Improving Lexical Memory Access and Decision Making Processes Using Cognitive Word Games

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Abstract

Strengthening semantic and orthographic associations among words in a lexicon may help to improve memory processes related to fluent organizing and retrieval of language. In the present study, we examined how training in several different word games impacts later retrieval access for the words. Games included a word-stem completion task (orthographic), a free association task (semantic), and a crossword paradigm task (orthographic+semantic). A within-subject experiment was used to compare the relative effectiveness of these three training methods on a lexical association task performed prior to and following training. Results showed that the games were able to improve participants' decision times, and the increased fluency in the lexical association task due to the free association task was greater than the other games. We will further apply and examine this study with non-native English speakers.

Keywords: Crossword Paradigm; Lexical Memory Access; Word-Stem Completion; Free Association

Lexical Memory Access as a Recognitional Decision Process

Previous research on lexical memory has often focused on how information is stored and organized in long-term memory (Atkinson & Shiffrin, 1969), as well as on aspects of memory retrieval, search, and forgetting (e.g. McGeoch, 1932; Underwood, 1957). When considering language as a domain of expertise (Ericsson & Kintsch, 1995), it is perhaps unmatched in terms of its size and complexity, containing thousands of words, rules, grammatical forms, and associations used for communication (Miller, 1972; Nickerson, 1977). Although most traditional studies of recognition and recall (e.g. Anderson & Bower, 1972; Brown & McNeill, 1966; Shiffrin, 1970) use linguistic material to assess performance, they typically have not examined linguistic memory from the context of expert knowledge retrieval, and so may miss important similarities in these domains.

Research on expertise is another approach to understand linguistic memory processes. Mueller and Thanasuan (2013) studied crossword experts' puzzle-solving abilities and developed the computational models based on the Recognition-Primed Decision (RPD) models (Klein, 1993; Klein, Calderwood, & Clinton-Cirocco, 1986) and the Bayesian Recognitional Decision Making (BRDM) model (Mueller, 2009), which itself was adapted from the REM models of human episodic memory (Shiffrin & Steyvers, 1997). These models were able to explain aspects of decision making and problem solving based on simple lexical memory representations of the clues and answers found in past puzzles. Subsequently, Thanasuan and Mueller (2014) examined the strategic contributors to expert crossword play by adapting the model to actually solve complete puzzles with abilities similar to crossword experts. Consequently, this research has demonstrated strong connections between theories of memory, problem solving, and expert decision making.

Cognitive Word Games as Language Training

As a consequence of this research, we have begun examining how word games might be used to improve lexical memory access, as well as to establish evidence for effective training strategies. Word games offer potential benefits, as they are engaging, they allow repetition, and they may be able to strengthen memory access routes that are not used in more traditional methods. Crossword and other similar word games are frequently used as language and vocabulary building exercises, both in second-language classrooms and in specific disciplines requiring a specialized vocabulary. Furthermore, Read (1998) has used similar tasks as a validated test for non-native English speakers, and found the tasks were good for assessing depth of vocabulary knowledge.

We hypothesize that lexical memory access may be enhanced by increasing either (or both) semantic and orthographic associations among words in a lexicon (see Figure 1). Different word games may selectively enhance different associations (see Figure 2), and better overall fluency may be promoted using games that enhance both routes.

To test this hypothesis, we selected three word games: a word-stem completion task; a free association task; and a crossword task. As an outcome measure, we developed task assessing lexical associations, which was assessed both prior to and following practice. In addition, we also collected some baseline data on cognitive abilities (in the form of a reading span task and a matrix reasoning task), to assess how general cognitive skills were related to performance.

Experiment

Participants

Sixty-one undergraduate students were recruited from the MTU subject pool. Only 55 students completed all tasks (Mean age = 20.38 $\pm$ 4.54 yrs). Participants included 54

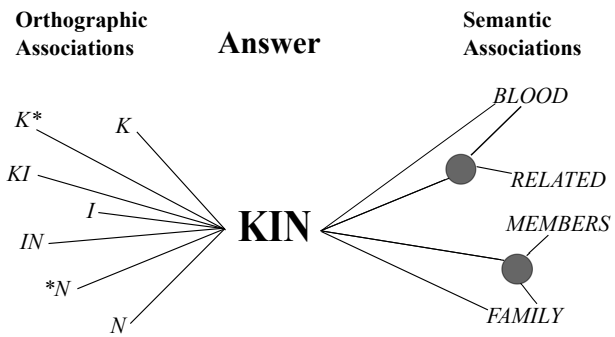

Figure 1: Example of semantic and orthographic associations to a word. Fluent language access requires access to both aspects of words.

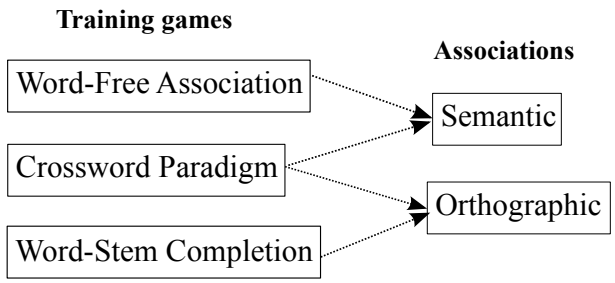

Figure 2: Training game strategies: a line indicates that a training game strengthens a particular type of association.

native English speakers and one non-native English speaker with 8 years of English. The experiment was reviewed and approved by the Michigan Technological University Institutional Review Board (IRB).

Design, Materials and Stimuli

Forty English words were selected from the book "Words for Students of English: A Vocabulary Series for ESL Vol. 1-7" (Pitt Series in English As a Second Language), stratified across seven different levels from beginning to advanced learners. The words were randomly assigned into one of four groups (10 words per group) and these four word groups (1,2,3 and 4) were assigned to the four training conditions via a Latin Square, as shown in Table 1. Participants were randomly assigned to one of the four training groups, so that each participant experienced every training condition. The conditions were composed of a control group (no learning), a word-stem completion task, a free association task, and a crossword paradigm task. The task details are shown in the following sections. Software from the Psychology Experiment Building Language (PEBL) test battery (Mueller & Piper, 2014) was used to collect data from the survey, matrix reasoning, and reading span tasks. The remaining tasks were conducted via a web browser.

Table 1: Training groups

Participant group	Word training conditions			
	WSC[1]	FA[2]	Cross.[3]	Control
A	1	2	3	4
B	2	3	4	1
C	3	4	1	2
D	4	1	2	3

Note: [1]WSC = Word-Stem Completion task; [2]FA= Free Association task; [3]Cross.= Crossword Paradigm task

Baseline Tasks

Participants were asked to perform the reading span task and the reasoning task at the beginning of the study. The reading span task was used to measure participants' working memory span and their reading ability. The reasoning task was used to assess intelligence and reasoning ability.

Reading Span Task The reading span task that we used in this study was originally conducted by Daneman and Carpenter (1980) and adapted by Unsworth, Redick, Heitz, Broadway, and Engle (2009). The goal of this task was to recall a set of unrelated letters, consisting of F, H, J, K, L, N, P, Q, R, S, T and Y. Participants were required to read a sentence, validate whether it is logical and memorize a letter presented after the judgment. The letter appeared for 1000 ms. The participants had to recall letters in a correct order. There were three trials of each set size between three to seven letters, for a maximum possible total of 75 letters to be recalled. The score was computed based on the number of correct letters in the correct positions and orders. This task took 15 minutes.

Reasoning Task A novel matrix reasoning task based on Raven's Raven and Court (1998) progressive matrices was used to measure participant reasoning ability in this study. This version used stimuli developed and discussed by Matzen et al. (2010). The types of shape transformations include shape change, shading change, orientation change, size change and number change. One, two or three types of shape combinations were given to participants in each trial. Their task was to identify the missing patterned shape that completed the matrix pattern. There was a total of 43 test problems and two practices at the beginning of the test. Participants had 15 minutes to complete all problems.

Lexical Association Task

The lexical association task was completed both prior to and following word game training. It was used to assess memory access process. On each trial, participants saw a target word along with four possibly related choice words. Their task was to determine which one of these cues was meaningfully related or strongly associated to the target word. All cues except the correct answer were selected at random from the Brown corpus (Kuĉera & Francis, 1967) and the Free As-

sociation Norms (Nelson, McEvoy, & Schreiber, 1998). The test was comprised of 40 problems that took ten minutes to complete. The target word and the correct answer were the same for the pre-test and post-test, but the other word cues and positions were changed randomly. The example of this task is shown in Figure 3.

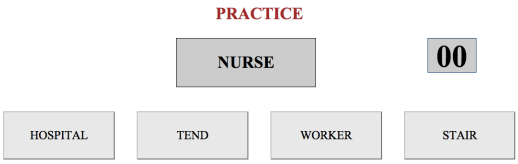

Figure 3: The example of Lexical Association Task

Treatment Tasks

Participants were asked to perform the training tasks twice. All tasks are described below. We hypothesized that the training intervention would differently assist participants' memory process on target words.

Word-Stem Completion Task The word-stem completion task was adapted from Mueller and Thanasuan (2014). In each trial, participants were given a word-stem with the first two letters filled and a blank space, such as "ST_____". Their task was to complete words by typing the remaining letters in the blank. They needed to generate as many unique words as they could in 30 seconds. When the time was up, the software showed some possible answers of the stem for four seconds. A screen shot from the task is shown in Figure 4.

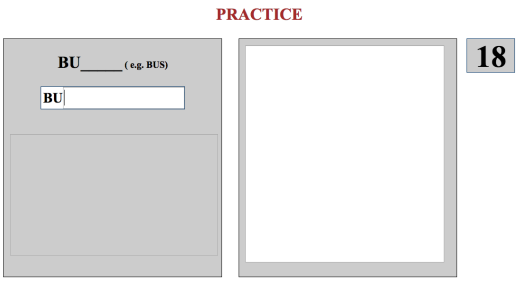

Figure 4: The example of Word-Stem Completion Task

Crossword Paradigm Task The crossword paradigm task was originally conducted by Goldblum and Frost (1988), and was adapted by Mueller and Thanasuan (2013). In this task, we gave each participant limited time (30 seconds per problem) to solve a series of crossword puzzle problems. Participants were shown a crossword clue and a word-pattern with two letters filled in as shown in Figure 5. They then entered a guess answer in the blank spaces. If the answer was incorrect, the software randomly generated one more letter to provide additional constraints. A total of 10 problems were given to participants. The crossword clue-answer pairs in this study were from the same database as in Mueller and Thanasuan (2013) and Thanasuan and Mueller (2014).

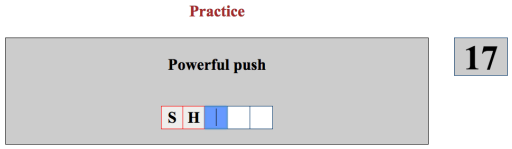

Figure 5: The example of Crossword Paradigm Task

Free Association Task In this task, participants were given a target word for each trial as shown in Figure 6. Their goal was to generate and type words that came to their mind, and were meaningfully related or strongly associated to the presented word. For example, if the given word was "BOOK", they might answer "READ, NOVEL, WRITE". They had 30 seconds for each trial to give as many answers as possible. There were a total of 10 problems in this task. After the time was up, some sample answers taken from the Nelson et al. (1998) Free Association Norm were shown in the screen for four seconds.

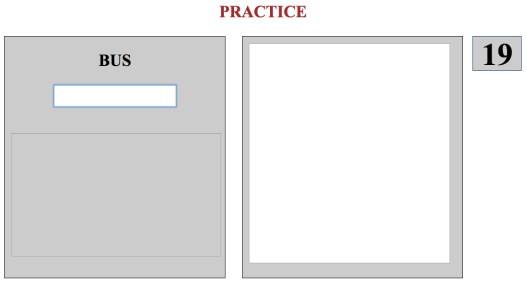

Figure 6: The example of Free Association Task

Task Sequence

Participants first read and signed the consent form. They were assigned to one of these four groups (A, B, C or D) as are shown in Table 1. They completed the survey, the reading span task, the reasoning task, and the lexical association task as a pre-test. Then, they performed the word-stem task, the free association task and the crossword paradigm task twice. Finally, they were asked to retake the lexical association task as a post-test. The entire experiment approximately took 1.5 hours to complete, but the average time spent for each participant was 56.8 $\pm$ 7.5 minutes.

Results

Data from 55 participants were analyzed in this study (15, 14, 12 and 14 in Groups A through D, respectively). The average scores of the reasoning and reading span tasks were 32.65 $\pm$

Table 2: Training results: Mean and standard deviation of training tasks on first and second administration of test

Task	1st Test	2nd Test	$t(54) =$
FA[1]: Legal words	5.61 (1.48)	6.39 (1.79)	−6.38*
WSC[2]: Legal words	6.05 (1.63)	6.64 (2.02)	−3.75 *
Crossword:[3]			
Accuracy	9 (1.02)	9.9 (0.29)	6.97 *
RT(s)	6.41 (2.73)	3.54 (1.48)	9.93 *
Letter cues	2.32 (0.35)	2.08 (0.17)	6.32 *
Cue Prop.	0.38 (0.05)	0.33 (0.03)	6.95*

Note: [1]WS= Word-Stem Completion task; [2]FA= Free Association task; [3]Cross.= Crossword Paradigm task; * p-value $< .0001$

4.61 and 59.89 $\pm$ 8.90, respectively. The correlation between the number of recognized letters and the accuracy of sentence distractions in the reading span task was 0.31 with t(52)=2.34, p= .02, whereas the correlation between the reading span task and the reasoning task was 0.24 (t(52)=1.81, p = .08). There was no significant correlation between the reasoning or reading span task with the other tasks' performance. Table 2 shows results from the training games. A Microsoft Excel 2013 main dictionary was used as a spell checker for scoring answer words that were generated from the word-stem completion task and the free association task. We conducted paired t-tests to compare both iterations of the games. Results showed significant improvements in each game in: the number of legal answers from the free association task ($p < .0001$) and the word-stem completion task ($p < .0001$) as well as response times, the number of letter cues ($p < .0001$) and cue proportion (computed by the number of letter cues and length in the crossword paradigm task) ($p < .0001$). Moreover, the average unique words generated per a target word from the free association task and the word-stem completion task were 64 $\pm$ 9.48 and 66.25 $\pm$ 21, respectively.

Accuracy of the pre-post tests of the lexical association task significantly increased from 37.98 $\pm$ 1.64 to 38.45 $\pm$ 1.91 (t(54) = -1.95, p = .05), whereas response times of these tests decreased from 3.56 $\pm$ 0.93 seconds to 2.67 $\pm$ 0.67 seconds (t(54) = 10.98, $p < .0001$). Response times of each game condition are shown in Figure 7. The figure indicates that all training conditions (including the control condition) were able to improve participants' performance. We computed post-pre difference scores on response time (Figure 8) which shows that most participants improved between tests, but a greater proportion of participants improved in their response speed for the free association task than for the others. Moreover, the response time improvement for each participant's group is shown in Figure 9, which also supports that the free association task was able to reduce memory time across the groups.

A regression analysis between the response time difference and the game conditions was conducted to compare which game was the most effective training and it showed that all games reliably influenced the response time improvement (with R^2 = .57, F(4,216) = 74.16 , $p < .0001$), and participants improved the response times of the words studied in the free association task greater than the words they had done in the other tasks (see Table 3). The coefficient (β) represents the intercept of response time difference between the pre-post tests, which means that the free association task was able to decrease response times in the post-test approximately a second from the pre-test. There was no evidence that word-stem completion had any advantage over the control condition as well as the crossword paradigm task. We also compared the response time improvement of each game group to the improvement of the control group using paired-samples t-tests, and the results indicated that the time difference between the free association group and control groups was significant (t(54) = -2.07, p = .02). However, there was no significant difference between the control group and the crossword paradigm task (t(54) = .16, p= .56) or the word-

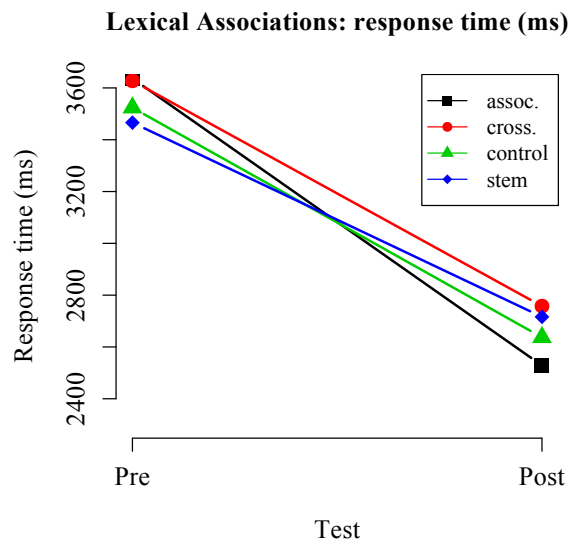

Figure 7: Lexical Association Task: Response time for each game condition

Table 3: Regression results: Training effects

Training	Coefficient (β)	Std. Error	t-value
FA[1]	-1108	106.0	-10.45*
Cross.[2]	-869.8	106.0	-8.2*
Control	-886.6	106.0	-8.37*
WSC[3]	-749.8	106.0	-7.07*

Note: [1]FA= Free Association; [2]Cross.= Crossword Paradigm; [3]WSC = Word-Stem Completion, * p-value $< .0001$

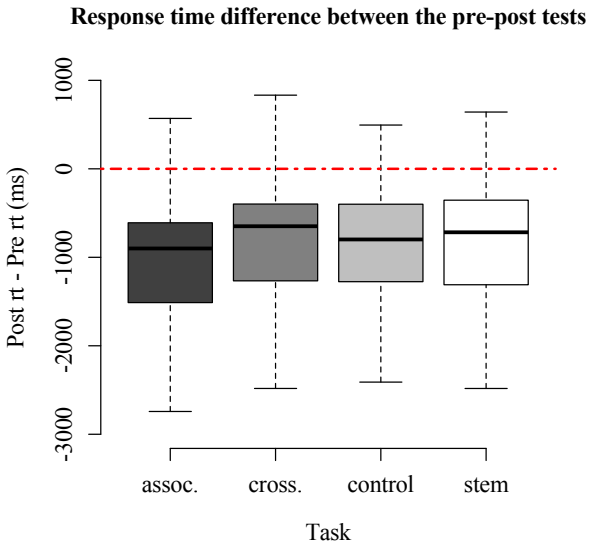

Figure 8: Lexical Association Task: Response time difference between the pre-post tests

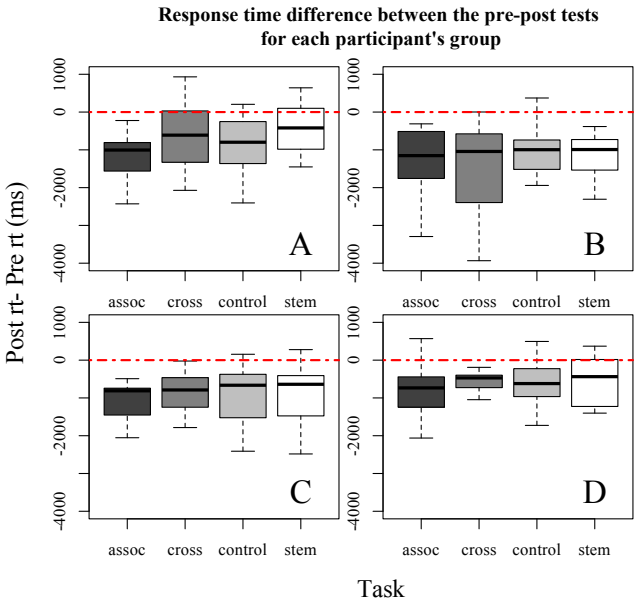

Figure 9: Lexical Association Task: Response time difference between the pre-post tests for each participant's group

stem completion task (t(54) = 1.36, p = .92). It suggests that the free association training (i.e. semantic association) was able to enhance memory access effectively and better than other training conditions or no training group.

Discussion

This experiment was proposed to study the short-term learning effects of the word training games, including word-stem completion, free association and crossword paradigm on lexical memory access. The results showed reliable progress from the pre-test to the post-test for all word games, and with lexical access, the most improved performance in comparison to the control group occurred with the free association task. We hypothesize that this advantage occurred because the testing method involves accessing exactly the same types of associations to the target word that participants generated during training. Moreover, they spent more time performing this task than the crossword paradigm task—less than three seconds on average for solving each problem in the crossword paradigm task for one answer, versus 30 seconds with multiple generated words for the free association task. Thus, this training was more efficient than the others.

One of our hypotheses was not supported by this study—that training in the crossword paradigm, which strengthens both orthographic and semantic routes, would provide additional benefit. Instead, our results essentially showed that semantic association training (from the free association task) is effective, but orthographic training (through crossword or word-stem) is not. However, orthographic-level training may show benefits for fluent retrieval tasks that are more focused on the surface features, and these may be especially helpful for non-native English learners, whose orthographic and phonological associations to words are weaker.

Another critical issue is that the repetition effects of the lexical association task were shown clearly in the control condition. Although in this task, the cues besides the answers were randomly selected, the answers corresponding to the given words were the same for both pre-post tests. We think that this may cause the effects in all game conditions, still the free association effect was greater than the others. To solve this problem, we may give two different answers for the pre-post tests of the same target words.

Consequently, this research provides a basis for understanding the use of word games to promote second language (L2) learning. According to Revised Hierarchical Model (Kroll & Stewart, 1994), L2 word learning in early stage is heavily relied on connections between learner's first language words and L2 words. After that, he may be able to learn new words via a concept mediation. Implicit word learning such as the games in this study may be another approach to establish or strengthen associations among new L2 words. Additionally, if learner plays the games iteratively, it may help to improve his long-term lexical memory.

There are many studies supporting that word games similar to the crossword word paradigm task were able to assist second language learners to boost their vocabulary skills (Anugerah & Silitonga, 2013; Keshta & Al-Faleet, 2013; Njoroge, Ndungu, & Gathigia, 2013; Ropal & Abu, 2014) such as spelling and semantic associations. The studies also showed that the word games were able to increase enjoyment and motivate L2 learners in the classroom (Njoroge et al., 2013). Moreover, another potential implication of the research is to help persons with reading disorders to develop

their literacy skills.

Acknowledgments

The authors thank the Royal Thai Fellowship for support of KT in this research.

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