounted for, and it is not clear how injury severity may affect the usefulness of the self-generation strategy. Third, the usefulness of self-generation was demonstrated in improving two everyday functional activities (cooking, finance); however, it is not clear how useful the strategy might be when applied to other tasks (e.g., housekeeping, vocational and academic activities).

Future Research

Replication of these results in larger, more diverse populations of people with TBI with differing levels of cognitive impairment is needed to ensure adequate generalization of the findings. In addition, we are now in the process of investigating whether severity of cognitive impairments and meaningfulness of the task to be learned have an effect on the benefit gains of self-generation. It would also be informative to study the potential benefits of self-generation on longer term recall by including 3-mo or 6-mo follow-up.
in the study design. Once effectiveness has been sufficiently demonstrated, future studies might examine the impact of self-generation on learning and memory in combination with other cognitive rehabilitation strategies or pharmacological intervention. ▲

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References


