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BRIEF REPORT

Using Testing to Improve Learning After Severe Traumatic Brain Injury

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Objective: Recent work in cognitive psychology suggests that testing can increase memory for both previously and subsequently studied information. Here we examined whether these beneficial (backward and forward) effects of testing generalize to individuals with severe traumatic brain injury (TBI). ***Method:*** Twenty-four persons with severe TBI, 12.7 years postinjury, and 12 healthy controls participated in the study. Participants studied three lists of items in anticipation of a final cumulative recall test. They were tested immediately between the study of lists or not. ***Results:*** Immediate testing of Lists 1 and 2 enhanced recall of both the previously studied information (Lists 1 and 2) and the subsequently studied information (List 3). The enhancement for the three lists arose for individuals with severe TBI and healthy controls, and did not differ in size between subject groups. ***Conclusion:*** The findings indicate that TBI persons show a very general benefit from testing, including both backward and forward effects of retrieval practice. Testing thus might be a powerful technique to improve learning and memory in persons with severe TBI.

Keywords: traumatic brain injury, memory, learning, testing, rehabilitation

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Memory deficits are among the most persistent residual cognitive deficits following severe traumatic brain injury (TBI) and they are among the most frequent complaints reported by persons with severe TBI (Levin, 1990; Oddy, Coughlan, Tyerman, & Jenkins, 1985; Vakil, 2005). Memory rehabilitation aims at reducing memory deficits arising from TBI. However, existing treatments in memory rehabilitation have been shown to sometimes produce small or even no effects on memory function in persons with severe TBI (Rohling, Faust, Beverly, & Demakis, 2009). These treatments have emphasized repeated study and the use of efficient study techniques, including elaborative encoding, imagery, and other mnemonic techniques to improve learning after TBI (Wilson, 2009). In contrast, recent experimental work in cognitive psychology and neuropsychology has stressed the critical role of retrieval practice to improve learning in both healthy and clinical populations.

Indeed, experimental work in cognitive psychology has shown that retrieval of previously studied information can increase its long-term retention more than restudy and elaborative encoding do (Karpicke & Blunt, 2011; Roediger & Karpicke, 2006; for reviews, see Karpicke, 2012; Roediger & Butler, 2011). This beneficial *backward effect* of testing has been attributed to a number of different mechanisms, like elaboration of the practiced items (Carpenter, 2009; Pyc & Rawson, 2010) or a particularly high degree of strengthening of the practiced items (Kornell, Bjork, & Garcia, 2011; see Roediger & Butler, 2011). The effect is not restricted to healthy populations. Retrieval of previously studied information has been shown to increase its long-term retention more than restudy does in persons with multiple sclerosis, persons with dementia, and persons with severe TBI, with effects comparable in size to those of healthy controls (Haslam, Hodder, & Yates, 2011; Sumowski, Chiaravalloti, & DeLuca, 2010; Sumowski, Wood et al., 2010).

In addition, experimental work in cognitive psychology has shown that retrieval of previously studied information can increase retention of subsequently studied information (Bäuml & Kliegl, 2013; Nunes & Weinstein, 2012; Pastötter, Schicker, Niedernhuber, & Bäuml, 2011; Szpunar, McDermott, & Roediger, 2008; Weinstein, McDermott, & Szpunar, 2011; Wissman, Rawson, & Pyc, 2011). This *forward effect* of testing is particularly striking, because it is on the learning of new material that is not related to the previously retrieved information. For instance, Szpunar et al. (2008) let healthy participants study five lists of items (Lists 1–5) in anticipation of a final, cumulative recall test. All participants were tested immediately on List 5. Participants, however, differed in whether they were tested immediately on Lists 1–4, restudied Lists 1–4, or did a distractor task after Lists 1–4. Results showed that immediate testing on Lists 1–4 but not restudy of Lists 1–4 produced higher List-5 recall rates and fewer prior-list intrusions than the distractor did. To account for this beneficial forward effect

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of testing, retrieval between lists has been suggested to enhance attentional encoding of the subsequently studied information (Pastötter et al., 2011) and to enhance retrieval of the information by improving list-discrimination processes (Bäuml & Kliegl, 2013; Szpunar et al., 2008). Whether this beneficial forward effect of testing generalizes to clinical populations has not been examined to date.

The present study aimed to examine the effects of testing on retention of both previously and subsequently studied information in persons with severe TBI and healthy controls. In each of two sessions, participants studied three lists of items (Lists 1–3), which they were asked to remember for a final cumulative recall test; they were tested immediately on List 3 and took part on the final cumulative recall test. In one of the two sessions, participants were also tested immediately on Lists 1 and 2 (*testing condition*), whereas in the other session, they did a distractor task after Lists 1 and 2 (*distractor condition*). Regarding the beneficial backward effect of testing on retention of the previously studied material, we followed Sumowski, Wood et al. (2010) and expected final, List-1 recall rates to be higher in the testing condition than the distractor condition, both in TBI persons and healthy controls. Regarding the beneficial forward effect of testing on retention of the subsequently studied material, we followed Szpunar et al. (2008) and expected healthy controls' immediate, List-3 recall rates to be higher in the testing condition than the distractor condition. Most important, the present results will indicate whether the beneficial effect of testing in individuals with severe TBI is restricted to memory for previously studied material or generalizes to memory for subsequently studied new material. Because different mechanisms mediate the forward and backward effects of testing, the results for the forward effect are not easily predictable from those for the backward effect.

Method

Participants

Participants were 24 persons with a history of severe TBI (mean age: 42.1, SD = 11.8, 16 men) and 12 age-matched healthy controls (mean age: 39.5, SD = 12.1, 7 men) in the study. All participants were recruited at the Ecksberg Foundation Institution in Mühldorf, Germany, a rehabilitation center that offers assisted living and sheltered work to persons with residual cognitive deficits following severe TBI. Age-matched controls were healthy employees of the institution. All participants spoke German as first language and reported normal or corrected-to-normal vision. No participant reported a history of alcohol or psychoactive substance abuse. The study was approved by the ethical review committee at Regensburg University Medical Center, Regensburg, Germany. Informed consent was obtained from all participants.

All TBI participants were diagnosed with severe TBI on the Glasgow Coma Scale (GSC: 3–8; Teasdale & Jennett, 1974), with length of coma at least 36 hr and posttraumatic amnesia more than 7 days (Williamson, Scott, & Adams, 1996). Mean age at injury was 26.8 years (SD = 13.8). Causes of TBI were car accidents (n = 13), motorcycle accidents (n = 3), bicycle accidents (n = 2), accidents at work (n = 2), and falls (n = 4). Examination of TBI persons' medical records and structural scans indicated that for most TBI participants, there was no consistent trend toward a clearly defined, residual focal lesion. Therefore the present data were not analyzed as a function of lesion localization. Persons with open-head injuries or other neurological (e.g., stroke, epilepsy, multiple sclerosis) or psychiatric conditions (e.g., depression, psychosis) were excluded from the study.

Neuropsychological Tests

One week before the first session of the memory task, neuropsychological tests assessing verbal intelligence and verbal memory were administered to both TBI participants and healthy controls. Assessing verbal memory, the Verbal Paired Associates I subtest of the German version of the Wechsler Memory Scale—Revised (WMS-R, Härting et al., 2000), measuring participants' ability to learn and retain novel word associations, was employed. Participants' task was to learn a list of four related and four unrelated word pairs over three study–test cycles (possible range of scores: 0 to 24). Healthy controls' mean score in the WMS-R was 20.25 (SE = 0.49). Assessing verbal intelligence, the Short Verbal Intelligence Test (Verbaler Kurz-Intelligenztest, VKI; Anger, Mertesdorf, & Wegner, 1980), a short version of the German Word–Picture General Intelligence Test (Wort-Bild-Test, WBT 10; Anger, Mertesdorf, Wegener, & Wülfing, 1971), measuring verbal intelligence and basic reasoning, was employed. Participants' task was to correctly assign 20 words to four graphical scenes showing typical everyday situations (possible range of scores: 0 to 20). Healthy controls' mean score in the VKI was 16.92 (SE = 0.67). Two more subtests of the Testbattery for Attentional Performance (TAP; Zimmermann & Fimm, 2002) were administered to TBI participants but not to healthy controls. Assessing working memory, a 2-back task was employed (possible ranges of scores for correct responses: 0 to 15, response errors: 0 to 85); assessing executive-control function, a go/no-go attention task was employed (possible ranges of scores for correct go responses: 0 to 20, erroneous no-go responses: 0 to 20).

To examine whether the beneficial effects of testing on retention of previously and subsequently encoded material in the memory task were related to the degree of (verbal) memory impairment in persons with severe TBI, two TBI subgroups were created based on a median split on participants' individual scores in the subtest of the WMS-R. Participants' performance in the present memory task was then compared between the subgroups of TBI persons with high memory impairment (TBI-high group; WMS-R scores $<$ 10) and low memory impairment (TBI-low group; WMS-R scores $\geq$ 10; for demographic and neuropsychological data of TBI subgroups, see Table 1). Although TBI subgroups and healthy controls differed reliably in verbal memory performance, the three groups did not differ in verbal intelligence, as indexed by mean scores in the VKI; moreover, the two TBI subgroups did not differ in the two subtests of the TAP (see Table 1).

Materials and Procedure of the Memory Task

Each participant took part in both experimental conditions, the testing condition and the distractor condition. Conditions were spaced one week apart in two sessions. Order of conditions was counterbalanced across participants, in both the two TBI subgroups and the control group. In both sessions, participants were asked to study three lists of 10 items. Each item showed a black-

Table 1
Demographic and Neuropsychological Data of TBI Subgroups

Variable	TBI-high	TBI-low	Statistics
Gender	7 males, 5 females	9 males, 3 females	$\chi^2(1) = 0.75$
Mean age	40.0 (*SD* = 11.7)	44.1 (*SD* = 12.1)	$t(22) = 0.87$
Mean age at injury	25.0 (*SD* = 14.4)	28.6 (*SD* = 11.8)	$t(22) = 0.67$
WMS-R: Mean scores	7.67 (*SE* = 0.74)†	12.67 (*SE* = 0.58)†	$t(22) = 5.30^*$
VKI: Mean scores	16.12 (*SE* = 0.37)	15.63 (*SE* = 0.77)	$t(22) = 0.58$
2-back task: Mean scores	9.50 (*SE* = 0.87)	9.67 (*SE* = 1.11)	$t(22) = 0.12$
2-back task: Response errors	16.00 (*SE* = 5.14)	23.17 (*SE* = 6.54)	$t(22) = 0.86$
Go/no-go: Mean scores	17.58 (*SE* = 1.33)	19.08 (*SE* = 0.58)	$t(22) = 1.03$
Go/no-go: Response errors	3.25 (*SE* = 1.21)	4.17 (*SE* = 1.45)	$t(22) = 0.46$

Note. TBI-high = persons with high memory impairment; TBI-low = persons with low memory impairment; WMS-R = Wechsler Memory Scale Revised; VKI = Verbal Intelligence Test. $p < .05$.
[*] Reliably different between TBI subgroups. [†] Reliably different from healthy controls.

on-white line drawing of an object together with its name; items were drawn from the Snodgrass and Vanderwart (1980) picture pool. Two sets of 30 items each were prepared; the assignment of items to sets was constant for all participants. The assignment of a set's items to the three lists was random for all participants. The two sets were used equally often in the testing and distractor conditions, and in the first and second sessions, counterbalanced across participants in each of the three subject groups. Presentation, randomization, and counterbalancing were done with E-Prime software (Version 1.1.4, Psychology Software Tools, Sharpsburg, PA).

Both experimental conditions consisted of a learning phase, an intermediate phase, and a final test phase (see Figure 1). Prior to the learning phase, participants were instructed to study three lists of items with each item showing a picture of an object together with its name. Participants were encouraged to pay close attention to the presented items for an upcoming final free recall test at the end of the session, in which all of the previously presented items would be tested. Participants were further told to expect two activities that may follow the presentation of each single list: backward counting in steps of one and an immediate free recall test, in which the items of the previously studied list would be tested. We pretended that activities following each list were determined randomly by the computer. In fact, however, activities following Lists 1 and 2 were always the same and depended on experimental condition. It was highlighted that, irrespective of whether a list's items were tested immediately or not, all lists' items would be tested on the final cumulative recall test (for a similar procedure, see Szpunar et al., 2008, or Pastötter et al., 2011).

In the learning phase, three 10-item lists were presented visually on a computer screen (5-sec item presentation, 1-sec blank screen). Black-on-white line drawings of the objects were depicted in the upper two thirds of the screen; the objects' corresponding names were shown in the lower third of the screen. After study of each single list, participants counted backward in steps of one from a random three-digit number (smaller than 200) for 30 sec. Experimental conditions differed in which activities followed backward counting after Lists 1 and 2. In the testing condition, immediate free-recall tests were conducted after Lists 1 and 2; participants

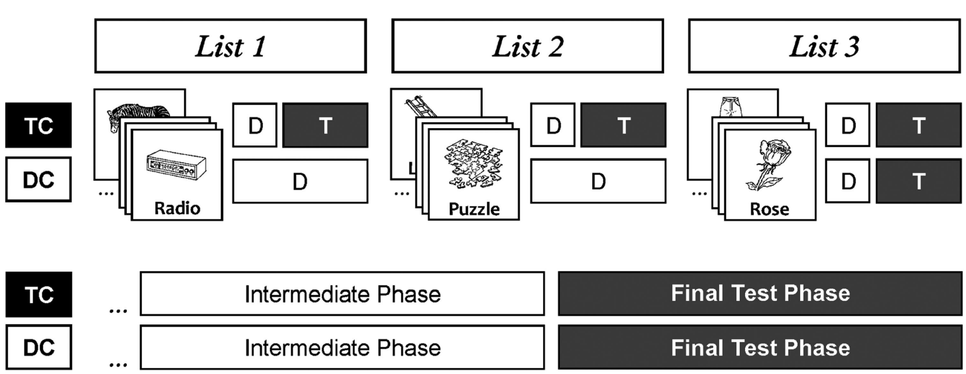

Figure 1. Procedure of the memory task. Both the testing condition (TC) and the distractor condition (DC) consisted of a learning phase, an intermediate phase, and a final test phase. In the learning phase, three 10-item lists with items showing black-on-white line drawings of objects together with its names were presented. Each list was followed by a short distractor (D). Whereas List 3 was tested immediately in both conditions, Lists 1 and 2 were tested immediately (T) in the testing condition but not in the distractor condition. In the intermediate phase, participants did an easy mathematical distractor. In the final test phase, participants were asked to recall the items from all three item lists. Each participant took part in both conditions, separated by a 1-week delay interval.

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were given 1 min to tell the experimenter in any order they wished as many objects as they could remember from the just-studied list. In the distractor condition, participants were not tested immediately on Lists 1 and 2; rather, backward counting following each list was prolonged for 1 min. After study of List 3 in both conditions, an immediate List-3 free-recall test was conducted following backward counting; participants were given 1 min to tell the experimenter in any order they wished as many objects they could remember from the preceding list. In the intermediate phase, participants did an easy mathematical distractor for 3 min in which they added pairs of one- and two-digit numbers as fast and correctly as possible. In the final-test phase, subjects were given 3 min to recall in any order they wished as many objects as they could remember from all three item lists. It was emphasized that participants should use the 3 min efficiently in their attempt to recall the items of the three lists. A session was completed in approximately 15 min by all participants.

Results

Immediate Recall

Regarding the forward effect of testing, a two-way analysis of variance (ANOVA) on immediate List-3 recall rates (Figure 2A) with the factors of condition (testing vs. distractor) and group (TBI-high vs. TBI-low vs. controls) showed a main effect of condition, $F(1, 33) = 11.63$, $p = .002$, partial $\eta^2 = .26$, and a main effect of group, $F(2, 33) = 23.05$, $p < .001$, partial $\eta^2 = .58$, but no interaction between the two factors, $F(2, 33) < 1$. Indeed, immediate List-3 recall in the testing condition (50.3%) was higher than in the distractor condition (37.8%). Moreover, immediate List-3 recall in the control group (62.5%) was higher than in both the TBI-high group (32.1%), $t(22) = 5.87$, $p < .001$, $d = 2.40$, and the TBI-low group (37.5%), $t(22) = 4.86$, $p < .001$, $d = 1.98$; recall rates did not differ between TBI subgroups, $t(22) = 1.39$, $p = .178$. A two-way ANOVA on number of prior-list intrusions from Lists 1 and 2 during immediate List-3 recall (Figure 2B) with the factors of condition (testing vs. distractor) and group (TBI-high vs. TBI-low vs. controls) showed a main effect of condition, $F(1, 33) = 14.14$, $p < .001$, partial $\eta^2 = .30$, but no main effect of group, $F(2, 33) = 2.18$, $p = .129$, and no interaction between the two factors, $F(2, 33) < 1$. Indeed, participants produced fewer prior-list intrusions in the testing condition (0.75) than in the distractor condition (1.72). Immediate testing of Lists 1 and 2 thus improved immediate List-3 recall (and reduced prior-list intrusions), regardless of subject group. The finding demonstrates comparable forward effects of testing in TBI persons and healthy controls.

Naturally, immediate List-1 and List-2 recall rates were measured in the testing condition only. Analysis of these recall rates showed that recall differed reliably between subject groups, $F(2, 33) = 25.62$, $p < .001$, partial $\eta^2 = .61$. List-1 and List-2 recall in the control group (70.4%) was higher than in both the TBI-high group (44.2%), $t(22) = 5.45$, $p < .001$, $d = 2.35$, and the TBI-low group (42.5%), $t(22) = 7.18$, $p < .001$, $d = 3.09$; recall rates did not differ between TBI subgroups, $t(22) < 1$.

Final Recall

A three-way ANOVA on final recall rates (Figure 2C) with the factors of list (List 1 vs. List 2 vs. List 3), condition (testing vs. distractor), and group (TBI-high vs. TBI-low vs. controls) showed a main effect of list, $F(2, 66) = 11.83$, $p < .001$, partial $\eta^2 = .26$, a main effect of condition, $F(1, 33) = 46.60$, $p < .001$, partial $\eta^2 = .58$, and a main effect of group, $F(2, 33) = 54.00$, $p < .001$, partial $\eta^2 = .77$, but no interactions, all Fs < 1. Regarding the main effect of list, List-3 recall rates (45.1%) were higher than both List-1 recall rates (35.1%), $t(35) = 3.93$, $p < .001$, $d = 0.65$, and List-2 recall rates (33.5%), $t(35) = 4.49$, $p < .001$, $d = 0.75$; List-1 and List-2 recall rates did not differ, $t(35) < 1$. Regarding the main effects of condition and group, results reflect the fact that final recall rates were higher in the testing condition (40.8%) than the distractor condition (27.8%), and recall rates in the control group (55.2%) were higher than in both the TBI-high group (23.5%), $t(22) = 8.86$, $p < .001$, $d = 3.76$, and the TBI-low group (24.2%), $t(22) = 8.59$, $p < .001$, $d = 3.64$; recall rates did not differ between TBI subgroups, $t(22) < 1$. These results indicate that immediate testing of List 1 and List 2 enhanced final recall of the three lists about equally in the three subject groups. The finding demonstrates the backward effect of testing for List 1, and a mixture of backward and forward effects of testing for List 2 and List 3; all of these effects were equally present in TBI persons and healthy controls.

Discussion

This study examined the effects of testing on retention of previously and subsequently studied information, both in persons with severe TBI and healthy controls. In line with prior work in healthy and clinical populations (Sumowski, Chiaravalloti et al., 2010; Sumowski, Wood et al., 2010), the present results show that immediate testing of encoded material enhances final recall of the tested material (List 1). The enhancement arose for severe TBI subjects and healthy controls, and did not differ in size between subject groups. Regarding the forward effect of testing, the results replicate prior work with healthy subjects by showing that immediate testing of previously encoded material enhances immediate recall of the subsequently studied information (List 3), and additionally reduces intrusions of the previously tested material (Szpunar et al., 2008). Going beyond the prior work, the results demonstrate that the forward effect of testing is not restricted to healthy people, but generalizes to persons with severe TBI. In particular, the enhancement did not differ in size between subject groups and was equally present in TBI persons and healthy controls.[1]

Prior work on testing effects suggests that the backward and forward effects of testing are mediated by different mechanisms. The backward effect of testing has been attributed to elaboration or a particularly high degree of strengthening of the practiced items (Carpenter, 2009; Kornell et al., 2011; Pyc & Rawson, 2010). In contrast, the forward effect of testing has

[1] Interestingly, the two TBI subgroups differed in the verbal memory subtest of the WMS-R but did not differ in the pictorial memory task. The finding indicates that TBI persons with high verbal memory impairment can benefit from pictorial encoding more than TBI persons with low verbal memory impairment.

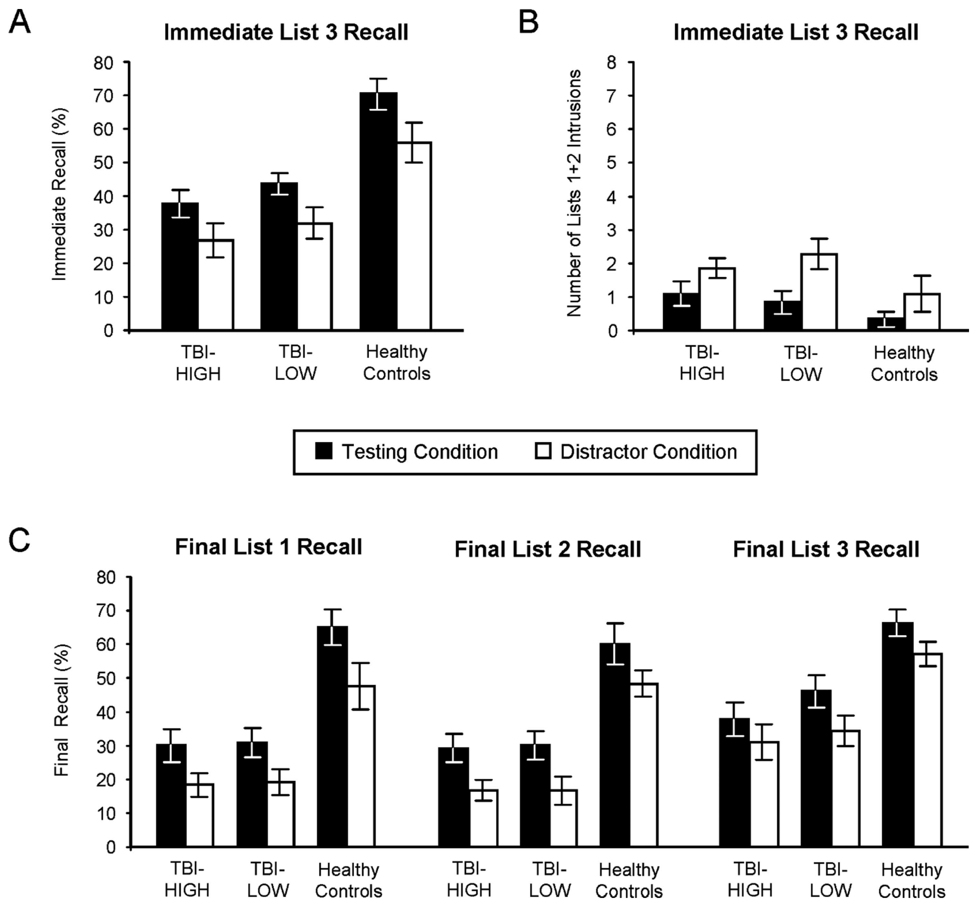

Figure 2. Mean recall and intrusion rates. (A) Immediate List-3 recall rates as a function of condition (testing, distractor) and group (TBI-high, TBI-low, controls). (B) Number of prior-list instrusions during immediate List-3 recall as a function of condition (testing, distractor) and group (TBI-high, TBI-low, controls). (C) Final recall rates of the three lists as a function of condition (testing, distractor) and group (TBI-high, TBI-low, controls). TBI-high = TBI persons with high verbal memory impairment as measured by the WMS-R; TBI-low = TBI persons with low verbal memory impairment shown by the WMS-R. Error bars represent standard errors.

been attributed to both improved encoding and improved retrieval, with testing enhancing attentional encoding of the subsequently studied information (Pastötter et al., 2011) and improving list-discrimination processes (Bäuml & Kliegl, 2013; Szpunar et al., 2008). The findings of an equivalent testing effect on final List-1 recall and an equivalent testing effect on immediate List-3 recall in TBI persons and healthy controls suggests that both the mechanisms underlying the backward effect and the mechanisms underlying the forward effect are equally present in TBI persons and healthy controls (see also Sumowski, Chiaravalloti et al., 2010).

Prior work on TBI has shown that memory deficits in persons with TBI arise mainly from deficient encoding and less from deficient retrieval (e.g., Blanchet, Paradis-Giroux, Pépin, & McKerral, 2009; DeLuca, Schultheis, Madigan, Christodoulou, & Averill, 2000). On the basis of that finding and the present results, the question arises to what extent the forward effect of testing in the present study enhanced TBI persons' encoding, and whether it improved encoding to an even larger extent than in healthy controls. Recording subjects' electroencephalogram, a recent study identified neural markers of efficient encoding in multiple list learning, showing how testing affected these markers and enhanced recall of the subsequently studied material (Pastötter et al., 2011). Future work thus may measure TBI persons' electroencephalogram during study to examine the extent to which testing enhances TBI persons' encoding of the new information.

In this study, TBI persons' immediate recall rates of Lists 1 and 2 in the testing condition were lower than those in healthy controls, reflecting the fact that TBI persons typically show impaired memory when compared with healthy controls. Despite this difference in immediate recall level, the size of the testing effect was not smaller in TBI persons than in healthy controls. The difference in immediate recall rates raises the possibility that TBI persons might even show disproportional testing effects. Indeed, if the forward effect of testing on the subsequently studied material increased with recall rates of the previously encoded material, an even larger testing effect in TBI persons than in healthy controls might arise. Future work may test this hypothesis by either equating TBI persons' and controls' immediate List-1 and List-2 recall rates experimentally, or controlling the level of List-1 and List-2 recall rates between TBI persons and healthy con-

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trols statistically.[2] The finding of disproportional testing effects in TBI persons would be of considerable relevance for TBI persons' memory rehabilitation.

In sum, prior work on the beneficial effects of testing on previously and subsequently studied information has shown that active retrieval promotes effective learning in healthy populations. The present study demonstrates similar beneficial effects of testing in persons with severe TBI. The findings suggest that retrieval practice can be a powerful technique to improve learning and memory in persons with severe TBI.

[2] Such statistical control requires larger data sets than are present in this study, so the issue can not be addressed here.

References

Anger, H., Mertesdorf, F., & Wegner, R. (1980). *Verbaler Kurz-Intelligenztest (VKI)*. Weinheim, Germany: Beltz.

Anger, H., Mertesdorf, F., Wegner, R., & Wülfing, G. (1971). *Wort-Bild-Test (WBT-10)*. Weinheim, Germany: Beltz.

Bäuml, K.-H. T., & Kliegl, O. (2013). The critical role of retrieval processes in release from proactive interference. *Journal of Memory and Language, 68,* 39–53. doi:10.1016/j.jml.2012.07.006

Blanchet, S., Paradis-Giroux, A.-A., Pépin, M., & McKerral, M. (2009). Impact of divided attention during verbal learning in young adults following mild traumatic brain injury. *Brain Injury, 23,* 111–122. doi:10.1080/02699050802649688

Carpenter, S. K. (2009). Cue strength as a moderator of the testing effect: The benefits of elaborative retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35,* 1563–1569. doi:10.1037/a0017021

DeLuca, J., Schultheis, M. T., Madigan, N. K., Christodoulou, C., & Averill, A. (2000). Acquisition versus retrieval deficits in traumatic brain injury: Implications for memory rehabilitation. *Archives of Physical Medicine and Rehabilitation, 81,* 1327–1333. doi:10.1053/apmr.2000.9390

Härting, C., Markowitsch, H. J., Neufeld, H., Calabrese, P., Deisinger, K., & Kessler, J. (2000). *Wechsler-Memory-Scale-Revised: Deutschsprachige Adaptation*. Bern, Switzerland: Huber.

Haslam, C., Hodder, K. I., & Yates, P. J. (2011). Errorless learning and spaced retrieval: How do these methods fare in healthy and clinical populations? *Journal of Clinical and Experimental Neuropsychology, 33,* 432–447. doi:10.1080/13803395.2010.533155

Karpicke, J. D. (2012). Retrieval-based learning: Active retrieval promotes meaningful learning. *Current Directions in Psychological Science, 21,* 157–163. doi:10.1177/0963721412443552

Karpicke, J. D., & Blunt, J. R. (2011). Retrieval practice produces more learning than elaborative studying with concept mapping. *Science, 331,* 772–775. doi:10.1126/science.1199327

Kornell, N., Bjork, R. A., & Garcia, M. A. (2011). Why tests appear to prevent forgetting: A distribution-based bifurcation model. *Journal of Memory and Language, 65,* 85–97. doi:10.1016/j.jml.2011.04.002

Levin, H. S. (1990). Memory deficit after closed head injury. *Journal of Clinical and Experimental Neuropsychology, 12,* 129–153. doi:10.1080/01688639008400960

Nunes, L. D., & Weinstein, Y. (2012). Testing improves true recall and protects against the build-up of proactive interference without increasing false recall. *Memory, 20,* 138–154. doi:10.1080/09658211.2011.648198

Oddy, M., Coughlan, T., Tyerman, A., & Jenkins, D. (1985). Social adjustment after closed head injury: A further follow-up seven years after injury. *Journal of Neurology, Neurosurgery & Psychiatry, 48,* 564–568. doi:10.1136/jnnp.48.6.564

Pastötter, B., Schicker, S., Niedernhuber, J., & Bäuml, K.-H. T. (2011). Retrieval during learning facilitates subsequent memory encoding. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 37,* 287–297. doi:10.1037/a0021801

Pyc, M. A., & Rawson, K. A. (2010). Why testing improves memory: Mediator effectiveness hypothesis. *Science, 330,* 335. doi:10.1126/science.1191465

Roediger, H. L., & Butler, A. C. (2011). The critical role of retrieval practice in long-term retention. *Trends in Cognitive Sciences, 15,* 20–27. doi:10.1016/j.tics.2010.09.003

Roediger, H. L., & Karpicke, J. D. (2006). Test-enhanced learning: Taking memory tests improves long-term retention. *Psychological Science, 17,* 249–255. doi:10.1111/j.1467-9280.2006.01693.x

Rohling, M. L., Faust, M. E., Beverly, B., & Demakis, G. (2009). Effectiveness of cognitive rehabilitation following acquired brain injury: A meta-analytic re-examination of Cicerone et al.'s (2000, 2005) systematic reviews. *Neuropsychology, 23,* 20–39. doi:10.1037/a0013659

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 174–215. doi:10.1037/0278-7393.6.2.174

Sumowski, J. F., Chiaravalloti, N., & DeLuca, J. (2010). Retrieval practice improves memory in multiple sclerosis: Clinical application of the testing effect. *Neuropsychology, 24,* 267–272. doi:10.1037/a0017533

Sumowski, J. F., Wood, H. G., Chiaravalloti, N., Wylie, G. R., Lengenfelder, J., & DeLuca, J. (2010). Retrieval practice: A simple strategy for improving memory after traumatic brain injury. *Journal of the International Neuropsychological Society, 16,* 1147–1150. doi:10.1017/S1355617710001128

Szpunar, K. K., McDermott, K. B., & Roediger, H. L. (2008). Testing during study insulates against the buildup of proactive interference. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34,* 1392–1399. doi:10.1037/a0013082

Teasdale, G., & Jennett, B. (1974). Assessment of coma and impaired consciousness. A practical scale. *The Lancet, 304,* 81–84. doi:10.1016/S0140-6736(74)91639-0

Vakil, E. (2005). The effect of moderate to severe traumatic brain injury (TBI) on different aspects of memory: A selective review. *Journal of Clinical and Experimental Neuropsychology, 27,* 977–1021. doi:10.1080/13803390490919245

Weinstein, Y., McDermott, K. B., & Szpunar, K. K. (2011). Testing protects against proactive interference in face–name learning. *Psychonomic Bulletin & Review, 18,* 518–523. doi:10.3758/s13423-011-0085-x

Williamson, D. J. G., Scott, J. G., & Adams, R. L. (1996). Traumatic brain injury. In R. L. Adams, O. A. Parsons, A. Oscar, J. L. Culbertson, L. Jan, & S. J. Nixon (Eds.), *Neuropsychology for clinical practice: Etiology, assessment, and treatment of common neurological disorders* (pp. 9–64). Washington, DC: American Psychological Association. doi:10.1037/10198-001

Wilson, B. A. (2009). *Memory rehabilitation: Integrating theory and practice*. New York, NY: Guildford Press.

Wissman, K. T., Rawson, K. A., & Pyc, M. A. (2011). The interim test effect: Testing prior material can facilitate the learning of new material. *Psychonomic Bulletin & Review, 18,* 1140–1147. doi:10.3758/s13423-011-0140-7

Zimmermann, P., & Fimm, B. (2002). *Testbatterie zur Aufmerksamkeitsprüfung (TAP)*. Herzogenrath, Germany: Psytest.

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