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Memory for performed and observed activities following traumatic brain injury

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Abstract

Traumatic brain injury (TBI) is associated with deficits in memory for the content of completed activities. However, TBI groups have shown variable memory for the temporal order of activities. We sought to clarify the conditions under which temporal order memory for activities is intact following TBI. Additionally, we evaluated activity source memory and the relationship between activity memory and functional outcome in TBI participants. Thus, we completed a study of activity memory with 18 severe TBI survivors and 18 healthy age- and education-matched comparison participants. Both groups performed eight activities and observed eight activities that were fashioned after routine daily tasks. Incidental encoding conditions for activities were utilized. The activities were drawn from two counterbalanced lists, and both performance and observation were randomly determined and interspersed. After all of the activities were completed, content memory (recall and recognition), source memory (conditional source identification), and temporal order memory (correlation between order reconstruction and actual order) for the activities were assessed. Functional ability was assessed via the Community Integration Questionnaire (CIQ). In terms of content memory, TBI participants recalled and recognized fewer activities than comparison participants. Recognition of performed and observed activities was strongly associated with social integration on the CIQ. There were no between- or within-group differences in temporal order or source memory, although source memory performances were near ceiling. The findings were interpreted as suggesting that temporal order memory following TBI is intact under conditions of both purposeful activity completion and incidental encoding, and that activity memory is related to functional outcomes following TBI.

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Keywords

Traumatic brain injury; Memory; Source memory; Temporal order memory; Activity memory

We often rely on contextual information to help us recall previous events and to plan future activities. For example, when recalling this week's events, we do not just rely on the content of what occurred (e.g., depositing a check, online bill pay transactions, and applying for a loan), but also the source (e.g., it was you who deposited a check and paid your bills online, while your sister applied for the loan with you as the cosigner) and the temporal order of the events (e.g., you deposited the check on Monday, and you paid your bills and cosigned for the loan on Wednesday). We integrate this information in order to make important decisions regarding our everyday functioning.

As the above example shows, multiple memory processes are involved in remembering daily activities. The interactions among these processes are critical to real-world decision making. Taken together, these component processes comprise “activity memory,” a form of executive memory for planning and goal-directed activities (Fuster, 2000). Activity memory can be distinguished from other types of memory in that it consists of information about a goal-driven activity (e.g., preparing a cup of coffee) rather than a discrete action or sequence of actions without an overall purpose (e.g., tapping your fingers on a table).

In comparison to content memory, source memory has been shown to be more similar to temporal order memory, particularly in regard to functional neuroanatomy. It has been shown that persons with frontal lobe damage show less difficulty in recalling and recognizing the content of previously learned information (Glisky, Polster, & Routhieaux, 1995; Janowsky, Shimamura, & Squire, 1989; Shimamura, Janowsky, & Squire, 1990) in contrast to *where* and *when* the information was learned (Butters, Kaszniak, Glisky, Eslinger, & Schacter, 1994; Shimamura et al., 1990). In addition, individuals with temporal lobe damage often exhibit impairments in content memory but show generally intact context memory (e.g., Milner, Petrides, & Smith, 1985). Taken together, these findings suggest that content memory might be dissociable from memory for context (temporal order memory and source memory) and that these processes may generally rely on different brain regions (Hurst & Volpe, 1982; Mangels, 1997; Stuss et al., 1994). However, the paradigms used in the aforementioned studies may not be completely reflective of the multidimensional aspects of activity memory (Schmitter-Edgecombe & Seelye, 2012).

While no two traumatic brain injuries (TBIs) result in exactly the same neuropathology, most cases are associated with acceleration–deceleration forces and result in diffuse axonal injury (Adams et al., 1989; Adams, Graham, Scott, Parker, & Doyle, 1980; Bigler, 2001; Takaoka et al., 2002), as well as lesions/atrophy to frontal and temporal lobe areas (Adams et al., 1989; Adams et al., 1980; Wilson, Hadley, Wiedmann, & Teasdale, 1995; Wright et al., 2013). Thus, TBI could potentially impair content memory for activities (via temporal lobe injury), temporal order memory and/or source memory for activities (due to frontal lobe injury), or all of these (due to degraded connectivity resulting from diffuse axonal injury and/or a combination of frontal and temporal lobe injury).

It is well known that content memory in various modalities (e.g., visual, verbal) is impaired following TBI (e.g., Schmitter-Edgecombe, Marks, Wright, &

Ventura, 2004; Vakil, 2005; Wright & Schmitter-Edgecombe, 2011; Wright, Schmitter-Edgecombe, & Woo, 2010). Also, we have a fairly well-developed understanding of memory for contextual information of verbal stimuli in TBI participants. TBI participants tend to show a uniform decrement in verbal content memory in contrast to comparison participants, but they do not always show a similar deficit for verbal temporal order memory (Cooke & Kausler, 1995; Vakil, Blachstein, & Hoofien, 1991; Vakil, Sherf, Hoffman, & Stern, 1998; Vakil & Tweedy, 1994). Specifically, TBI and comparison participants demonstrate similar verbal temporal order memory ability under incidental learning instructions (where participants are not told that their memory for item order will be tested; Vakil et al., 1991) and under intentional learning instruction conditions with greater study list exposure (i.e., eight list learning trials instead of five; Vakil et al., 1998). TBI participants show both content memory and temporal order memory deficits under intentional learning instructions when there are fewer list exposures (e.g., five; Vakil et al., 1991; Vakil & Tweedy, 1994). Thus, content memory for verbal information is generally impaired following TBI, but temporal order memory is intact under conditions of incidental learning and/or greater exposure of the to-be-learned material. This suggests that temporal order information may be at least partially encoded implicitly under certain conditions. However, comparison participants tend to outperform TBI participants in temporal order memory for verbal material when given intentional learning instructions, which suggests that they may be better able to mobilize the explicit memory system to aid in encoding of temporal order.

Interestingly, research has shown that content memory of performed activities is superior to that of verbal materials (e.g., Engelkamp & Zimmer, 1989; Helstrup, 1989). Schmitter-Edgecombe and Wright (2003) suggested that this difference could be due to memory for performed activities involving greater processing of multimodal information (e.g., visual, verbal, tactile) that could increase the likelihood of remembering of such material in contrast to remembering unimodal information (e.g., an auditorily presented list of words). To our knowledge, three studies of activity memory in TBI have been conducted (Cooke & Kausler, 1995; Schmitter-Edgecombe & Seelye, 2012; Schmitter-Edgecombe & Wright, 2003). All three assessed content memory and temporal order memory following the completion of various tasks by healthy adults and TBI survivors. These studies all found that the TBI participants evidenced poorer content memory than comparison participants, but they conflicted with regard to temporal order memory for activities. Some studies (Cooke & Kausler, 1995; Schmitter-Edgecombe & Seelye, 2012) showed impaired temporal order memory in TBI participants relative to comparison participants, while other research (Schmitter-Edgecombe & Wright, 2003) showed equivalent temporal order memory in TBI and comparison participants. Importantly, when intentional learning instructions are used, there is poorer temporal order memory in TBI (Cooke & Kausler, 1995; Schmitter-Edgecombe & Seelye, 2012). When incidental learning instructions were utilized, poorer temporal order memory in TBI is found when the activities are shorter in duration (<1 minute; Cooke & Kausler, 1995) and less purposive/goal-directed (Cooke & Kausler, 1995); they used a series of discrete actions (e.g., opening an umbrella) in their study. However, there are no group differences in temporal order memory under incidental learning instructions when the task duration is longer (3–15 minutes; Schmittter-Edgecombe & Wright, 2003) and more purposive (Schmitter-Edgecombe & Wright, 2003). Purposive activities involve greater goal-directed demands. For example, preparing a pot of coffee would be more purposive than stirring liquid in a cup. Both Schmitter-Edgecombe studies employed neuropsychological tests as the target activities, which are likely more purposive than the activities employed by Cooke and Kausler.

Overall, temporal order memory is poorer in TBI when intentional learning instructions are used and for incidental learning only with shorter task duration and less purposive activities. This effect is found across verbal and performed actions. However, for verbal information, greater study list exposure removes this effect. Still, studies of activity memory that equate the same methods across stimuli are needed to clarify the conditions that lead to better temporal order memory in TBI survivors. Additionally, data are needed to establish whether or not TBI participants are able to remember source information related to these activities. Neuroimaging data indicate that similar areas of activation are found in the frontal and parietal lobe regions during execution and observation of motor action (Iacoboni et al., 1999), suggesting that content and temporal order memory performances should be similar for observed and performed activities in healthy participants and TBI participants. However, these data do not provide any clarification as to whether TBI participants would be able to distinguish performed from observed activities at a level similar to that for healthy comparison participants.

In the current study, we aimed to replicate and extend findings from previous activity memory research in TBI. We investigated incidental memory for the content, temporal order, and source memory of performed and observed activities that simulate real-world tasks (e.g., balancing a checkbook). We expected that TBI participants would show poor content memory for activities in contrast to comparison participants but that they would demonstrate similar temporal order memory, consistent with the findings of Schmitter-Edgecombe and Wright (2003). Additionally, it was hypothesized that content and temporal order performances would be similar for observed and performed activities in both groups, given the data showing that execution and observation of actions elicit activations in similar brain regions (Iacoboni et al., 1999). Finally, since temporal order and source memory have been found to be more similar to one another, but partially dissociable from content memory, with regard to functional neuroanatomy (Butters et al., 1994; Milner et al., 1985; Shimamura et al., 1990), we hypothesized that TBI and comparison participants would show equivalent source memory for activities.

We also assessed the association between TBI participants’ functional outcomes and their activity memory performances. Given that activity memory likely plays a role in everyday functioning and decision making, we hypothesized that one or more aspects of activity memory would be associated with functional outcomes following TBI.

METHOD

Participants

Eighteen individuals with a TBI (13 males) and 18 comparison participants (13 males) participated in this study. All participants were Caucasian and well matched for age and education (see Table 1). All TBI participants were at least one year post injury and were recruited from various clinical programs, support groups, and community settings in eastern WA. Participants were excluded if they had preexisting neurological conditions (other than TBI), current psychiatric diagnoses, developmental disorders, substance abuse/dependence histories, and/or a history of multiple head injuries. Comparison participants were recruited from the community in eastern WA through the use of advertisements and from the undergraduate student psychological research pool at Washington State University (WSU), Pullman. All participants recruited from the community were compensated for their time at a rate of $10.00 per hour. Participants recruited from the undergraduate student psychological research pool at WSU Pullman were compensated with course credit.

All TBI participants suffered severe closed-head injuries as indicated by posttraumatic amnesia (n = 16, M = 57.31 days, SD = 93.71, range = 7 to 390 days), loss of consciousness (n = 17, M = 12.53, SD = 12.39, range = 0 to 42 days), and/or acute Glasgow Coma Scale scores (n = 9, M = 6.56, SD = 3.71, range = 3 to 15); all TBI participants had at least one of the aforementioned severity indicators in the severe range. All TBIs resulted from acceleration–deceleration injuries; 11 participants were involved in motor vehicle accidents as a driver or a passenger, three were pedestrians struck by motor vehicles, three suffered long falls, and one was involved in a bicycle accident.

Materials and procedure

This study was approved by the institutional review board of WSU and was conducted at the WSU campuses in Pullman and Spokane, WA. After providing voluntary consent, participants underwent an interview to gather relevant demographic, medical, developmental, and educational information. Following the interview, participants were administered a brief neuropsychological battery (see below) and a self-report measure of functional outcome. The activity memory task was administered following the neuropsychological battery and just prior to the self-report measure of functional outcome.

Neuropsychological function—We assessed cognitive ability with the California Verbal Learning Test (CVLT; Delis, Kramer, Kaplan, & Ober, 1987), the Symbol Digit Modalities Test (SDMT; Smith, 1982), the Trail Making Test (TMT; Army Individual Test Battery, 1944), and the Wisconsin Card Sorting Test, 64-card version (Heaton, 1981). All neuropsychological tests were administered and scored in accordance with standard instructions.

Functional outcome—The Community Integration Questionnaire (CIQ; Willer, Ottenbacher, & Coad, 1994) was used to assess functional outcome. The CIQ is a brief instrument (15 items) designed to measure community integration following TBI. It yields indices of home integration (ability to complete household tasks), social integration

(finances, shopping, leisure activities, and friendship), and productive activities (travel outside of the home, work, training/school, and volunteering), as well as an overall integration index. The CIQ was administered and scored in accordance with its standard instructions.

Activity memory—We employed two lists of eight simulated everyday activities (List A and List B) for the current study (see Table 2). Participants performed activities from one list and observed the experimenter perform similar activities from the other list. It should be noted that there were no differences in memory performances between the two lists (all *t*s = 0.28 to 1.12); therefore, the stimuli were equivalently memorable. All of the activities required the participant or examiner to act on black-and-white stimuli printed on 8.5″ × 11″ sheets of paper. The lists were counterbalanced across participant, and both performance and observation of the activities were randomly determined and interspersed (e.g., Participant Activity 1, Experimenter Activity 1, Participants Activity 2, Experimenter Activity 2, etc.). Performances of each activity were discontinued after two minutes to control for task duration.

Participants were instructed that they would be completing and observing an experimenter complete several everyday activities. They were also told that they were to rate how much they would like to perform each activity in the future on a 5-point Likert scale (1 = *not at all*, 3 = *neutral*, 5 = *a lot*). The ratings were meant to enhance incidental encoding of the activities. Incidental learning instructions were used, as participants were not told that their memory for the activities would be tested.

Activity recall—Following the last Likert rating, participants were asked to recall each activity they completed and observed in as much detail as possible. They were also instructed that the order of their recall of the activities did not matter. The experimenter transcribed participant responses verbatim and asked for clarification whenever necessary. Recall of an activity was scored as correct if two research team members were independently able to recognize the described task and were able to distinguish it from the others on the activity lists. We recorded the correct number of performed and observed activities recalled (eight each).

Activity recognition and source memory—Following the recall trial, participants were read 32 activity descriptions, 16 descriptions of the activities they performed and observed, and 16 distractor descriptions. The distractor descriptions each contained one task element in common with one of the performed/observed activities. They were asked to identify each description as “me” (performed), “you” (observed), or “new” (distractor). These responses were used to calculate both recognition discriminability (hits – false positives = P_r; see Feenan & Snodgrass, 1990) and conditional source identification measures (CSIM; see Murnane & Bayen, 1996) of performed and observed activities to further assess content memory and source memory, respectively.

Temporal order memory for activities—Following the recognition/source memory trial, participants were given a stack of sixteen 8.5″ × 1″ cards with activity descriptions printed on them. They were instructed to arrange the cards in the order they thought that they completed and observed the activities, placing the card for the first task furthest from them and the card for the last task closest to them on the testing table, with the other cards being placed in between in order. We recorded each participant's temporal order reconstruction and calculated the Pearson product–moment correlation coefficient between their reconstruction and the actual order of activity completion/observation. We used each participant's observed and performed temporal order correlation as our measure of activity temporal order memory. We utilized the correlational method to assess temporal order data rather than hit rates, as correlations reflect greater variation in performances. Also, the correlational method evaluates performances on a continuum like the absolute deviation method, although it is more widely understood than the latter (Vakil, 2006).

RESULTS

As can be seen in Table 1, the TBI group exhibited poorer attention and memory performances than the comparison group, although they did not have significant deficits in executive ability. The means and standard deviations for activity memory performances are displayed in Table 3. We utilized an alpha level of $p < .05$ for all analyses. Multiple comparisons/correlations (five or more) were corrected via q-values with a predetermined false discovery rate (FDR) cutoff of .05 (Storey, 2002).

Content memory

Recall—A 2 (group) × 2 (activity type) mixed analysis of variance (ANOVA) revealed a main effect of group, $F(1, 34) = 11.18$, $p = .002$, $\eta^2 = .25$, with the TBI group recalling fewer activities than the comparison group (see Table 3). No within-participant effects or interactions were observed (all Fs ≤ 0.44).

Recognition—A 2 (group) × 2 (activity type) mixed ANOVA showed that TBI participants had poorer discriminability (P_r) than comparison participants, $F(1, 34) = 4.71$, $p = .04$, $\eta^2 = .12$. No within-participant effects or interactions were observed (all Fs = 0.03).

Context memory

Source memory—A 2 (group) × 2 (activity type) mixed ANOVA did not detect any effects (all Fs ≤ 2.66). However, both groups performed near ceiling with regard to source memory (CSIM values of 1.0 indicate perfect performance; see Table 3). Nevertheless, these data indicate that both groups had no difficulty distinguishing performed from observed activities.

Temporal order memory—This analysis included all but one participant: a TBI survivor who shuffled the activity description cards prior to the examiner being able to record the order. A 2 (group) × 2 (activity type) ANOVA for the temporal order memory correlations revealed no significant effects (all Fs ≤ 1.06).

Activity memory and functional outcome

Since no differences were detected between memory for performed and observed activities, these were averaged for the following analysis. Pearson product–moment correlation coefficients were calculated to determine associations between activity content memory (recall and P_r), temporal order memory (temporal order correlations), source memory (CSIM values), and CIQ indices (home integration, social integration, productive activities, and total integration) in the TBI group. A significant correlation emerged between social integration and activity P_r ($r = .67$, $p = .003$, $q = .045$). The other coefficients failed to reach significance (all *r*s = –.32 to .31).

DISCUSSION

In the current study, we aimed to replicate and extend findings from previous activity memory research in TBI. We investigated incidental memory for the content (recall and recognition) and context (temporal order memory and source memory) for performed and observed simulated daily activities. Based on previous work (Schmitter-Edgecombe & Wright, 2003), we expected that TBI participants would show poor content memory for activities in contrast to comparison participants but that they would demonstrate similar temporal order memory. We also hypothesized that content and temporal order performances would be similar for observed and performed activities in both groups, given neuroimaging data showing similar activations for performed and observed acts (Iacoboni et al., 1999); both types of activities engage the left inferior frontal lobe and the right superior parietal lobule. In addition, since the neuroanatomical underpinnings of temporal order and source memory are fairly similar (more frontal) and partially dissociable from content memory (more temporal) (Butters et al., 1994; Milner et al., 1985; Shimamura et al., 1990), we hypothesized that TBI and comparison participants would show equivalent source memory for activities. Finally, we posited that activity memory would be associated with functional outcomes following TBI.

Consistent with previous research (Cooke & Kausler, 1995; Schmitter-Edgecombe & Seelye, 2012; Schmitter-Edgecombe & Wright, 2003), and as expected, we found that content memory (both recall and recognition) for activities was significantly poorer in TBI participants than in ageand education-matched comparison participants. That said, similar to Schmitter-Edgecombe and Wright (2003), and as predicted, our TBI group demonstrated intact temporal order memory for activities. This contrasts with Cooke and Kausler (1995) and Schmitter-Edgecombe and Seelye (2012), who both showed impaired temporal order memory for activities in TBI. Both the current study and Schmitter-Edgecombe and Wright utilized only incidental learning procedures (participants were not told they would be asked to remember the activities they completed). Cooke and Kausler did find poorer temporal order memory with incidental instructions, but their study differed from the current study in that they employed less purposive activities. Since the present study and their study used tasks that were relatively shorter in duration (in contrast, Schmitter-Edgecombe & Seelye, 2012; Schmitter-Edgecombe & Wright, 2003), task duration does not seem to impact temporal order memory in TBI compared to comparison participants. Overall, it appears that temporal order memory for activities may be encoded more implicitly and at equivalent levels in TBI and comparison participants for purposive activities under incidental learning conditions; intentional learning conditions seem to override this effect by engaging effortful, explicit memory processes. Additional evidence for the potential automatic/implicit encoding of temporal order memory for continuous activities under incidental learning conditions was presented in Schmitter-Edgecombe and Wright, as they showed that longer task durations and multimodal task demands resulted in better content memory for TBI and comparison participants, but these factors did not impact temporal order memory in either group. In other words, temporal order memory was not improved by factors that typically influence explicit memory. Additionally, given that we utilized everyday activities, whereas Schmitter-Edgecombe and Wright employed neuropsychological tests for their activities, but both studies had similar findings with regard to temporal order memory for continuous activities, it appears that task novelty did not govern temporal order memory abilities following TBI (neuropsychological tests should be more novel to participants than everyday type tasks).

Like our findings regarding performed activities, our results indicate that content memory is poor while temporal order memory is intact in TBI participants in contrast to comparison participants for observed activities. In fact, both groups demonstrated almost identical memory performances for performed and observed activities. Unlike previous studies of activity memory following TBI, we also investigated source memory. With regard to source memory for performed and observed activities, there were no group differences, as predicted, but both groups performed near ceiling. Despite this ceiling effect, our results suggest that TBI and comparison participants have little or no difficulty distinguishing between performed and observed activities, even when elements of the activities overlap.

It has been suggested that the implicit memory system is one that encompasses the entire cortex, with numerous cortical–subcortical connections, and that involves slow encoding and storage of categorical and sequential data, especially from repetitive experiences, while the explicit memory system is moderated by medial–temporal structures, the frontal lobes, and, ultimately, the cortex, and involves rapid encoding and initial storage of facts and events (Reber, 2013). That said, repetition is not always required for implicit learning (e.g., repetition priming; see Reber, 2013). While the explicit and implicit memory systems have been traditionally thought to be independent, recent work has shown that they are dynamically related. Specifically, explicit and implicit learning have been shown to create retroactive interference for each other during periods of wakefulness, although this effect is abolished by an intervening period of sleep (Brown & Robertson, 2007). It is possible that temporal order, being sequential in nature, and source information, being categorical in nature, are biased toward slow, cortically based, implicit encoding. If true, this could partially explain our results and the differences between studies of activity temporal order in TBI. TBI survivors are known to have impaired explicit memory, but generally intact implicit memory (Vakil, 2005). That said, temporal order and source data may be encoded by the implicit memory system, unless disrupted by the engagement of the explicit memory system via intentional learning instructions. Additionally, greater purposiveness of activities may lead to greater cortical involvement, thus making implicit encoding more likely.

Finally, we evaluated the association between functional outcome and activity memory. Recognition discriminability for activities (performed and observed) was strongly associated with social integration index of the CIQ. This social integration index is made up of items that reflect financial management, shopping, leisure activities, and friendships. Thus, it appears that the ability to recognize completed activities may play an important role in functional outcomes for TBI survivors.

Limitations

While the current study helps to resolve some inconsistencies regarding activity memory following TBI, it is not without limitations. First, although the current study supports the notion that content memory for performed and observed goal-directed activities is impaired, while temporal order and source memory for such activities is intact under incidental learning conditions in TBI, our sample was relatively small. Additionally, the current study did not systematically assess instruction type (intentional vs. incidental) or the level purposiveness on memory for activities. Such manipulations may have led to greater certainty with regard to the conditions that impact temporal order memory, and potentially source memory, for activities following TBI. Finally, while both TBI and comparison participants had no difficulty differentiating performed from observed activities, we did not evaluate source memory for other types of activity information or components of shared activities. Future work should address these limitations.

CONCLUSIONS

Our study supports the finding that content memory for performed activities is impaired following TBI and extends it to observed activities as well. Also, we found that temporal order memory for observed and performed activities was intact following TBI under incidental learning conditions for purposive activities. We showed that both TBI and comparison participants could easily distinguish between observed and performed activities. Moreover, we found no within-participant differences in memory for performed versus observed activities. Finally, recognition memory for performed and observed activities was strongly related to an index of social integration (finances, shopping, leisure activities, and friendship).

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TABLE 1

Demographic and neuropsychological test data for TBI and control groups

	Comparison		TBI				
Variable or test	**M**	**SD**	**M**	**SD**	**t**	**p**	**d**
Age (in years)	30.72	10.10	30.94	10.03	–0.07	.948	0.02
Education (in years)	13.67	2.63	13.11	1.84	0.73	.469	0.16
Attention & processing speed							
SDMT Written	59.28	11.45	47.50	12.02	3.01*	.005	1.03
SDMT Oral	67.72	12.92	56.83	14.88	2.35*	.025	0.81
TMT A (s)	23.11	6.05	29.94	12.37	–2.11*	.046	0.72
Learning & memory							
CVLT 1-5	53.72	8.56	41.94	18.15	2.49*	.020	0.85
CVLT LDFR	11.72	2.40	8.12	4.74	2.81*	.010	0.96
Executive ability							
TMT B (s)	50.28	18.67	79.22	62.28	–1.89	.074	0.65
WCST Perseverative Errors	6.06	2.49	7.94	6.57	–1.11	.278	0.39

Note. Table displays raw values, test statistics, and effect sizes for demographic and neuropsychological test performances. All neuropsychological tests were administered and scored in standard fashion. TBI = traumatic brain injury; SDMT = Symbol Digit Modalities Test; TMT A = Trail Making Test, Part A; CVLT–II = California Verbal Learning Test-Second Edition; 1–5 = Learning Trials 1 through 5; LDFR = long-delayed free recall;TMT B = Trail Making Test, Part B; WCST = Wisconsin Card Sorting Test (64-card version).

[*] Significant result; $p \leq .05$ and $q \leq .05$.

TABLE 2

Activity lists

List A		List B	
Activity	**Description**	**Activity**	**Description**
Maze	A long, visually complex maze	Dot-to-dot	A 32-point dot-to-dot task
Checkbook balance	Table containing a starting balance and a series of credits and debits to be calculated	Practical math	Two math problems, where a total and sales tax were to be calculated; one also required calculation of a tip
Picture copy	Two detailed line drawings that were to be copied	Incomplete pictures	Ten line drawings with missing components that had to be drawn in
Word find	A 12-item word find task	Crossword	A 15 × 17-item crossword puzzle
Supermarket shopping list	A list of ingredients that had to be transcribed under 5 meal headings	Phone number find	Nine phone numbers had to be found and transcribed from a list of 54 fictitious, alphabetically listed phone numbers
Word jumbles	A list of 15 scrabbled words that had to be unscrambled and written	News story	A news story regarding politics in Bolivia that was to be read aloud
Mapping	An exercise where a line was to be drawn to 10 consecutive destinations on a map of a fictitious land	Letter edit	A fictional letter to a landlord that contained many typos that had to be proofread and corrected
Picture find	A visually complex, 15-item picture find	Appointment scheduling	Twelve events to be scheduled on a month view calendar; some to be scheduled events included compound instructions

Note. Table displays activity lists used in the current study. Each activity was completed one at a time in a random order. Participants completed one list and observed the experimenter complete the other list. List assignments were counterbalanced across participants. Activity performances were terminated after 2 min, and each activity was designed to require more than 2 min to complete, assuring that participants and experimenters would be engaged in each task for the allotted time. All activity stimuli were black and white and were presented on 8.5″ × 11″ sheets of paper. There were no differences between the lists with regard to memory performances (all *t*s = 0.28 to 1.12, *p*s = .30 to .78). Participants were not told that their memory for the activities would be tested later, but they did rate their liking of each task on 5-point rating Likert (1 = *not at all*, 3 = *neutral*, 5 = *a lot*) after its completion.

TABLE 3

Activity memory data

	Comparison		TBI	
Activity memory performances	**Performed M(SD)**	**Observed M(SD)**	**Performed M(SD)**	**Observed M(SD)**
CM recall	4.89 (1.84)	4.44 (1.65)	3.17 (1.58)	3.28 (1.64)
CM P_r	7.17 (1.04)	7.06 (1.73)	6.22 (1.90)	6.22 (1.35)
TM correlation	0.77 (0.13)	0.70 (0.15)	0.71 (0.17)	0.70 (0.15)
SM CSIM	1.00 (0.00)	0.98 (0.05)	0.94 (0.14)	0.94 (0.13)

Note. Displays means and standard deviations for content memory (CM; CM recall, P_r), temporal order memory (TM; TM correlation), and source memory (SM; SM CSIM) performances for both groups. TBI = traumatic brain injury; P_r = recognition discriminability; TM correlation = Pearson product-moment correlations between actual order and reconstructed order for observed and performed activities; CSIM = conditional source identification measure.