2015

# USING COGNITIVE WORD GAMES TO PROMOTE LEXICAL MEMORY ACCESS AND VOCABULARY RETRIEVAL IN SECOND LANGUAGE LEARNERS

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# USING COGNITIVE WORD GAMES TO PROMOTE LEXICAL MEMORY ACCESS AND VOCABULARY RETRIEVAL IN SECOND LANGUAGE LEARNERS

By

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A DISSERTATION

Submitted in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

In Applied Cognitive Science and Human Factors

MICHIGAN TECHNOLOGICAL UNIVERSITY

2015

This dissertation has been approved in partial fulfillment of the requirements for the Degree of DOCTOR OF PHILOSOPHY in Applied Cognitive Science and Human Factors.

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# Contents

# List of Figures

# List of Tables

# Preface

Chapter 1-3 provide introduction, background and research objectives of this dissertation. A version of Chapter 4 has been published in the Proceedings of the $37^{th}$ Annual Cognitive Science conference as Thanasuan & Mueller (2015). Kejkaew Thanasuan conducted the experiment, analyzed the data and prepared the manuscript for the conference. Dr. Shane Mueller also revised the paper. Chapter 5-6 of this dissertation are original and unpublished experiments conducted by Kejkaew Thanasuan. Finally, Chapter 7 provides conclusions and future directions of this research.

# Acknowledgments

This dissertation has been supported and contributed by many people. First, I would like to thank my advisor, Dr. Shane Mueller, for all his help in revising the dissertation, and a lot of academic advice that he has given me over the past four years. Many thanks to the committee members, Dr. Robert Pastel, Dr. Adam Feltz and Dr. Alena Esposito, whose comments and suggestions I greatly appreciate.

Thank you to the Royal Thai government for a graduate fellowship, which supported me financially for all my graduate degrees. I also would like to thank the Michigan Tech graduate school for the Finishing Fellowship, which supported me during the Fall 2015 semester, so I had more time to collect data and complete the dissertation.

Thanks to faculties at the department of Cognitive and Learning Sciences, who taught, guided and prepared me in the field of cognitive science and human factors, and staffs at Michigan Tech Multiliteracies Center (MTMC) who helped me improve my dissertation writing and announce the participant recruitment for my experiments.

Thanks are also due to all participants in this dissertation. I really appreciate help from Assistant Professor Dr. Tipsuda Janjamlha at Thammasat University and Assistant Professor Paunluck Puntahachart Saengsawang at King Monkut's University, North Bangkok (KMUTNB) for recruiting participants for me.

Thank you to my friends and colleagues at Michigan Tech, especially ACSHF graduate students—all discussions and comments helped me improve the research skills and knowledge in this field.

Finally, thank you to my parents, sister, uncle and aunt (Dr. Sieting and Prapasri Wong), who supported and encouraged me throughout my study.

# Abstract

Fluency in a second language (L2) is one of the most important skills for the modern world. However, adults learning a new language face many obstacles, including motivation, time, and other challenges in learning. Technology learning tools may help solve these problems. In this dissertation, I tested the effectiveness of cognitive word games as a vocabulary learning method, with the main goal of investigating how different word games including a crossword paradigm task, a free association task and a word-stem completion task were effective at improving vocabulary memory access. The games selectively increased semantic (meaning) or orthographic (spelling) associations in an English lexicon, which may lead to improved access and usage of L2 vocabulary.

Three experiments were conducted. Experiment 1 examined lexical memory and recognition/retrieval processes in native English speakers. The results showed a significant effect of the game conditions on response times of a lexical association task, such that the most effective training game was the free association task. Experiment 2 was designed to probe the same game effectiveness with non-native English speakers. This time, the findings indicated significant effects of the training games on correct responses of the lexical association task and response times of a new anagram solving task.

Experiment 3 was designed to investigate the game effectiveness on comprehensive English reading test scores. The results suggested that after a week of training, the games failed to improve learners' performance on the English reading scores. However, training methods differed in how much the learners improved during the practice, with crossword practice leading to large improvements and word stem completion getting worse, indicating differences in engagement and in-task language learning. In addition, feedback from participants revealed that some of them enjoyed the games, especially the crossword paradigm task.

In summary, these studies provided a broad understanding of using the word games to enhance English vocabulary skills. The games can be used for further lexical investigations or adapted for classroom purposes.

# Chapter 1

# Introduction

Previous studies in second language learning and bilingualism have often focused on the relationship between two languages, including attempts to understand how bilinguals retrieve a word from two different lexicons, and how words are stored and represented in the memory. For example, Kroll & Stewart (1994) proposed a lexical representation and organization called the Revised Hierarchical model. The model assumed that the connections or translations between a native language (L1) and a second language (L2) can be performed directly between languages or via a conceptual-mediation route. However, the associated link from L1 to L2 is typically weaker than the one from L2 to L1. Similarly, Dijkstra et al. (1998) and Van Heuven et al. (1998) adapted McClelland & Rumelhart's Interactive Activation (IA) model to word recognition in bilingual domain and called it the Bilingual Interactive Activation

(BIA) model. The researchers assumed that the two lexical representations share the same conceptual knowledge but distinct surface structure so that lexical access between the two languages competed with one another. Thus, they suppose that second-language vocabulary requires semantic activation with language selection to identify surface structure.

However, these experiments and models may not accurately represent how learners use a second language in real situations. For example, successful second language learners improve their skills by practicing and interacting with native speakers via bottom-up and example-based learning. They produce or acquire a L2 sentence or word forms based on their knowledge and experience, apparently, without struggling with the language selection process or translation.

Consequently, experience and knowledge with a recognition process should be considered as one aspect of the lexical accesses and a language proficiency development. Although language is often considered its own unique domain, some insights can be gained by focusing on expertise in general (Ericsson et al., 1993), which has been argued to involve similar process to language expertise (Ericsson & Kintsch, 1995). Thus, it requires fast access and encoding of information, similar to other expertise domains such as in chess (Calderwood et al., 1988) or in fire-ground commanders studies (G. A. Klein et al., 1986; G. A. Klein, 1993). The practical language function of fluent bilinguals utilizes available cues (e.g. words, grammar, etc.) to understand sentences while listening to, reading, and producing words based on experience without needing language translation. Similarly, much like other kinds of expertise, L2 learners can use exemplar and case-based learning to learn from native speakers and practice new word forms, phrases, and idioms. This is akin to deliberate practice strategies in other expertise domains (Ericsson et al., 1993) as well as in the cognitive literature on skill acquisition (Ackerman, 1988; J. R. Anderson, 1982).

One hallmark of expert performance is automaticity (J. R. Anderson, 1982; Schneider & Shiffrin, 1977). The concept of automaticity may play an important role in linking second language acquisition and cognitive skill development as a consequence of frequency effects and practice-based repetition. It may be also used for distinguishing fluent from non-fluent L2 proficiency. The early research in this issue was conducted by Favreau & Segalowitz (1983), who compared the reading speed and comprehension in L2 between the fluent and less fluent groups of bilinguals. They found that the stronger bilinguals were able to read L2 materials as fast as L1 with the same level of comprehension, whereas the weaker group spent more time reading in L2 than in L1 in order to understand the same content. They hypothesized that the slower reading process in L2 is a result of less automatic lexical processes in L2. They further investigated this by using a primed lexical decision task, and found that only the fluent bilingual group showed facilitation and inhibition effects in L2 from primes. They concluded that some underlying language processes in the highly skilled bilinguals were ballistic and automatic, but not presented in the lower skill group.

These findings align with existing theories of Naturalistic Decision Making (NDM), in which the fluent bilinguals may, most of the time, rely on their experiences and knowledge when communicating in L2. Thus, the NDM theories may help to provide insight into second language phenomena.

A related domain of language expertise involves the study of word games, such as crossword puzzles. In fact, there are a number of studies showing that the puzzles can help and motivate second language learning students (Keshta & Al-Faleet, 2013; Njoroge et al., 2013; Ropal & Abu, 2014; Anugerah & Silitonga, 2013), by improving their vocabulary and spelling as well as increasing classroom participation and engagement. For example, Njoroge et al. (2013) indicated that using crossword puzzles to teach English vocabulary in Kenyan classrooms was an effective strategy to help their students improve language skills. They also found that one advantage of using such games was that learners enjoyed and gained interest during their English class. Another study from Ropal & Abu (2014) showed significant improvement of students' spelling tests comparing pre- and post-tests after they completed a crossword puzzle with pictures and scrambled words as clues. Other studies, such as Hung & Young (2007) and Galimova (2014), have also shown the similar benefits of using crossword puzzles as an English learning aid in schools.

Nevertheless, the cognitive processes involved in crossword solving have rarely been discussed, even for one's native language. The processes by which crossword players search and retrieve the specific knowledge was perhaps first pointed out by Nickerson (1977) and Nickerson (2011). He explained his memory, search and retrieval in crossword domain without an empirical study. More recently, Mueller & Thanasuan (2013) proposed using a crossword paradigm task to investigate the lexical access of crossword experts, and found that there were two different routes that facilitate the solving performance: semantic and orthographic routes. Again, these two important aspects may share features in L2 learning.

Learning a foreign language has often been argued to be more difficult for adults, compared to children, since they have already passed the critical period of L2 learning (Johnson & Newport, 1989). Many researchers have investigated factors that impact child L2 learning. For instance, Ausubel (1964) indicated that children typically get more practice in new languages than adults because they need to communicate with their friends and participate in classrooms. Other factors in L2 learning such as teacher perception, gender, aptitude, learning style, personality type, ego boundary, motivation, and anxiety may have a greater impact on adults than children. However, currently there are many tools aimed at promoting second-language learning in adults, such as Rosetta Stone (www.rosettastone.com) or other online courses. This self-learning path has the potential to save time and money, in comparison to a classroom setting. In both contexts, word games can be used as another aid in English learning. Their benefits include that they can make learning both challenging and enjoyable.

The purposes of this dissertation was to investigate how to improve a lexical access of non-native English speakers using English word games, including a crossword paradigm game, a word-stem completion game and a free association game. The hypothesis was that for highly-skilled bilinguals or second language learners, their lexical processes mostly rely on direct L2 experiences and knowledge, and they retrieve words in L2 by using a recognition process without doing language translation or selection. Therefore, increasing the semantic and orthographic associations by performing the L2 word games may improve lexical retrieval process, which may in turn induce the growth of English vocabulary and English proficiency. To determine whether the games were able to assist the English skill in reality, tests of lexical access and English reading tests were used to validate training efficiency. As part of this project, a web-based training interface was designed to collect data (challenge.cls.mtu.edu). Consequently, the usability and design of the training games and interface were also evaluated in the study.

To achieve the goals of this dissertation, three studies were proposed and conducted. Experiment 1 was designed to understand the cognitive lexical skills of native English speakers. It was composed of: a demographic survey, a basic cognitive measurement (working memory capacity test and a fluid intelligence test), training via several methods (a crossword paradigm task, a word-stem completion task and a free association task) as well as a pre-test and a post-test using a lexical association task. Experiment

2 was designed to use a similar method to study second language learners, and determine whether after the word game training, increases in semantic and orthographic associations were able to enhance learners' access to the L2 lexicon. In this study, an anagram solving task was added to examine how orthographic-semantic retrieval was influenced by the different training methods. In the final study, the transfer effect between the games and English lexical skills was examined. The tasks composed of a working memory task, a reasoning task and English reading tests as a pre-test and a post-test, as well as a user survey to assess usability. The training games in this study were a crossword paradigm task and combined training with the free association and word-stem completion tasks. Figure 1.1 illustrates the overview of these studies. Also, the user experience of the experiment website was assessed in five components: fulfillment, usefulness, enjoyment, errors and positive emotions.

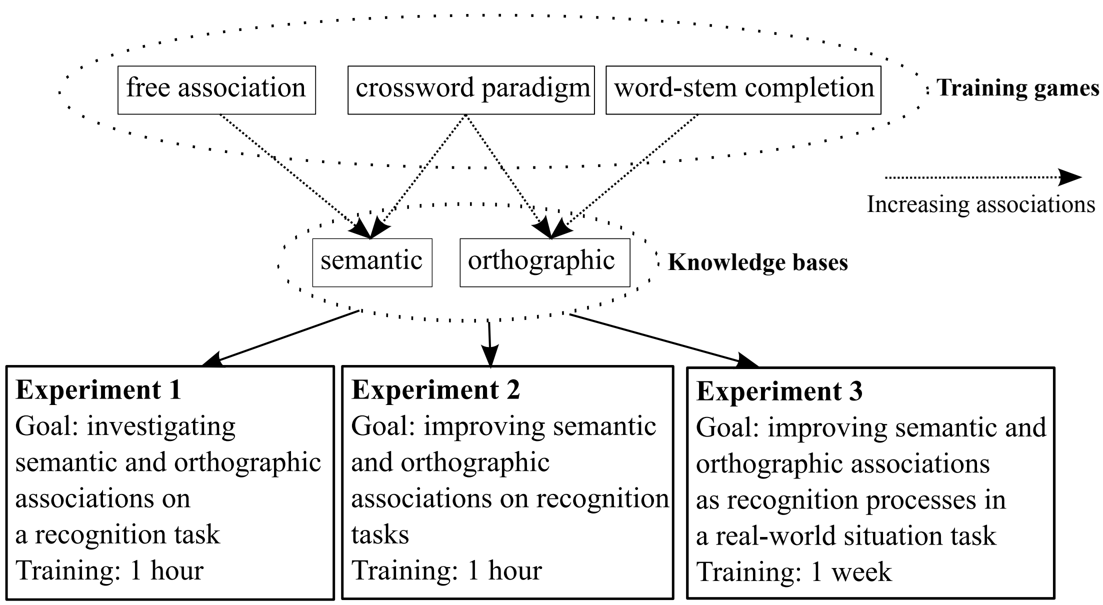


**Figure 1.1:** Overview of the experiment design

## 1.1 Outline of Literature Review (Chapters 2 and 3)

The remainder of the literature review is structured as follows: In Chapter 2, past research on expertise relating to lexical memory access, such as in a crossword domain, as well as in the domain of Naturalistic Decision Making (NDM) and its related models are discussed. The crossword studies and their computational models are also reviewed in this chapter. Chapter 3 discusses the bilingual models and representations, including the Revised Hierarchical model, the Bilingual Interactive Activation model and some perspectives in bilingual models. Automaticity, possible lexical access models in bilingualism and vocabulary learning in L2 are also discussed in Chapter 3.

# Chapter 2

# Memory Access in Expertise

In this chapter, past research of memory access in expertise is reviewed, as well as the Naturalistic Decision Making models relating to a crossword domain, such as the Recognition-Primed Decision model and the Bayesian Recognitional Decision model. Moreover, connections between these algorithms and second language learning are established in order to develop and understand learners' cognitive language performances.

## 2.1 Naturalistic Decision Process in Expertise

The Recognition-Primed Decision Model (RPD) was introduced nearly 30 years ago by G. Klein & Klinger, and went on to form a foundation for the field of Naturalistic Decision Making (NDM). The RPD model investigates how people make decisions in real-world situations under time pressure, uncertainty, complex setting environments and dynamic conditions (G. Klein & Klinger, 1991; G. Klein, 2008). G. A. Klein (1993) proposed the RPD model by focusing on how people use their experiences and vast knowledge to make effective decisions. For example, G. A. Klein et al. (1986) conducted interviews with the firefighter commanders to examine their reactions and decision making processes when faced with a complex and uncertain situation. They found that when the commanders saw a fire or fire spread, they often knew exactly what to do, and did not generate options or compare between choices. The RPD model was based on this concept, and is composed of three different strategies capturing the firefighters' behaviors and decision making processes. The first one is a simple match or recognition process. The next strategy is used when they were in more complex situations (such as an event that they never experienced before but it is nonetheless similar to what they have been through), they evaluate and modify previous action to suit the current situation. Finally, if a situation is totally different from their past experiences, they may need to seek more information, reassess the situation and implement the best action or the first one that comes to their mind, or use mental simulation to assess whether a course of action will succeed.

Although used to explain domain expertise, this decision model shares similarities with theories of bilingual function and acquisition, in terms of automaticity in lexical access (see Segalowitz & Hulstijn, 2005). They found that that second language (L2) acquisition relies on practices and repetitions of the L2 lexicon, which leads to the L2 skill improvement and eventually automaticity. This automatic process helps a learner perform some tasks such as letter recognition rapidly, unconsciously and effortlessly. As this process occurs in proficient L2 learners, the RPD model provides an complementary explanation of the underlying cognitive process in L2 acquisition.

## 2.2 Lexical Memory Access in Crossword Solving

Lexical memory involves the ability to recognize vocabulary and its meaning in a language. This memory is very large and contains tens of thousands of words and lexical units, which is required in order to communicate among people (Miller, 1972). It also involves linguistic rules, association, and conventions (Nickerson, 1977). Many memory theorists have been interested in how the lexical memory stores information in long-term memory (e.g. Shiffrin & Atkinson, 1969), which includes effective memory organizations, retrieval performance, and failure of memory recall such as forgetting (e.g. McGeoch, 1932; B. J. Underwood, 1957). One critical question guiding this research is how memory is organized and accessed.

The section examines lexical memory access from the perspective of research on crossword and word-stem completion tasks. The primary difference between this and more traditional memory search and retrieval investigations, such as free recall experiments or the pair-list cuing paradigm (Raaijmakers & Shiffrin, 1981), is that most traditional memory approaches provide episodic memory events to participants who recall them shortly after; these tasks involve knowledge learned over years of experience, but many aspects of memory recall, search, and processing are similar.

The American-style crossword puzzle was first introduced over a hundred years ago. Today it remains a well-loved mental activity for millions of people, from casual players who play crosswords occasionally to serious players who solve several every day. High-developing crossword skill is associated to various aspects of cognition and memory skills, and an experienced crossword solver is well-informed in many types of knowledge, including linguistic, general and puzzle-specific (Nickerson, 2011; Toma et al., 2014). Therefore, crossword studies provides significant notions of the advanced memory search and retrieval skills which have not been examined in the traditional memory research.

Memory search processes have been recognized as an important part of memory retrieval (see Shiffrin, 1970; Raaijmakers & Shiffrin, 1981). Nickerson (1977) may have been the first person who tried to investigate these processes in the context of crossword puzzles, clues and expertise. He proposed that the crossword solving process could be explained as a cued retrieval task. He also suggested that the search process in crossword puzzles would be classified into at least two types: one that works rapidly in parallel and below the level of awareness, and the other one works slowly in series and can be introspected. In order to solve these puzzles, solvers need clues to limit their possible solutions and search spaces, which serve as both memory activation and memory constraint.

### 2.2.1 Crossword Clues

To understand lexical mechanisms in crossword expertise, Nickerson (2011) identified a number of types of clues commonly used in puzzles. Each one has potential for offering useful learning opportunities for a second-language learner, which I will discuss next.

#### 2.2.1.1 Semantic Clues

Typically, semantic clues involve a synonym, an abbreviated definition, a word association and general knowledge. They are the most obvious clues, but sometimes it is hard to retrieve a correct answer especially for the general knowledge, which is called "feeling of knowing" and "tip-of-the-tongue" phenomena (Nickerson, 2011). Semantic clues could be used for investigating the organization of lexical memory in the human brain. For example, Brown & McNeill (1966) proposed that an organization of words and definitions might be similar to keysort cards. Each word was defined as a set of features, which were the definition of a word on the card. A hole at the edge and an indentation on the card represent the presence and the absence of the feature, respectively. Searching words from specific features can be done by extracting words with the constraining features, and the particular words with the common features will be identified. However, the sorting principles that are implemented in a computer and represent the human brain are lists or collections of features, instead of individual feature units (e.g. J. R. Anderson & Bower, 1972; Craik & Lockhart, 1972).

Second-language learners may benefit from exposure to semantic clues in terms of expanding their vocabulary knowledge and word senses. Specifically, when they see or learn new semantic clues in a crossword puzzle, which may be new L2 words in a lexicon, they may try to relate the new or unknown words to the old ones that they have already known. It may help them growing their vocabulary knowledge, which may lead to understand or read a L2 text faster.

#### 2.2.1.2 Structural and Orthographic Clue

Structural and orthographic clues are the second most important aspect of solving a crossword clue. Such cues provide highly significant criteria to decide the potential solutions including the number of letters in the target words, letters presented and English knowledge of the statistical dependencies. For example, if a puzzle solver is looking for a four-letter word, the other word lengths rarely appear in his mind or if he finds that this four-letter word starts with "T", he is able to eliminate the words that begin with the other letters. Furthermore, Nickerson (2011) mentioned that the presence of a letter at the first position is not necessarily more helpful than a letter from other positions, because the retrieval performance also depends on word and letter frequency of occurrence and other specific constraints. For example, generating words from a pattern "- - - - S" is easier than "Q - - - -". Nevertheless, there are systematic differences in the difficulty of different letter constraints, and these reflect aspects of lexical memory access.

Mueller & Thanasuan (2013) also postulated that the mental lexicon related to part-whole word associations is an essential skill in crossword solving. An empty crossword grid without any semantic clues seems very difficult to get correct answers with. However, some partially filled grids can increase chances of guessing the correct answers, since more constraints are available. In the Mueller & Thanasuan (2013) and Thanasuan & Mueller (2014) crossword play model, they adapted the word-stem completion model (Mueller & Thanasuan, 2014) as one of two routes in retrieval mechanism. This solving process is discussed in section 2.2.3.

Second-language learners may benefit from orthographic and structural clues with regard to implicit repeated exposure to word-forms. It may also deliberately help and motivate learners' spelling ability and pronunciation as well as vocabulary retrieval based on word patterns (see section 2.2.1.3).

#### 2.2.1.3 Acoustic or Phonetic Clue

An acoustic clue can also assist in retrieval from long-term memory. For instance, in the crossword puzzle paradigm experiment (Goldblum & Frost, 1988), the authors designed the experiment to investigate whether four syllabic unit conditions including syllable (e.g. - - -DIC- - - -), pronounceable nonsyllable (e.g. - - - -ICT- - -), unpronounceable cluster (e.g. - -NDI- - - - -), and nonadjacent letters (e.g. - -N-I-T- - -) facilitate the crossword retrieval process or not. They found that the reaction times and non-response rates among the four conditions were significantly different. The syllable condition had the lowest results on both response time and non-response rate. The results clearly showed that the syllabic units, which are normally pronounceable, improve word retrieval performance.

In research on second language learning from a working memory perspective, Baddeley et al. (1998) suggested that the phonological loop, which is a combination of phonological short-term store and a rehearsal process that serves to maintain the information in the phonological store, plays an important role in learning new words for adults. Figure 2.1 shows the process of the phonological loop. Visual input activates the articulatory system and auditory input activates the phonological short-term memory. The articulatory system and the phonological short-term store can activate each other, which aids the retrieval from the phonological long-term memory. Furthermore, Ellis & Beaton (1993) showed that a combination of the keyword techniques and the repetition strategy elevates learning foreign language vocabularies. These indicated that solving crossword puzzles may also help L2 learner improve English skills.

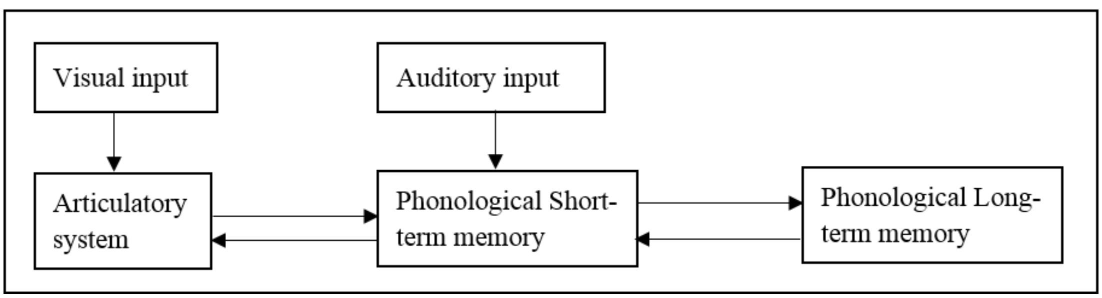


**Figure 2.1:** Overview of the phonological loop (adapted from Baddeley et al. (1998))

#### 2.2.1.4 Grammatical Clues

The number of objects, part of speech and tense are grammatical cues that provide constraints on target words. For example, if the cue is given as a plural noun, a target answer should be plural, and if the cue is given as a past tense verb, a target word should be past tense. These types of cues affect retrieval performance by limiting the search space. However, this may be an important factor overlooked by language learners, and so experience with such clues may help increase awareness of grammatical forms such as verb tense and plural/singular noun status.

#### 2.2.1.5 Thematic Clues

Crossword constructors often create and associate several target answers in some ways. The thematic cues can be used to check whether the solutions are correct or not. The effects of these cues have been shown in the retrieval priming effects. For example, Loftus (1973), asked subjects to produce a member of a particular category (e.g. An animal's name that begin with D). Then after training interventions, she asked them to do the same tasks again. The results showed that the response time of subsequent trials (when they had to name a member of the same category) decreased.

These thematic clues may provide challenges for second-language learners, since such clues often involve more complex relationships than are typically present in a single clue. Moreover, these clues may help broaden understanding of particular cultural or language themes.

#### 2.2.1.6 Complete-the-Expression Clues

In these types of the clues, crossword solvers have to produce well-formed sentences. Such clues appear in many forms such as phrases, figures of speech, idioms, or well-known expressions. For example, a puzzle constructor provides "May the - - - - - be with you". The answer "FORCE" is obviously matched to the phrase and the word pattern. Typically, proficient solvers can figure it out in less than a second. However, not all the cues are easily recognized. For instance, if the cue is "Just in - - - -", there are two possible solutions that fit the pattern, a four-letter word, and the phrase, which are "TIME" and "CASE". The puzzle solver may need more confirmation evidence from orthogonal answers.

For second language learners, idioms can be difficult to learn or understand, because they often do not mean exactly what the words indicate. Thus, deliberate exposure to this kind of clue not only can help learners experience such phrases and expand vocabulary meaning, but also improve their fluency of English skills.

In summation, the clue types above serve as constraints for generating or searching an answer in a knowledge base. This is a combination of linguistic knowledge, general knowledge and puzzle-specific knowledge. Each type can provide distinct opportunities as training aids for L2 learners to practice and develop their English skills.

### 2.2.2 Crossword Expertise Studies

Research characterizing crossword expertise (e.g. Nickerson, 1977; G. Underwood et al., 1994; Hambrick et al., 1999; Mueller & Thanasuan, 2013) has suggested that crossword solving mechanisms involve processes that are similar to the ones hypothesized by researchers studying Naturalistic Decision Making (G. A. Klein et al., 1986; G. Klein & Klinger, 1991). Nickerson (1977) and Hambrick et al. (1999) mentioned that there are at least three types of solving processes. First, a solver retrieves an answer immediately after reading a clue without using any constraints, which is corresponding to the pattern matching process in the RPD model. There is another type of solver which needs more information or constraints to implement an answer, such as word length or filled letters. This process is similar to the generate and evaluate case in the RPD model. The last process is that a solver has to interpret the meaning of a clue, by deliberately identifying the puzzle theme and generating many answers to satisfy the constraints. This introspection accounted for Mueller & Thanasuan (2013) to implement computational crossword models based on the RPD and the Bayesian Recognitional Decision Making (BRDM) model (Mueller, 2009).

The successful models represented memory search and retrieval. They also replicated human performances reasonably-well, out-performing novices and coming close to the abilities of the best experts to complete a range of puzzles.

Crossword expertise has been studied by a number of cognitive scientists. G. Underwood et al. (1994) examined the necessary component subskills for solving cryptic crosswords among two skill levels of crossword enthusiasts by using crossword-related tasks, including a word generation task, an anagram solving task, a word completion task, a lexical decision task, and a synonym judgments task. The result showed that all five tasks significantly predict the levels of crossword expertise. Hambrick et al. (1999) investigated the factors contributing to crossword puzzle proficiency in older adults. They found that general knowledge and crossword experiences were both successful crossword predictors, although fluid reasoning ability was not. They hypothesized that not all crossword solvers need this skill to solve clues (as the clues may be retrieved directly from memory). They also argued that reasoning ability and problem solving skills are not necessary if the solver has great general knowledge or high experience in solving crossword puzzles. However, these skills may still be important for the novice solvers and non-native English speakers, because they do not have enough experience and information to generate answers from memory. They need to integrate and utilize cognitive skills to come up with an answer.

Toma et al. (2014) investigated cognitive abilities contributing to both Scrabble and crossword experts. They found that the game experts have superior visuospatial and verbal working memory abilities. These skills highly correlate to the game proficiency. In addition, working memory capacity also influences language learners (e.g. Baddeley et al., 1998; Ellis & Beaton, 1993). Therefore, a working memory capacity may impact crossword performance in non-native English speakers as well.

### 2.2.3 The Recognition-Primed Model in Crossword Solving

Some of the linguistic and expert processes involved in crossword play can be understood by examining a computational model of crossword play first developed by Mueller & Thanasuan (2013). This model adapted the Bayesian Recognitional Decision Making (BRDM) model (Mueller, 2009) of expert naturalistic decision making, with a focus on the lexical properties (orthographic and semantic information) required for expertise in the crossword domain. It replicates expert decision making by using past events or experiences as a recognition memory for making future decisions. The model calculates the probability of obtaining an answer word by using a naturalistic corpus of clue-answer pairs described by Ginsberg (2011). The model considers each clue of a clue-answer pair as a set of features or cues for the possible answers. It computes a probability of a clue-answer appearing in the database as well as letter-answer pairs. The two different routes, which are semantic and orthographic, access the crossword corpus (i.e. lexical memory) independently. Each route is shown in Figure 2.2:

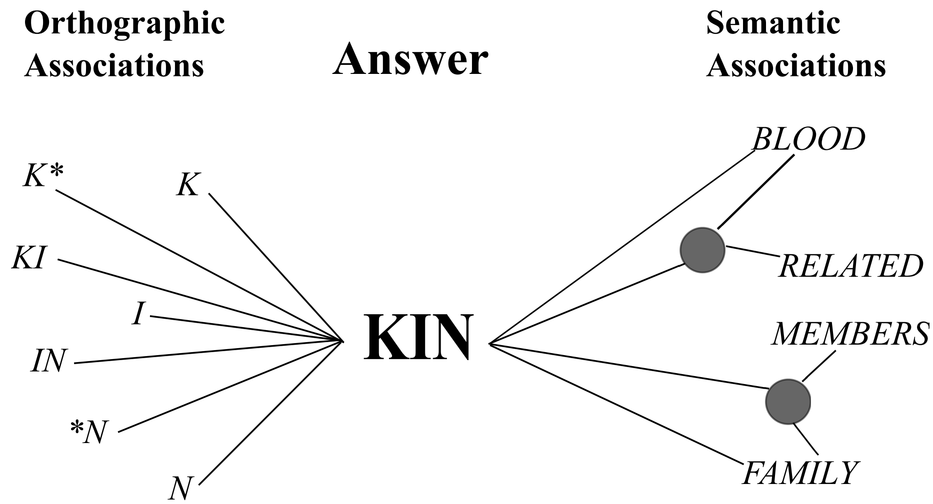


**Figure 2.2:** Example of semantic and orthographic routes (Thanasuan & Mueller, 2015)[1]

**A semantic route**: The model representing this route uses a semantic clue, containing one or more than one word, as a retrieval cue. Each word in the clue serves as a feature word in the crossword database, shown in Figure 2.2, for a retrieval process. The model computes the semantic probability based on those words and retrieves candidate answers with a high likelihood. Then it checks them with the word pattern for feasibility. The first candidate word that fits the pattern will be used as an answer.

**An orthographic route**: The model of this route takes letters with a pattern as a retrieval cue to generate candidate answers. However, not all the answers from this model match the given pattern. They are filtered out based on pattern matches as well as semantic probability. The example is shown in Figure 2.2.

[1]see the permission document in Appendix D

#### 2.2.3.1 Retrieval Mechanisms

Both routes adopted similar retrieval mechanism based on the BRDM and the Search of Associative Memory (SAM) model of recognition memory (Raaijmakers & Shiffrin, 1981). This mechanism was described fully in Mueller & Thanasuan (2013) and Thanasuan & Mueller (2014). The model is first assumed that both the orthographic and semantic routes perform the retrieval process similarly, but each route operates independently. During the solving process, the strengths between a clue and candidate answers from both routes are evaluated, and the one with a greater likelihood is chosen. The association strengths between the answers and words or bigrams are computed based on the number of co-occurrences between clue-answer pairs in the crossword corpus. Once they are learned (i.e. associated), a set of features (i.e. a word or a bigram for the semantic route and a letter or letter-pair for the orthographic route) in a clue or a word pattern will have association strengths to possible answers. The strengths are computed from Equation 2.1 and 2.2:

$$Pr^O(A_i|u_j) = O_{ij}/\sum_i O_{ij} \tag{2.1}$$

$$Pr^S(A_i|u_j) = S_{ij}/\sum_i S_{ij} \tag{2.2}$$

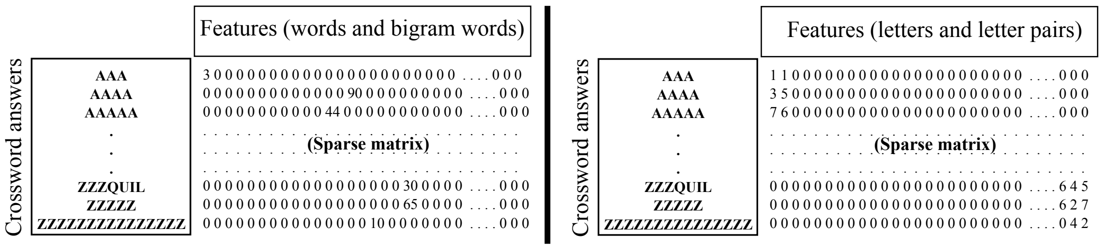


**Figure 2.3:** Example of semantic and orthographic distributions (adapted from Thanasuan & Mueller (2014))[2]

where $u_j$ represents either semantic or orthographic features indexed by $j$ and $A_i$ is a candidate answer $i$ for either the orthographic ($Pr^O$) or semantic ($Pr^S$) memory. $O_{ij}$ and $S_{ij}$ are the association strength matrix representing the orthographic and semantic features respectively, shown in Figure 2.3. Since the $Pr^O(A_i|u_j)$ and $Pr^S(A_i|u_j)$ only account for the probability of candidate answers with one feature from a clue, the probabilities of candidate answers $Pr^X(A_i|u)$ ($X$ is either $O$ or $S$) given all features form a clue $u$ are computed as:

$$B(A_i|u) = (\prod_{j \in u} Pr^X(A_i|u_j) + \sigma)^{(1/n)} \tag{2.3}$$

$$Pr^X(A_i|u) = B(A_i|u)/\sum_i B(A_i|u) \tag{2.4}$$

where $n$ is the number of features in a clue $u$. $B(A_i|u)$ is the association strength between answer $A_i$ and a clue $u$. $\sigma$ is a smoothing parameter for any $A_i$. $Pr^X(A_i|u)$ indicates a relative likelihood of answers retrieved from memory, given the clue $u$. Thus, the greater likelihoods in the word distribution represents the earlier answers coming to mind compared to the lower ones. In order to model the crossword experts and differentiate them from the novices, the probability of recovery adopting from Raaijmakers & Shiffrin (1981) model is determined as:

$$Pr_{recovery} = 1 - exp(-Pr^S(A_i|u) * recovery) \tag{2.5}$$

The probability of recovery represents the semantic fluency of experts and novices. Specifically, since they use the same information (crossword database) to solve the puzzles, the recovery parameter will indicate how much the knowledge base for each level of expertise should have.

### 2.2.4 The Recognition-Primed Decision Model with Second Language Learners

There are several insights indicating that the Recognition-Primed Decision model can be adopted to investigate and understand the lexicon memory of second language learners through word games, such as crossword puzzles. The first aspect is linguistic expertise. The model is able to represent various levels of fluency and lexicon size based on individual learners. This may be useful in terms of examining and improving vocabulary or English skills of each student. Another important aspect is the association routes or retrieval processes, including the semantic and orthographic associations. The learners possibly increase their vocabulary and English skills via the routes, and this can happen by accomplishing the games. Again, these ideas have been already developed as a goal of this dissertation and a computational model of L2 learners may be developed using results from the games. An implication of the model is that it may represent human language operation better than bilingual models in Chapter 3. However, the implementation and simulation of the model are beyond the dissertation's goal.

Chapter 3 describes bilingual lexical access and models. It includes reviews of lexical representation, computational models in bilingualism, associative model and vocabulary learning in L2.

# Chapter 3

# Bilingual Lexical Access

In this chapter, I review topics of bilingual lexical access, including lexical representation, selection, and models of bilingualism such as the Bilingual Interactive Activation (BIA) model and the Inhibitory Control (IC) model. Finally, the chapter will discuss automaticity in bilinguals and vocabulary learning in second language (L2), which are necessary for fluent vocabulary and language skill development.

## 3.1 Lexical Representation

Past research in bilingualism had tried to understand how bilinguals store and organize their linguistic knowledge. Specifically, whether they are combined into a single large lexical memory, or separated or segregated into multiple stores. Researchers have used several methods to investigate this issue, including (1) word association between a native and a second language, (2) naming tasks, (3) recognition and recall task, and (4) language transfer and interference tasks (French & Jacquet, 2004). These studies have created many debates about misinterpretations, experimental design, and analysis techniques. One possible source of this, as mentioned by Francis (1999), is that researchers from many different backgrounds have been interested in bilingualism (including linguistics, psychology, education, computer science, etc.), so that there is no great consistency among methods, analysis, or even terminology–including the definition of the word "bilingual" itself.

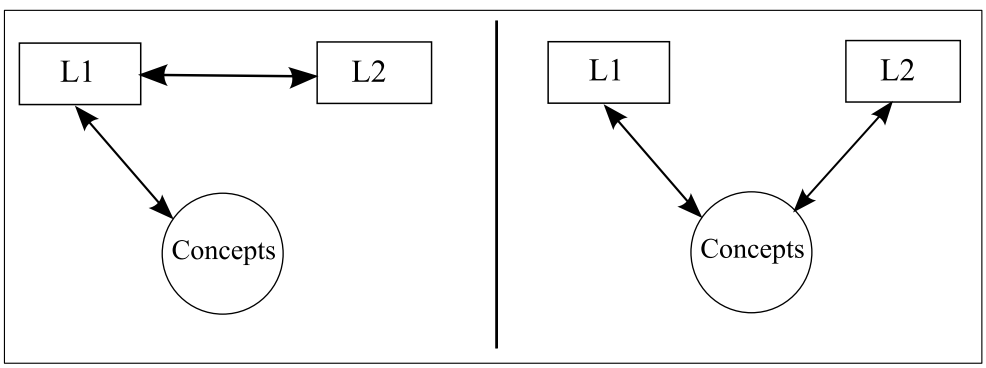


**Figure 3.1:** (Left) The word association model shows a direct association between words in two languages. (Right) The concept mediation model suggests that two languages are connected via semantic representation or concept node.

Many current studies in bilingual memory access have been directed toward and focused on the relationship between words and semantic meaning. This has been done using experimental methods such as inference tasks and priming tasks (French &

Jacquet, 2004). The findings from those studies helped to establish a model that separates word-level representations from deeper semantic or conceptual representations (e.g. J. R. Anderson & Bower, 1973; Snodgrass, 1980; Potter, 1979). Potter et al. (1984) proposed two bilingual representation models: the word association model and the concept mediation model (see Figure 3.1). In the word association model, knowledge within a language is directly associated with corresponding lexical units in a second language, whereas in the concept mediation model, this association is mediated through the conceptual representations that both languages share. In a study designed to discriminate these models, participants with two different levels of English proficiency (fluent and nonfluent) were asked to perform a word-for-word translation from first language (L1) to L2 and a picture naming task. Results showed that the concept mediation model was more favorable and more accurately described the bilingual memory for both groups of participants than the word association model. However, others (e.g. Kroll & Tokowicz, 2005) have disagreed with Potter et al. conclusions. They thought that the nonfluent bilinguals would perform word-by-word translation, which corresponded more closely to the word association model. They also questioned whether the experiments were designed in favor of the concept mediation model. Thus, it may be true that conceptual mediation is a state achieved by experts, but not by novices.

This possibility of the word association model representing the less-proficient bilinguals was investigated by Chen & Leung (1989) and Kroll & Curley (1988). They replicated the experiments exactly as in Potter et al. (1984), except they tested participants with poorer English ability to represent the nonfluent group. The results showed that the nonfluent bilinguals performed the translation tasks relatively faster than a naming task in L2. This suggested the word association model matched the less proficient bilinguals' lexical processing more than the concept mediation one, and this indicates that there is a transition between states of acquisition, in which nonfluent speakers change their lexical process from the word association to the mediation concept after improving language proficiency.

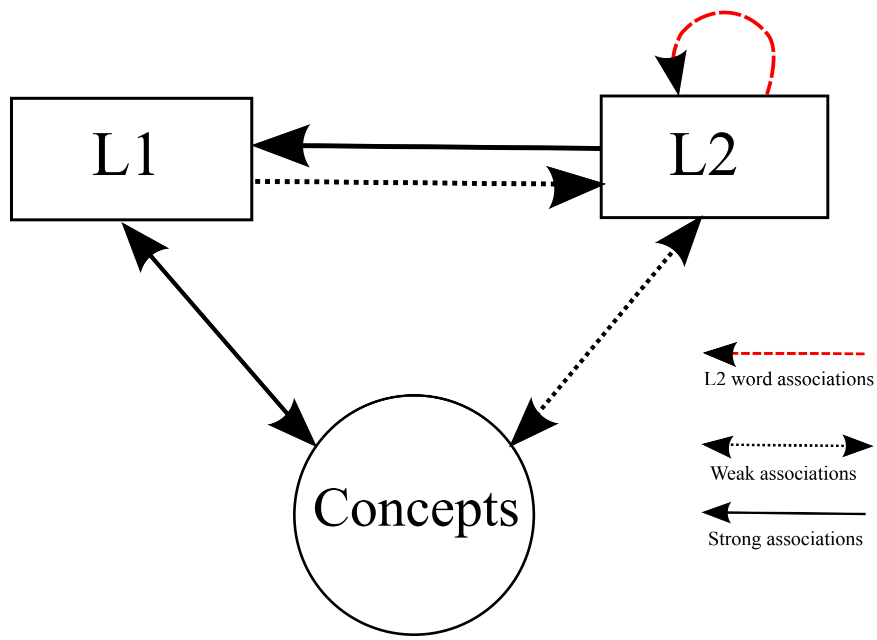


**Figure 3.2:** The Revised Hierarchical model (adapted from Kroll & Stewart (1994)): The red line indicates L2 word associations.

Kroll & Stewart (1994) proposed a bilingual integration model, which is a combination of the word association and concept mediation models, and named it the Revised Hierarchical model (see Figure 3.2). The model explains that when people start learning new languages, they learn a new word via concept memory from L1 to L2 and also develop the connection between L2 to L1 during the learning. However, the L1-L2 link may be weaker than the L2-L1 link. After substantial practice in the new language, the learners develop the link between L2 and the concept node in order to process L2 words directly and faster. Still, the connection from L1 to the concept node typically remains stronger than the one from L2. This suggests that the mental associations of second language learners may change as they improve. Consequently, the types of training they benefit from may also change.

These models were created based on translation and naming tasks that do not reflect the bilingual performance in many real-world situations. In this dissertation's paradigm, the concept node, the separated lexical memory in the Revised Hierarchical model as well as the stages of acquisition have been considered as the lexical representation. However, the mental associations were not limited only between L2 and the concept mediation, but also associations among L2 words. These associations were a consequence of improvement of language proficiency as well.

## 3.2 Computational Models of Bilingual Access

Although the conceptual models have been used to characterize bilingual language access, computational models of these processes have provided important insights because they can demonstrate and validate the effectiveness of different theoretical assumptions. In the second language learning domain, Thomas & Van Heuven (2005) separated bilingual comprehension models into two general approaches: localist and distributed models. The localist models contain discrete units and many separated layers representing lexical information, whereas the distributed models typically do not have specific units representing particular linguistic units, but rather represent words as distinct activation patterns which is similar to a neural network. Unlike the localist models, the network cannot be separated into an individual unit. In this dissertation, the Bilingual Interactive Activation Model will be discussed as an example of the localist models.

### 3.2.1 The Bilingual Interactive Activation Model

The most well-known localist model is the Bilingual Interactive Activation (BIA) model which was first developed by Dijkstra & Van Heuven (1998) and Van Heuven et al. (1998). The model was extended from the McClelland & Rumelhart's Interactive Activation (IA) model, which was originally developed for explaining general language phenomenon such as the word superiority effect. The basic structure of this model is shown in Figure 3.3, which is similar to the IA architecture. It uses orthographic input nodes to represent visual word recognition. These nodes are composed of a feature level, a letter level, a word level and a language node level. The model process starts when a word in one language is given; it then activates the feature and letter levels. Meanwhile, it inhibits the other letters and features that are not activated, via lateral inhibition. Then the activated letters excite words in both languages at the word level, and suppress the other words. The activated words sequentially excite the nodes at the language level, and the words in the inactivated languages are suppressed by inhibitory feedback.

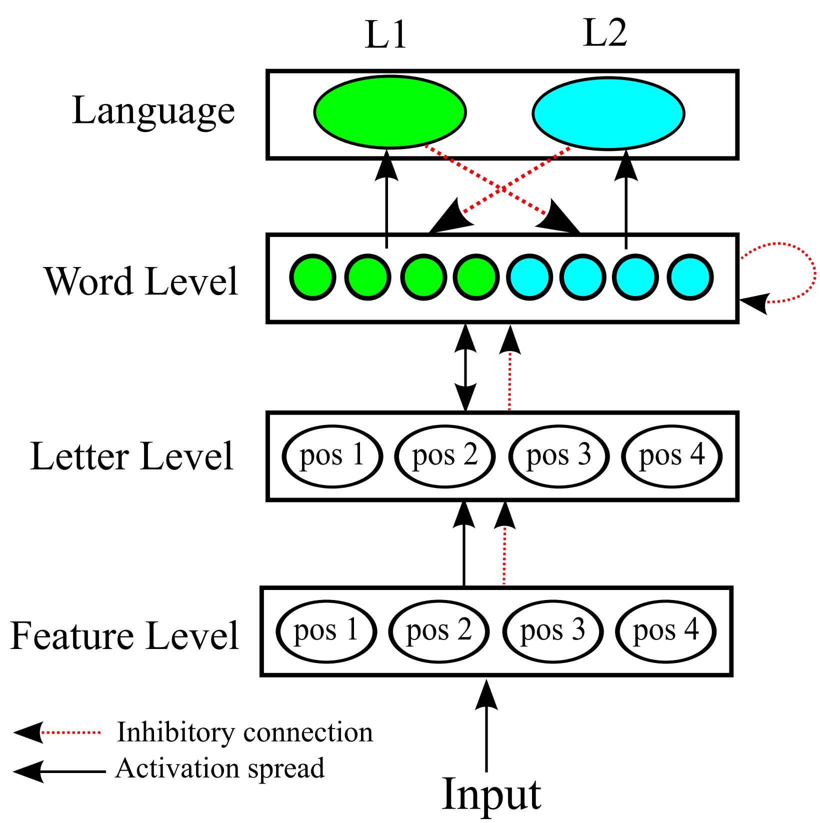


**Figure 3.3:** The Bilingual Interactive Activation (BIA) model (adapted from Thomas & Van Heuven (2005))

This model was able to simulate many language phenomena, including neighborhood effects, priming effects, interlingual homographs, and cognates (Thomas &

Van Heuven, 2005). The model has also been developed to account for more features such as phonemes and semantic representation. For example, Grosjean (1988) implemented a model of bilingual speech perception called the Bilingual Interactive Model of Lexical Access (BIMOLA). It consists of an auditory feature level, a phonemes level and a word level. It looks similar to the BIA model, except that it does not categorize words into different languages at the word level, but instead represents all language-specific differences at the level of phonemic patterns. Similarly, Dijkstra & Van Heuven (2002) proposed an extension of the BIA model called the BIA+ model. This model is similar to the BIA model, except that the BIA+ model includes phonological and semantic representations. The Semantic, Orthographic, and Phonological Interactive Activation or the SOPHIA model is an implementation version of the BIA+ model. Although the SOPHIA model has focused on simulating findings in monolingual visual word recognition, in principle it can be implemented to support some empirical effects in bilingual lexical processing (Thomas & Van Heuven, 2005).

A similar model that handles language selection and production was proposed by Green (1998). The main mechanism of Green's Inhibitory Control model is that words in a particular language are associated with language-specific nodes, so that a target language can be activated while other languages inhibited. For example, L1 is typically more strongly activated than L2, so when L1 is not a target language, it will also be strongly inhibited. The IC model was used to explain patterns of results in the Lexical Decision Task, and to predict a switch cost between two languages

(Von Studnitz & Green, 1997).

## 3.3 Automaticity in Bilingualism

In fluent bilinguals, automaticity may be another important factor that helps L2 learners improve their language proficiency. Segalowitz & Hulstijn (2005) described automaticity as:

> "Generally, automaticity refers to the absence of attentional control in the execution of a cognitive activity, with attentional control understood to imply the involvement, among other things, of intention, possibly awareness, and the consumption of cognitive resources, all in the service of dealing with limited processing capacity (Kahneman, 1973). Some have also associated parallel processing with automatic processing and serial processing with nonautomatic or attention based processing (Schneider & Shiffrin, 1977)". (pp. 371)

Favreau & Segalowitz (1983) used the primed lexical decision task to investigate automaticity in fluent and nonfluent bilinguals, and found that when the interval between a prime and semantic related target in L2 was short, the stronger bilingual group showed a facilitation effect in these trials (i.e. they had faster response times than the control condition). This indicated that the underlying cognitive mechanism in highly skilled bilinguals is automatic or spontaneous, and the practical ways to promote the automaticity leading to improvement of language skills may include repeating and rehearsing language materials. These approaches have already been applied to second language teaching. For example, Gatbonton (1994) proposed that language skills could be automatized by repeating chunks of useful utterances; a technique they called *creative automatization*. Segalowitz et al. (1995) also showed support for this approach in a case study with one participant. They asked the participant to analyze a psychology article for three weeks as a tutorial section. Then, the participant completed lexical decision tasks containing words appearing in the article as well as control words that were not presented. The researchers found that response times for the words appearing in the article improved significantly. This suggested that the meaningful activities and deliberate practice with repetition can promote automaticity in lexical access, which in turn may enhance language proficiency.

## 3.4 Associative Learning Model: Bilingual Development

The existing computational models in a bilingual domain, however, have primarily been used to simulate language recognition and lexical decision performance, and they do not represent bilingual cognitive processes or learning effects in real situations. For example, these models typically do not address language skill development. Finkbeiner et al. (2006) argued that the assumption of lexical selection by competition between two languages was unnecessary and unrealistic. They pointed out that according to most models, language selection process is difficult. It requires a suppression process which needs integration of various cognitive processes, including consciousness, attention and control. However, when proficient bilinguals speak in L2 or switch between languages, it seems very easy and effortless. They also suggested that to solve the problem of lexical selection mechanism, researchers can do simply by developing models simulating from only the target lexicon. This position is similar to the NDM approach discussed earlier in Chapter 2. Instead of focusing on choosing between two options (i.e, either L1 or L2 vocabulary), L2 ability is closely tied to a person's ability to fluently retrieve and produce the correct word forms within a language.

Previous models of associative learning may be relevant in understanding vocabulary acquisition. For example, the associative learning model from Mueller & Thanasuan (2014) combined both semantic and orthographic representations, but activated each memory separately. They also adopted Estes' Stimulus Sample Theory (SST) (Estes, 1950) to model how repeated exposure increases relative associative strength between concepts in domains such as word-stem association and crossword paradigm.

## 3.5 Vocabulary Learning in a Second Language

So far, this chapter has examined the lexical memory of second language (L2) learning, including both empirical research and computational models. This work in general suggests that vocabulary (the fluent ability to recognize and produce words in a language) is a critical aspect of L2 learning. However, most of the research reviewed has focused on fairly limited experimental paradigms such as priming and lexical decision tasks. The present section discusses research on how vocabulary learning is related to L2 language abilities, especially in more educational contexts. This research includes comparative studies of reading, writing, and word manipulation tasks that have often been used to improve students' L2 abilities.

In a language classroom, teachers tend to consider the vocabulary knowledge as a consequence of other higher cognitive language skills, such as reading and writing, and usually assess vocabulary to validate the effectiveness of those abilities. Consequently, when vocabulary is not a focus of learning, proficiency (typically English) can suffer, especially in Asia where native languages have relatively little in common with English. Nurweni & Read (1999) showed that on average the first year students in an Indonesian university knew only 1226 English words after an average of 900 hours of learning, which was deemed not enough to fully understand English university textbooks. Similarly, Barrow et al. (1999) surveyed vocabulary knowledge of Japanese college students. They estimated that the students knew on average 2300 English word families (i.e. root words and their alternate forms). However, the necessary vocabulary size that was required for independent reading of an English text is roughly 7,000 word families (Nation, 2001, 2006, 2013). Moreover, Read (1988) mentioned that a process of measuring vocabulary knowledge of L2 students was inadequate and neglected. Thus, suitable vocabulary tests have been developed to measure learners' knowledge on vocabulary of both depth and breadth.

In reading comprehension, R. Anderson & Freebody (1981) defined breadth of vocabulary knowledge as the number of words that learners know and the depth indicated the quality of how well learners understand particular words. Read (1993) developed a word association task to assess second language proficiency. The task gave students a target word along with some possibly related words. They had to identify the most strongly related or meaningfully associated words. The related words were always in one of three categories: analytic (one aspect of a target word definition), paradigmatic (synonyms of a target word) and syntagmatic (two words usually occur together) (Read, 1998). The results showed a high correlation between proficiency in this task and other independent measures of second language skills, as well as a reliable measure of vocabulary knowledge.

Prior to the word association task used by Read (1993), word associations in L2 learners had been assessed repeatedly with varying success. Meara (1980) summarized experiments of word association tasks conducted between 1950-1980, and argued that they were difficult to compare because they used distinct methods, different word stimuli, and different population samples. Some researchers tried to compare association norms between native and non-native speakers, sometimes based on level of competence (e.g. Lambert, 1956; Davis & Wertheimer, 1967), whereas others conducted studies to compare interlingual responses with intralingual responses (e.g. Kolers, 1963; Champagnol, 1974). Kruse et al. (1987) also tried to use word association as an assessment of language proficiency, but it was unsuccessful in predicting a more complex English proficiency test.

More recently, San-Mateo-Valdehita (2015) summarized results from many previous empirical studies of vocabulary learning, and concluded that some learning activities such as writing or producing words can help promote learners' vocabulary skills more than others, such as reading. For example, Hulstijn & Laufer (2001) conducted a study with second language adult learners in the Netherlands and Israel comparing effects of three tasks: writing with target words, reading and reading plus filling in target words on long-term retention performance. They found that the greatest retention was for the writing group, followed by the reading with filling group, and finally the reading-only group. Moreover, Browne (2003) compared the reading comprehension activities with writing complete sentences and completing vocabulary tasks such as crossword puzzles. He found that the groups with writing and word game activities were able to learn more new words than the reading group. This suggests that activities requiring fluent production of language will benefit L2 learners the most.

In the previous chapter on crossword expertise, it was argued that the critical aspect that promotes expert skill is the ability to fluently retrieve the surface form based on semantic cues. A similar problem faces L2 language learners, in that to produce L2 language, they need to access lexical units and produce L2 language forms. However, it presents a challenge if L2 learners hope to use crossword puzzle games to effectively learn vocabulary, especially when their L2 vocabulary is small. Consequently, for a non-native English speaker, it is difficult to even start solving a crossword puzzle because of their limited English and cultural general knowledge abilities, even for an easy puzzle. Typically, the clues are too short, contain relatively few words, and are too ambiguous to obtain an answer. For example, a six-letter word with the clue "Small cave" is relatively obvious for a native English speaker ("GROTTO"), but for second language learners, they need to know the meaning of both the clue phrase and the word "GROTTO", which is uncommon and rarely appears in L2 textbooks. Another obstacle is that problem solving techniques such as eliminating candidate answers by answering a crossing clue is more difficult for L2 learners who may be less likely to produce the crossing clue. For example, a four-letter word with the clue "Libertine" might be associated with both "RAKE" and "ROUE" in proficient solvers. Thus, to fill in the correct answer, even experts need to solve a crossed clue first. Thus, it may not be appropriate to use standard American-style puzzles for English-language learners with relatively poor English skills, and the games might need to be adapted to suit their particular needs.

Nevertheless, a number of studies (Keshta & Al-Faleet, 2013; Njoroge et al., 2013; Ropal & Abu, 2014; Anugerah & Silitonga, 2013) have shown that young students who complete crossword games had a significant improvement in English vocabulary compared to the control groups. However, there are several issues that these researchers have rarely discussed that may limit their findings. First, these studies often use custom puzzles that focus on specific vocabulary, rather than general puzzles found in newspapers. Second, these have been used mostly in developmental populations, and it is still a question of whether this kind of learning aid will be effective for second language learning in adults, or more proficient English speakers. Third, there are a number of related word games and puzzles that may be equally or more effective at enhancing L2 vocabulary, but these have not been tested.

Thus, in this dissertation, I investigated the cognitive learning process of several distinct cognitive word games, including a crossword paradigm task, a free association task and a word-stem completion task. These were tested on adults (between 18-40 years old) to compare their training effectiveness, and assess whether different types of word games may be effective L2 vocabulary training for this population.

## 3.6 Outline of Experiment 1-3

The next three chapters describe the experiments and results in detail. The first experiment in Chapter 4 was to determine an effect of the word game training on native English speakers. The next study in Chapter 5 was to examine the same effect on non-native English speakers, especially on Thai and Chinese participants. The final experiment in Chapter 6 was designed to investigate the game effect on comprehensive English reading tests, specifically whether the games were able to assist L2 learners on the test scores or not. Moreover, the conclusions and future work of this dissertation are discussed in Chapter 7.

# Chapter 4

# Experiment 1 [1]

The goal of the first experiment was to investigate the impact that word games had on native English speakers' lexical memory. Previous research on lexical memory has often focused on how information is stored and organized in long-term memory (Shiffrin & Atkinson, 1969), as well as on aspects of memory retrieval, search, and forgetting (e.g. McGeoch, 1932; B. J. 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 tens of 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. J. R. Anderson & Bower, 1972; Brown & McNeill, 1966; Shiffrin, 1970) have used linguistic material

[1]This experiment is the extended version of Thanasuan & Mueller (2015) which has been published in the Proceedings of the 37th Annual Cognitive Science conference (see Appendix D).

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 & Thanasuan (2013) studied crossword experts' puzzle-solving abilities and developed computational models to account for their ability, based on the Recognition-Primed Decision (RPD) model (G. A. Klein et al., 1986; G. A. Klein, 1993) and the Bayesian Recognitional Decision Model (BRDM) (Mueller, 2009). The BRDM was adapted from the REM (Retrieving Effectively from Memory) 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 & 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.

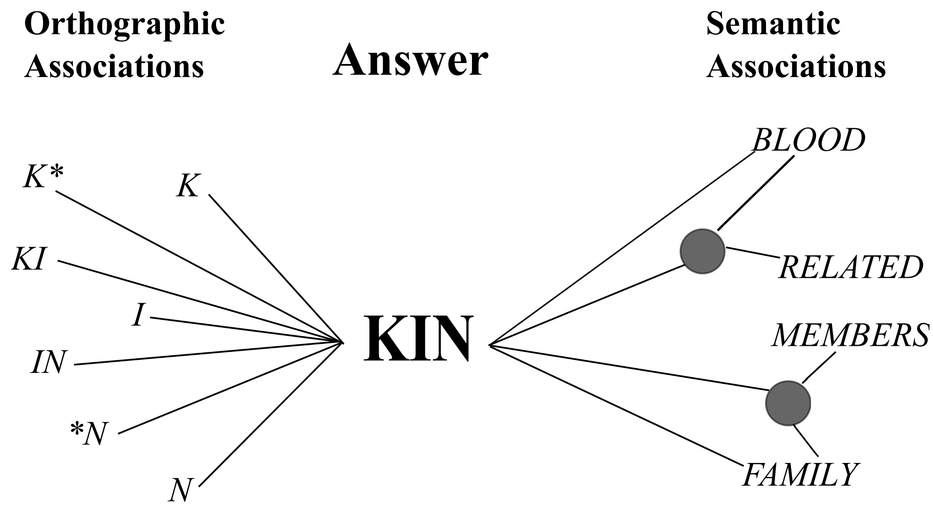


**Figure 4.1:** Example of semantic and orthographic associations to a word. Fluent language access requires access to both aspects of words.

## 4.1 Cognitive Word Games as Language Training

As a consequence of this research, I have begun to examine 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, allow repetition, and 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.

The hypotheses of this experiment were that lexical memory access may be enhanced by increasing either (or both) semantic or (and) orthographic associations among words in a lexicon (see Figure 4.1). Different word games may selectively enhance different kinds of associations (see Figure 4.2), and better overall fluency may be promoted using games that enhance both routes.

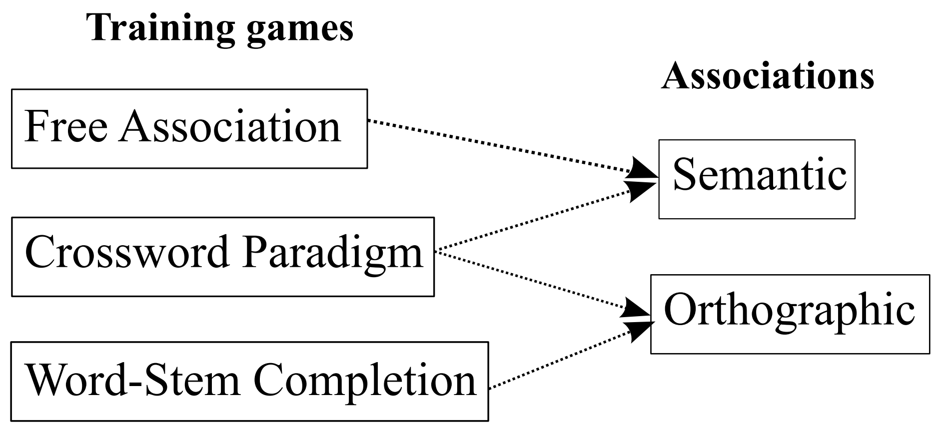


**Figure 4.2:** Training game strategies: A line indicates that a training game strengthens a particular type of association.

To test this hypothesis, three word games were developed, including a word-stem completion task; a free association task; and a crossword paradigm task. A lexical association task was implemented to measure lexical memory fluency both prior to and following practice. In addition, some baseline data on cognitive abilities were collected (complex memory span and a fluid intelligence measure) to determine whether general cognitive skills would influence performance on the tests.

## 4.2 Method and Materials

Forty English words were selected from the books, *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 that targeted beginning to advanced learners (see Appendix A for the word-pool). 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 4.1. 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 (for assessing fluid intelligence), and reading span (to assess complex memory span) tasks. The remaining tasks were implemented within via a web browser using HyperText Markup Language (HTML), JavaScript and PHP.

**Table 4.1**
Training groups

| Participant group | Word training condition | | | |
|---|---|---|---|---|
| | **Word-stem** | **Free assoc.** | **Crossword** | **Control** |
| A | 1 | 2 | 3 | 4 |
| B | 2 | 3 | 4 | 1 |
| C | 3 | 4 | 1 | 2 |
| D | 4 | 1 | 2 | 3 |

### 4.2.1 Participants

Sixty-one undergraduate students were recruited from the Michigan Technological University (MTU) subject pool. Only 55 students completed all tasks (Mean age = 20.38 $\pm$ 4.54 years). Participants included 54 native English speakers and one non-native English speaker with eight years of learning English. They received one experiment credit for each half-hour of participation time. The experiment was reviewed and approved by the Michigan Technological University Institutional Review Board (IRB). The entire study took up to 1.5 hours to complete, but the average time spent for each participant was 56.8 $\pm$ 7.5 minutes.

### 4.2.2 Demographic Survey

The goal of this survey was to determine background and cognitive factors that might influence participants' lexical ability. They were asked about their age, native language and level of education. The questions are shown in Appendix A. The survey took about two minutes to finish. A sample survey screen shot is shown in Figure 4.3

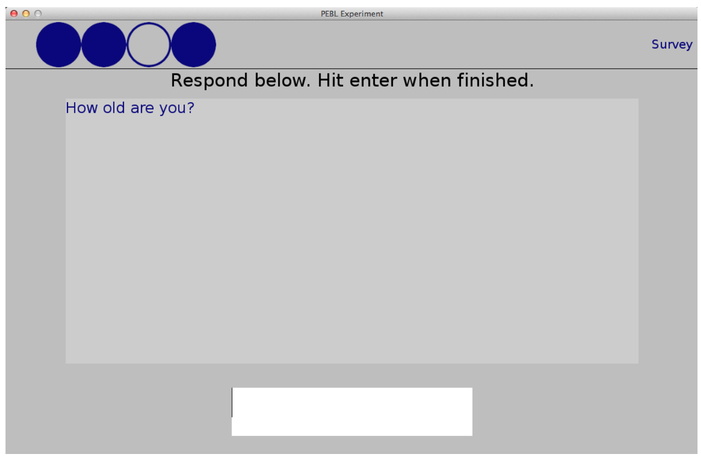


**Figure 4.3:** Demographic survey software

### 4.2.3 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.

#### 4.2.3.1 Reading Span Task

The reading span task in this study was based on a task originally conducted by Daneman & Carpenter (1980) and adapted by Unsworth et al. (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. Before the test, participants had to perform three practice phases. The first one was letter span, in which they were asked to recall the letters that they had seen. Each letter appeared for 1000 ms. In the next practice phase, participants read a sentence and they had to determine whether the sentence made sense or not. The last practice phase combined the first two tasks together. Participants were required to read a sentence, validate whether it was logical and memorize a letter presented after the judgment. The testing phase was similar to the last practice phase. 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 task sequence is shown in Figure 4.4. The score was computed based on the number of correct letters in the correct position and order, as well as a memory span size. This task took 15 minutes.

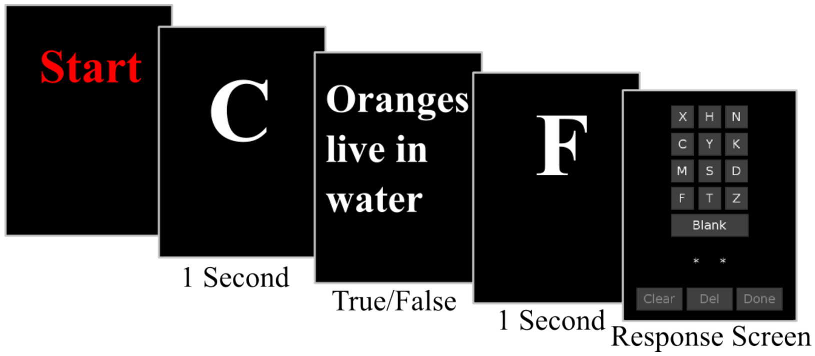


**Figure 4.4:** Example of reading span task

#### 4.2.3.2 Reasoning Task

A novel matrix reasoning task based on Raven's Raven & 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, with two practice problems at the beginning of the test. Participants had 15 minutes to complete all problems. A screen shot of this task is shown in Figure 4.5.

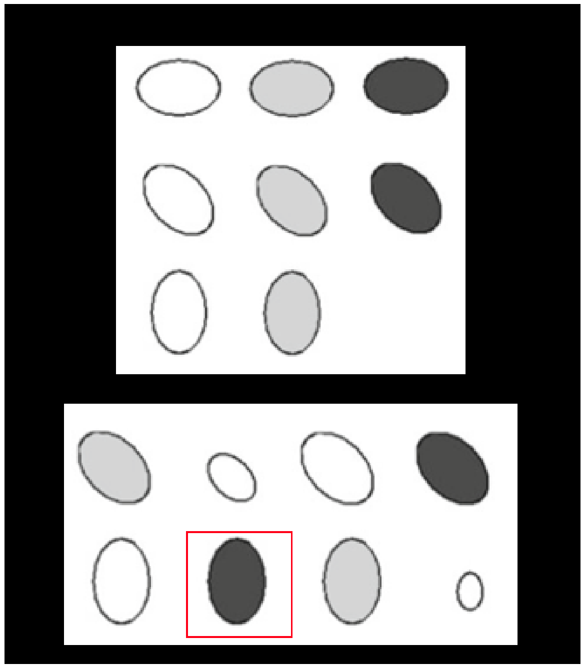

**Figure 4.5:** Example of reasoning task

### 4.2.4 Training Tasks

Three training tasks were given to participants. They were asked to perform the training tasks twice. All tasks are described below and all words and possible answers are shown in Appendix A. Again, the hypothesis was that the training intervention would differently impact participants' memory retreival fluency on target words.

#### 4.2.4.1 Word-Stem Completion Task

The word-stem completion task was adapted from Mueller & 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 and then pressing enter or return key. The answers from the given stem might be "STATION, STAR, STAY". 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 4.6.

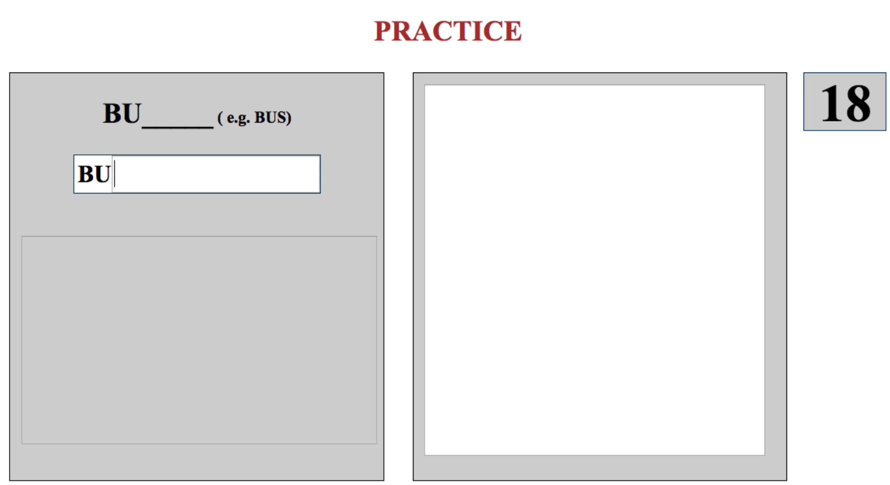


**Figure 4.6:** Example of word-stem completion task

#### 4.2.4.2 Crossword Paradigm Task

The crossword paradigm method was originally described by Goldblum & Frost (1988), and further adapted by Mueller & Thanasuan (2013). In this task, each participant was given 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 4.7. 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 & Thanasuan (2013) and Thanasuan & Mueller (2014).

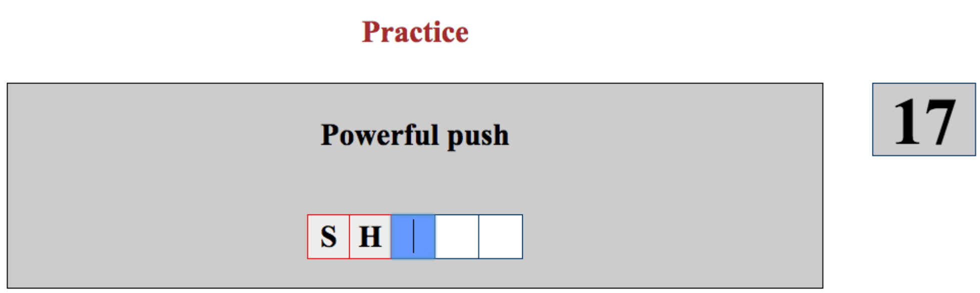


**Figure 4.7:** Example of crossword paradigm task

#### 4.2.4.3 Free Association Task

In this task, participants were given a target word for each trial as shown in Figure 4.8. 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 "BUS", they might answer "CAR, DRIVER, STATION". They had 30 seconds for each trial to give as many answers as possible. There was 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 on the screen for four seconds.

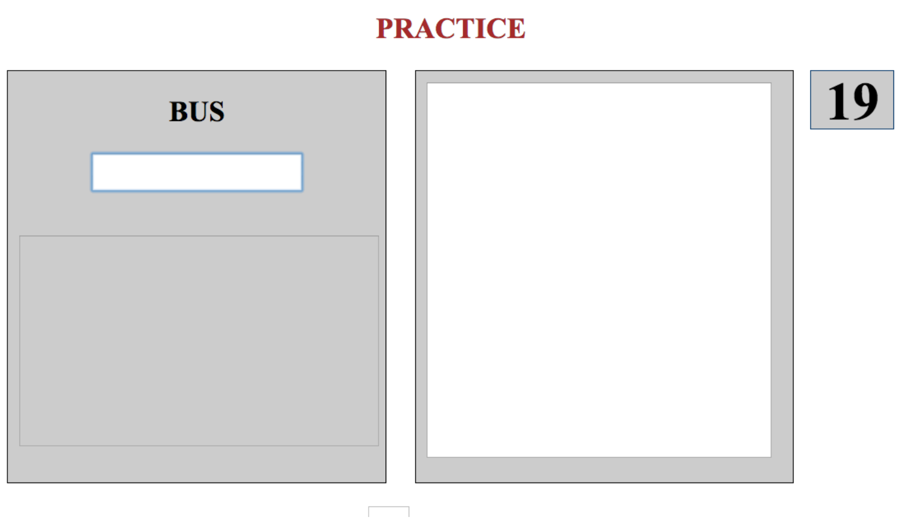


**Figure 4.8:** Screen shot of word free association task

### 4.2.5 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 (Kucera & Francis, 1967) and the Free Association Norms database (Nelson et al., 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 distractor word cues and positions were changed randomly. The example of this task is shown in Figure 4.9.

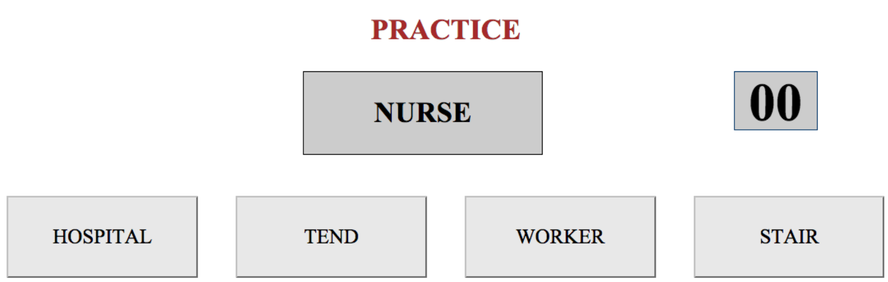


**Figure 4.9:** Screen shot of lexical association task

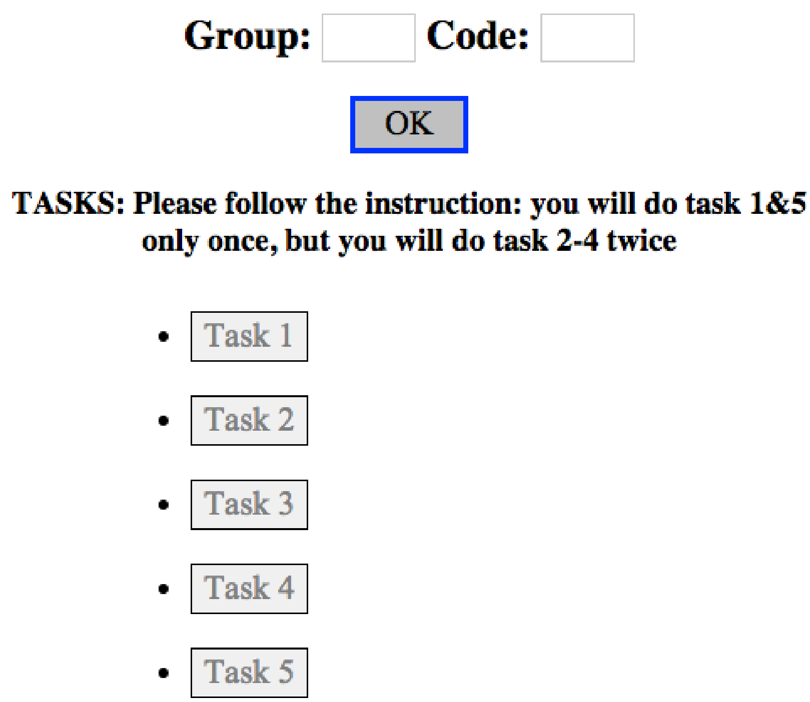


**Figure 4.10:** Experiment 1: A screen shot of experiment 1 interface

### 4.2.6 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 4.1. They did not know that the experiment was a pre-post test design, nor the overall task sequence. They were informed only that the study was related to word games and they had to follow the task instructions on a computer screen indicating which games that they had to perform consecutively. The experiment interface is shown in Figure 4.10. First, 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 completion 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 experiment process is also shown in Figure 4.11.

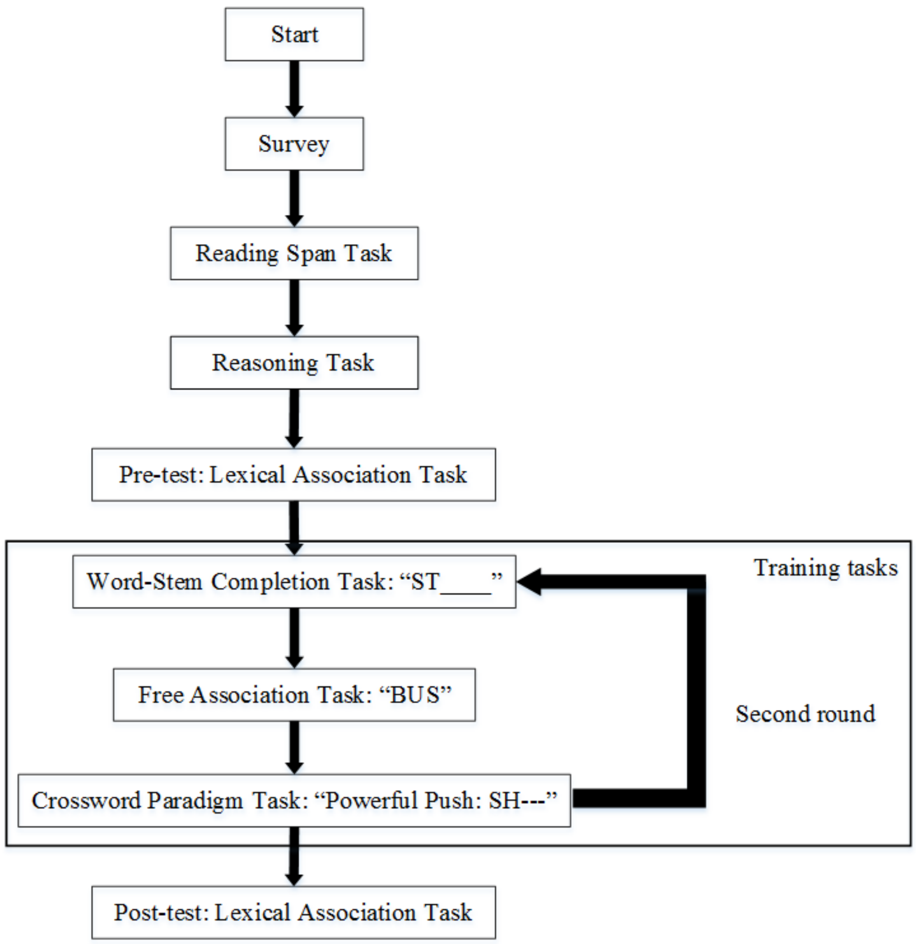


**Figure 4.11:** Experiment 1: Procedure

## 4.3 Results

Data from 55 participants were analyzed in this study. The number of participants for each group A through D was 15, 14, 12, and 14, respectively.

### 4.3.1 Baseline Tasks

**Table 4.2**
Baseline results

| Task | | Mean ± SD | Range | Skewness | Kurtosis |
|---|---|---|---|---|---|
| Reading span | Accuracy (%) | 79.85 ± 11.87 | 33.33-100 | -1.36 | 6.13 |
| | Memory Span (Max:5) | 3.2 ± 0.83 | 1-5 | -0.42 | 3.01 |
| | Distraction: Accuracy (%) | 96.37 ± 2.5 | 90.67-100 | -0.41 | 2.3 |
| Reasoning: | Accuracy (%) | 75.93 ± 10.73 | 41.86-97.67 | -0.6 | 3.7 |

Descriptive statistical data of the baseline task are shown in Table 4.2. Participants tended to perform the tasks very well, and the left-skewed data typically indicates a longer tail representing a few poorer performers. The significant 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

[2] The results were arranged based on the Friendly (2002)'s angular order of the eigenvectors. Note: diff (difference), acc (accuracy: correct responses) and rt (response time)

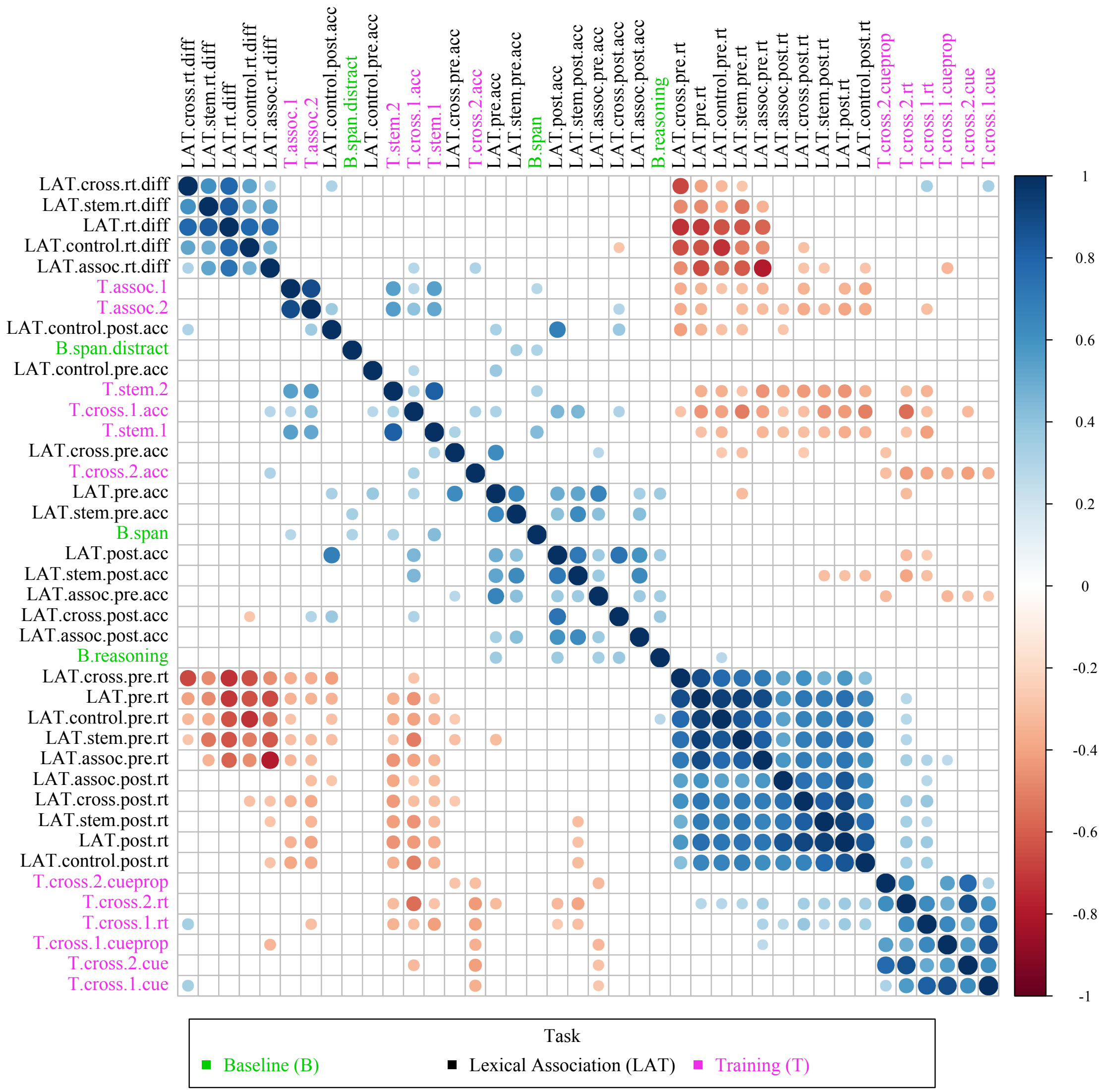


**Figure 4.12:** Correlation matrix of the lexical association task: The empty spaces indicate non-significant correlations and the color scale from dark blue to dark red indicates the strength of correlations (1 to -1)[2].

the reading span task and the reasoning task was 0.24 ($t(52) = 1.81$, $p = .08$) and non-significant. There were some significant weak correlations between performance in the baseline tasks and the other tasks (either accuracy or response time) such as the correlation between the reasoning task and the pre-test of the lexical association task ($R = .36$, $t(52) = 2.74$, $p = .008$), which is shown in Figure 4.12.

### 4.3.2 Training Tasks

Table 4.3 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. I 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 ($p < .001$) and the word-stem completion task ($p < .001$) as well as response times, the number of letter cues ($p < .001$) and cue proportion (computed by the number of letter cues and length in the crossword paradigm task) ($p < .001$). Moreover, the average unique words generated per target word from the free association task and the word-stem completion task were 64 ± 9.48 and 66.25 ± 21, respectively.

**Table 4.3**
Training results: Means and standard deviations of training tasks on first and second administration of test

| **Task** | | **$1^{st}$ Test** | **$2^{nd}$ Test** | **$t$-value** |
|---|---|---|---|---|
| Free Association[1] | | 5.61 ± 1.48 | 6.39 ± 1.79 | $t(53) = -6.38$* |
| Word-Stem Completion[1] | | 6.05 ± 1.63 | 6.64 ± 2.02 | $t(54) = -3.75$* |
| Crossword: | Accuracy | 9 ± 1.02 | 9.9 ± 0.29 | $t(54) = 6.97$* |
| | RT(s) | 6.41 ± 2.73 | 3.54 ± 1.48 | $t(54) = 9.93$* |
| | Letter cues | 2.32 ± 0.35 | 2.08 ± 0.17 | $t(54) = 6.32$* |
| | Cue Prop. | 0.38 ± 0.05 | 0.33 ± 0.03 | $t(54) = 6.95$* |

Note: [1]the number of legal words; * $p$-value < .001

### 4.3.3 Lexical Association Task

Accuracy of the pre-post tests of the lexical association task significantly increased from 37.98 ± 1.64 (mean ± standard deviation) to 38.45 ± 1.91 ($t(54) = -1.95$, $p = .05$). However, results from a mixed (between and within subjects) Analysis of Variance (ANOVA) indicate that there were not significant effects of the training conditions (within subjects: $F(3, 153) = 1.53$, $p = .21$), the participants' groups (between subjects: $F(3, 51) = 1.91$, $p = .14$) and the interaction between the conditions and the groups ($F(9, 153) = 1.59$, $p = .12$) on accuracy difference between the pre-post tests. Meanwhile, response times of these tests decreased from 3.56 ± 0.93 seconds to 2.67 ± 0.67 seconds ($t(54) = 10.98$, $p < .001$). Response times of each game condition are shown in Figure 4.13. The figure indicates that all training conditions (including the control condition) were able to improve participants' performance. I computed post-pre difference scores on response time (Figure 4.14) 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 4.15, which also supports that the free association task was able to reduce memory access time across the groups.

[3]The confidence intervals of a within-subject design were computed based on Morey (2008).

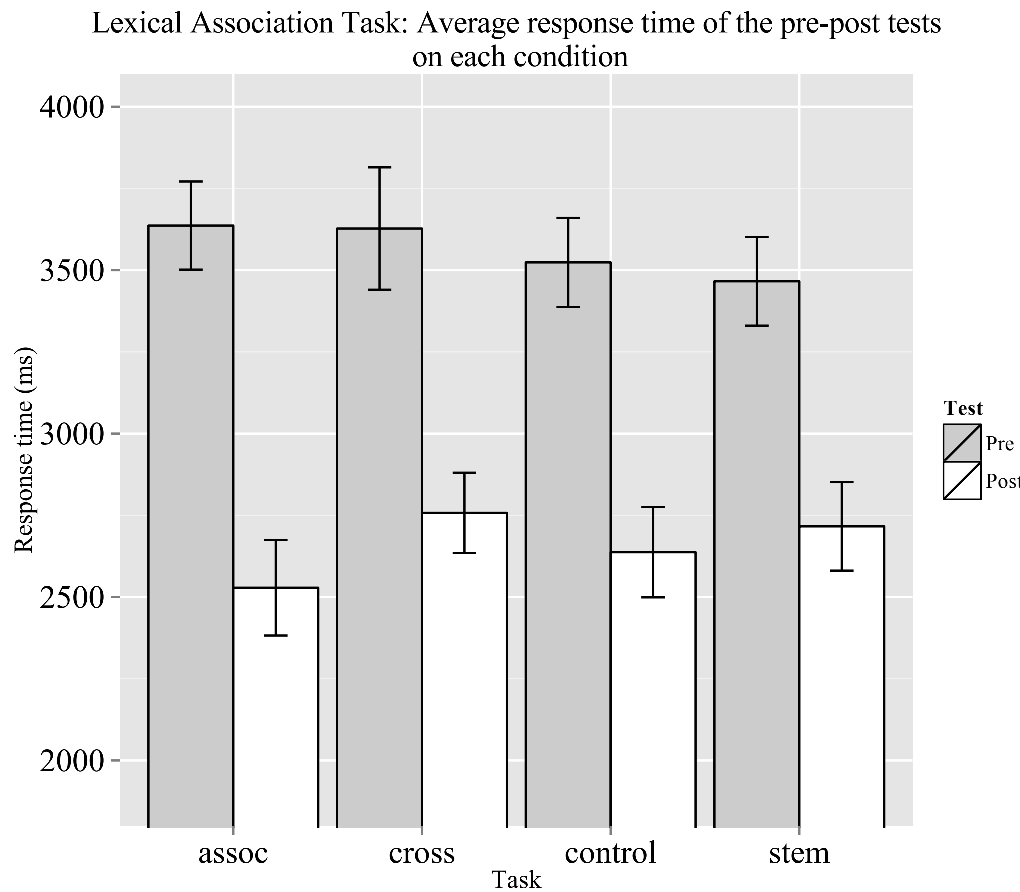


**Figure 4.13:** Lexical association task: Response times of the pre-post tests for each game condition. Error bars indicate 95% confidence interval (CI)

**Table 4.4**
Regression results: Training effects

| **Training** | **Coefficient ($\beta$)** | **Std. Error** | **$t$-value** |
|---|---|---|---|
| **Free Association** | -1108 | 106.0 | -10.45* |
| **Crossword** | -869.8 | 106.0 | -8.2* |
| **Control** | -886.6 | 106.0 | -8.37* |
| **Word-Stem Completion** | -749.8 | 106.0 | -7.07* |

Note: * $p$-value $<$ .001

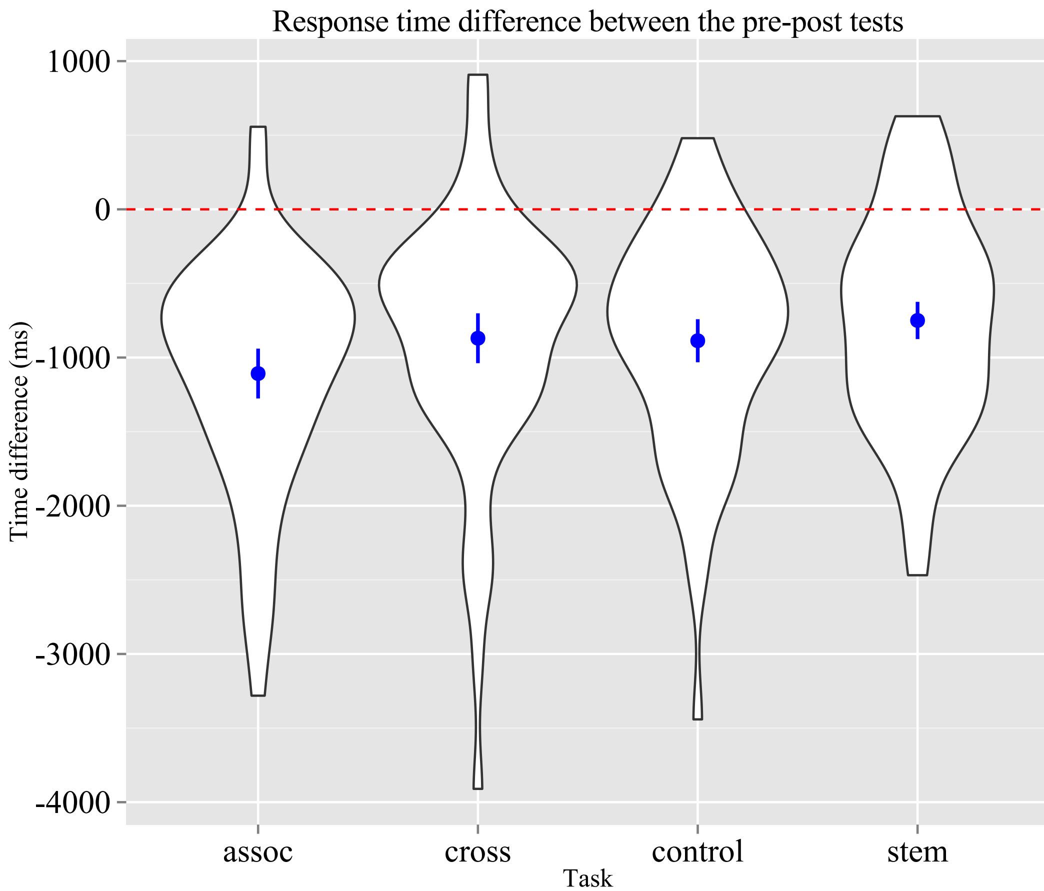


**Figure 4.14:** Lexical Association Task: Response time difference between the pre-post tests. Dots and lines indicate means and 95% confidence intervals[3] of each game condition.

A regression analysis between the response time difference and the game conditions was conducted to compare which game was the most effective training method. It showed that all games reliably influenced the response time (with $R^2 = .57$, $F(4, 216) = 74.16$ , $p < .001$ ), and participants improved the response times for the words studied in the free association task better than the words they had experienced in the other tasks (see Table 4.4). The coefficient ($\beta$) represents the intercept

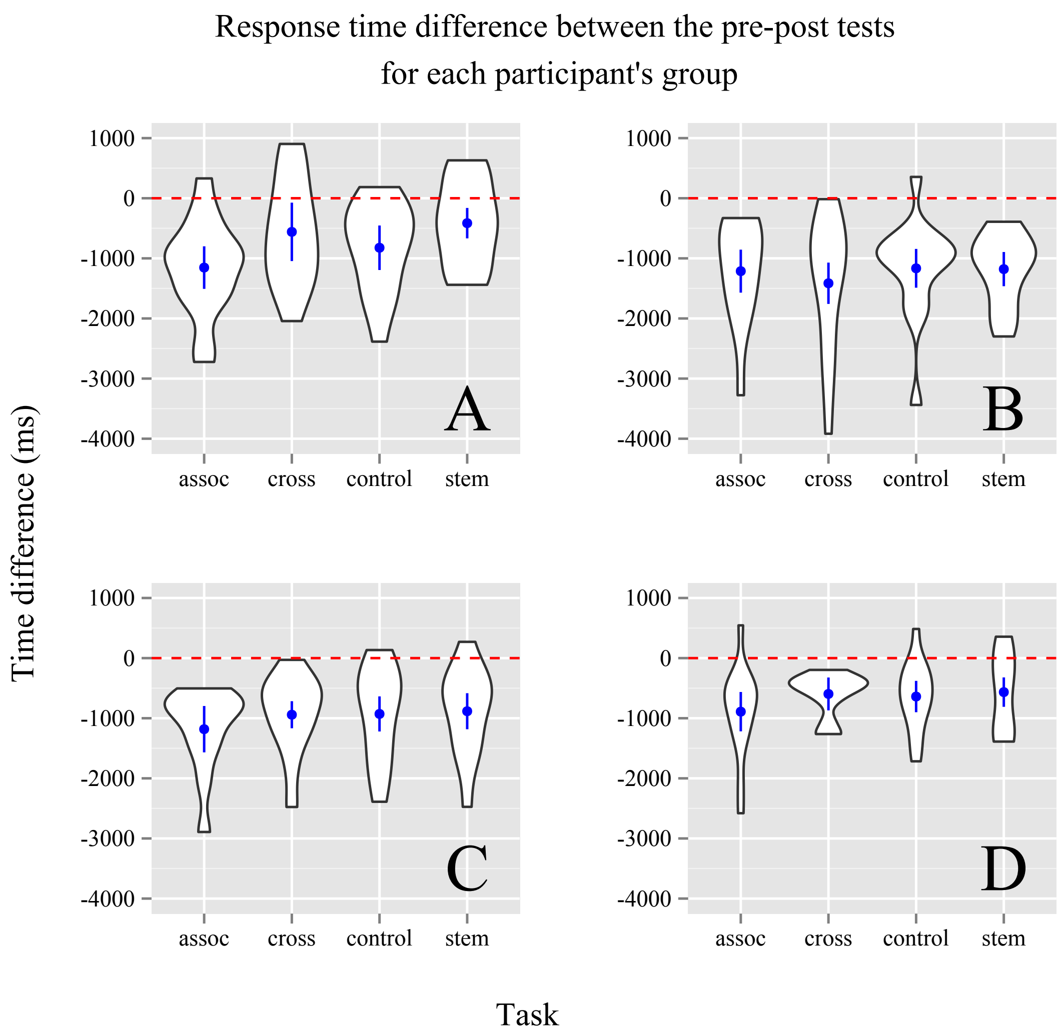


**Figure 4.15:** Lexical association task: Response time difference between the pre-post tests of each participant's group

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 or the crossword paradigm task.

A mixed ANOVA was also conducted to compare effects of the game conditions, the participants' groups and the interaction between the conditions and the groups on the response time difference. The results show that the effect of the game condition was significant at .05 level (within subject: $F(3, 153) = 3.86$, $p = .01$), whereas there were no significant effects of the counterbalancing groups (between subject: $F(3, 51) = 2.75$, $p = .052$) or the interaction between the conditions and the groups ($F(9, 153) = 1.13$, $p = .35$). A pairwise $t$-test was conducted to compare which game conditions were significantly different, and it indicated that only the free association training results differed from the stem completion training results($t(54) = -3.63$, $p < .001$). I 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 ($t(54) = 0.16$, $p = .56$) nor the word-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 the other training conditions or no training group.

## 4.4 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. I hypothesized that this advantage occurred because the testing method involves accessing exactly the same types of associations to the target words that participants generated during training. Moreover, they spent more time performing this task than other tasks. Specifically, they spent 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 effective than the others

One of the 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, the results essentially showed that semantic association training (from the free association task) is most 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 within 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 distractor cues were randomly selected, the answers corresponding to the given words were the same for both pre-post tests. This may have improved performance in all game conditions, including the control condition, although the free association effect was greater than the others. To address this problem, future studies may choose to give two different answers for the pre-post tests of the same target words.

Consequently, this experiment demonstrates that the word games may be an effective training method for promoting and understanding fluent lexical memory access. It may be further developed and implemented as new computational models representing memory processes. Furthermore, this research can also be an important part of a second-language learning (L2) toolkit. The study provides a basis for understanding the use of word games to promote L2 learning. According to the Revised Hierarchical Model (Kroll & Stewart, 1994), L2 word learning in early stages heavily relies on connections between learners' first language words and L2 words. After that, they 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. Again, if the learners play the games iteratively, it may help them to improve their long-term lexical memory. This assumption led to an investigation of Experiment 2, which is discussed in Chapter 5.

# Chapter 5

# Experiment 2

Since the results from Experiment 1 showed a reliable difference between training games, Experiment 2 was designed to investigate the same effect with non-native English speakers who have learned English as a second language. This experiment was similar to Experiment 1, but some tasks had been modified in order to be suitable for non-native English speakers.

The goals of this study were to investigate non-native English speakers' learning performances using English word games, and to determine whether the word training games were able to facilitate second language (L2) performance and inhibit participants' automatic native language (L1) processes. Participants whose native languages were Thai or Chinese were recruited to take part in this study. Again, a pretest-posttest design was conducted, using both a lexical association task and an anagram-solving task in order to assess the training game effectiveness.

The lexical association task in this study differed from the previous experiment. In this task, participants had to determine either whether English-English word pairs were associated, or whether English-native language word pairs had the same meaning. These question styles required only recognition processes, which is more appropriate than the previous method that used judgments among four different options. I anticipated that the performance improvement in English-English trials would be greater than English-native language improvement, as the effects of the training games were established using tests of English-English associations. Furthermore, since the trials in this task were randomly presented to participants, the switching cost between two languages (e.g. Green, 1998; Meuter & Allport, 1999; Meuter, 1994) may be shown in this study, but it was beyond the dissertation's goal.

Another pre-post test was an anagram solving task. This task was designed to test an effect of the crossword paradigm task more directly. It had been modified to be easier than the crossword paradigm training, by giving letter cues and deliberately selecting simple or obvious semantic clues. Moreover, effects of the training games on the performance improvement between the pre-post tests were expected to be seen in this task, especially from the crossword paradigm task.

## 5.1 Hypotheses

The following hypotheses were examined in this experiment.

**Hypothesis 1** After the English word games training, participants will significantly improve their performance on both accuracy and response time in the lexical association task and the anagram solving task.

**Hypothesis 2** For each game condition, words that are from the word free association task will have the largest improvement on both accuracy and response time on the lexical association task, compared to the other games. In contrast, words trained in the crossword paradigm task will have the best improvement on both accuracy and response time in the anagram solving task compared to the other games.

**Hypothesis 3** For the second round of the English word games, participants will show significant improvement in their performances on both accuracy and response time in all games.

**Hypothesis 4** The results from both the reading span task and reasoning task will positively correlate to the word game performance and the amount of improvement in the post-test of the lexical association task and the anagram solving task.

**Hypothesis 5** Words trained in the crossword paradigm task and the word free association task will have significant improvement on both accuracy and response latency in the post-test of the lexical association task with English-English word pairs compared to the other conditions. The words from the control group will have no improvement. Moreover, the English-native language word pairs will show no improvement in accuracy and response time.

## 5.2 Method and Materials

Sixty-four English words were selected from the books, *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 (see Appendix B for the word-pool). The words were randomly assigned into one of four groups (16 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 5.1. Participants were randomly assigned to one of the four training groups, so that each participant experienced every training condition with a different subset of words. The conditions were composed of a control group (no learning or training), 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 symmetry span tasks. The remaining tasks were conducted via a web browser using HTML, JavaScript and PHP. Moreover, the English words translated to Thai and Chinese were revised by native speakers of those languages.

**Table 5.1**
Training groups

| Participant group | Word training condition | | | |
|---|---|---|---|---|
| | **Word-stem** | **Free assoc.** | **Crossword** | **Control** |
| A | 1 | 2 | 3 | 4 |
| B | 2 | 3 | 4 | 1 |
| C | 3 | 4 | 1 | 2 |
| D | 4 | 1 | 2 | 3 |

### 5.2.1 Participants

Seventy-seven participants were recruited for this study (43 males, 34 females). They were international students from the Michigan Technological University (MTU) community, and Thai students from two universities in Bangkok, Thailand. The criteria of participation were set up to reduce performance variations. They were composed of a limited age (18-40 years old), learning English as a second language and having at least a high school diploma or equivalent. The average age of the participants is $22.75 \pm 3.53$ years old. They were Thai and Chinese native speakers. Their average

English experience in years is 13.60 $\pm$ 3.73 years. They reported their English proficiency scores. The common English skills they usually used from most to least were reading, listening, writing and speaking. The compensation in this study was based on the minimum wages of the USA and Thailand. If they participated in Thailand, they received 200 Baht or six US dollars. On the other side, if they participated the study in the USA, they received $15 for their time. The experiment was set up and conducted in the MTU laboratory at MEESE building (data collection was conducted during April - July 2015) and in computer labs (data collection was conducted during March 2015) of the universities in Thailand. The study was reviewed and approved by the Michigan Technological University Institutional Review Board (IRB). The entire study approximately took 1.5 hours to complete, but the actual time spent for each participant was roughly 1.5-2 hours.

### 5.2.2 Demographic Survey

The goal of this survey was to determine cognitive factors and levels of English proficiency of each participant that might influence participants' lexical ability. They were asked about their personal information such as age, native language, level of education and their English experience. The questions are shown in Appendix B. The survey took only five minutes to finish and a sample survey screen shot is shown in Figure 5.1.

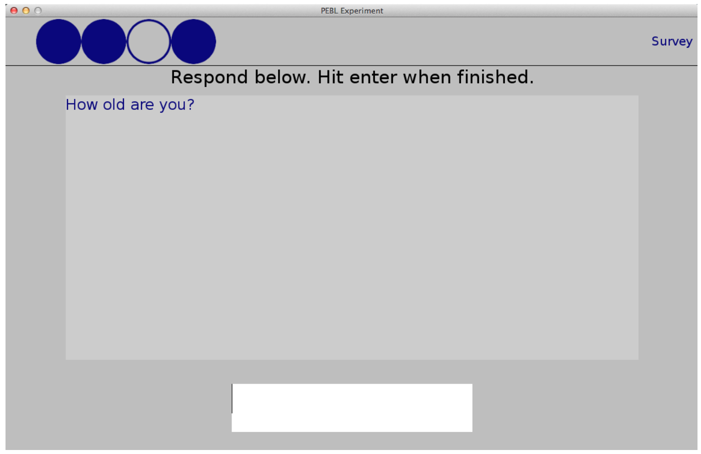


**Figure 5.1:** Demographic survey software

### 5.2.3 Baseline Tasks

Participants were asked to perform the symmetry span task and the reasoning task at the beginning of the study. The symmetry span task was used to measure participants' working memory span. The reasoning task was used to assess intelligence and reasoning ability. Both were non-verbal tasks, which were appropriate to evaluate the performance of non-native English speakers.

#### 5.2.3.1 Symmetry Span Task

The goal of the symmetry span task was to recall positions of red squares within a 4 x 4 matrix. Before the test, participants had to perform three practice phases. The first phase involved position recall, in which they saw red squares appearing continuously in various positions inside the matrix. Each red square appeared for 1000 ms. To recall the information, participants had to identify the red square locations by clicking at the empty matrix in the correct order. The next practice was symmetry-judgment. Participants were shown a matrix with some black squares and they had to determine whether the matrix was vertically symmetrical. The last practice combined the first two tasks. Participants were required to decide whether the matrix was vertically symmetrical and then were shown a randomly red square in a 4 x 4 matrix promptly after the judgment. They had to do these two tasks alternatively until the recall matrix appeared. The real test was similar to the last practice. There were two trials of each set size between two to five, and it took about 10 minutes to complete. The symmetry span task sequence is shown in Figure 5.2.

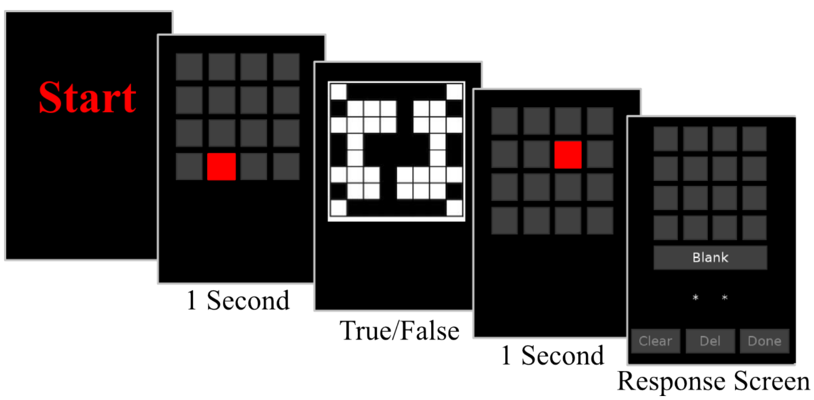


**Figure 5.2:** Example of symmetry span task

#### 5.2.3.2 Reasoning Task

A novel matrix reasoning task based on Raven's Raven & 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 20 test problems and two practice problems at the beginning of the test. Participants had 5 minutes to complete all problems. A screen shot of this task is shown in Figure 5.3.

### 5.2.4 Training Tasks

Three training tasks were given to participants. They were asked to perform the training tasks twice. All tasks are described below and all words and possible answers are shown in Appendix B. Again, the hypothesis was that the training intervention would differently assist participants' lexical memory fluency on target words.

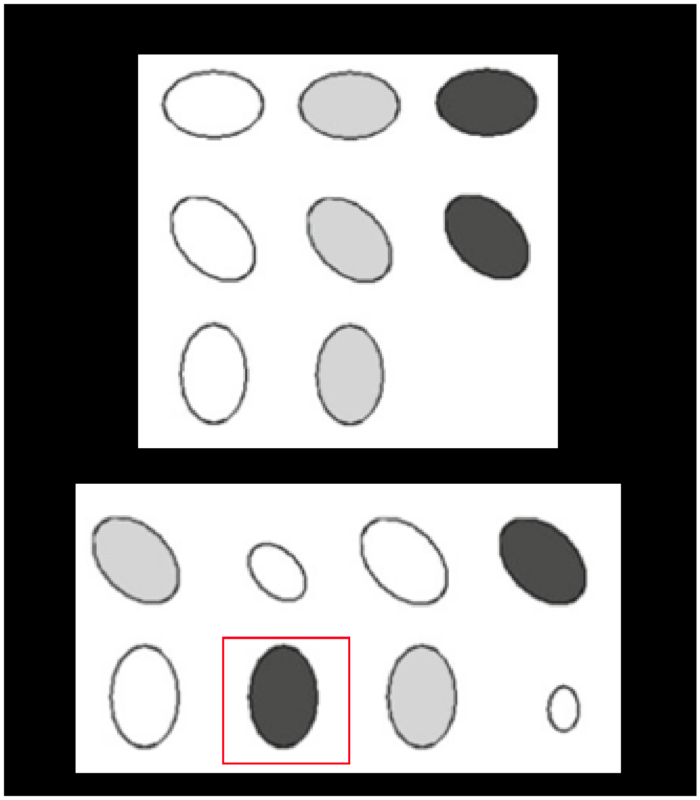

**Figure 5.3:** Example of reasoning task

#### 5.2.4.1 Word-Stem Completion Task

The word-stem completion task was adapted from Mueller & Thanasuan (2014). All stems and some possible answers are shown in Appendix B which were taken from (Kucera & Francis, 1967). 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 and answers from the given stem might be ”STATION, STAR, STAY”. 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. Sixteen words were given to participants in this training.

#### 5.2.4.2 Crossword Paradigm Task

The crossword paradigm task was originally developed by Goldblum & Frost (1988), and was adapted by Mueller & Thanasuan (2013). In this task, each participant was given 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. They then entered a guess answer in the blank spaces. If the answer was incorrect, the software randomly revealed another letter to provide additional constraints. A total of 16 problems were given to participants. The crossword clue-answer pairs in this study were from the same database as in Mueller & Thanasuan (2013) and Thanasuan & Mueller (2014).

#### 5.2.4.3 Free Association Task

In this task, participants were given a target word for each trial. 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 “BUS”, they might answer “CAR, DRIVER, STATION”. They had 30 seconds for each trial to give as many answers as possible. There was a total of 16 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.

### 5.2.5 Lexical Association Task

The lexical association task was completed both prior to and following word game training. In each trial, participant saw either English-English word pairs or English-native languages word pairs. Their task for an English-English word pair was to determine whether the two given words were associated meaningfully or not. For example, they might see a trial similar to Figure 5.4. For the English-English words, their goal was to decide whether the words "NURSE" and "TEND" were meaningfully related or strongly associated. On the other hand, they had to justify whether or not the bilingual word pairs had the same semantic meaning. The participants were given a bilingual word pair based on their native languages. They had 10 seconds for each trial to give the answer by pressing either "Left Shift" or "Right Shift" indicating "Yes" or "No", respectively. Three practice problems were given at the beginning of the test. There was a total of 88 different test problems, 44 English word pairs and 44 bilingual word pairs. It took about 10-20 minutes to complete.

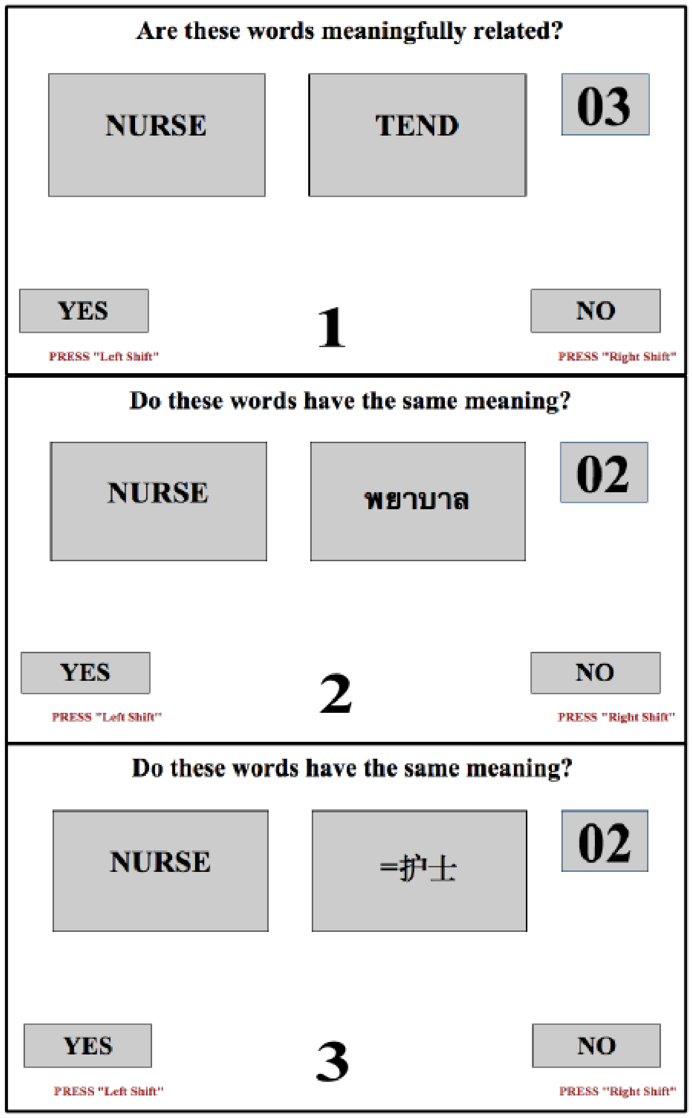


**Figure 5.4:** Lexical association task: Top (1) indicates an English-English word pair. Middle (2) indicates an English-Thai word pair. Bottom (3) indicates an English-Chinese word pair.

### 5.2.6 Anagram Solving Task

The anagram solving task was completed both prior to and following word game training. This task was similar to a crossword puzzle training, as it involved both semantic and orthographic information. Participants were given a semantic clue along with two letter cues inside answer spaces and the remaining letters were randomly positioned on the other side. Their goal was to generate a word from the given letters that was meaningfully related to or associated with the semantic clue in 20 seconds. For example, they might see a trial similar to Figure 5.5. Their goal was to generate a word from the letters "H V S" and it had to meaningfully relate to the clue "POWERFUL PUSH", when the correct word was "SHOVE". After they completed the word, they had to press enter key to continue. The two letter cues were randomly generated and given to participants. Three practice problems were added to the task at the beginning. There was a total of 20 test problems. It took about 7-10 minutes to complete.

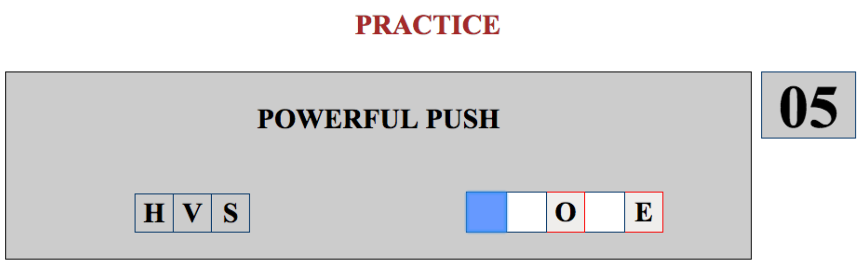


**Figure 5.5:** Example of anagram solving task

### 5.2.7 Task Sequence

Participants first read and signed the consent form. They were assigned to one of four counterbalancing groups (A, B, C or D) as shown in Table 5.1. They did not know

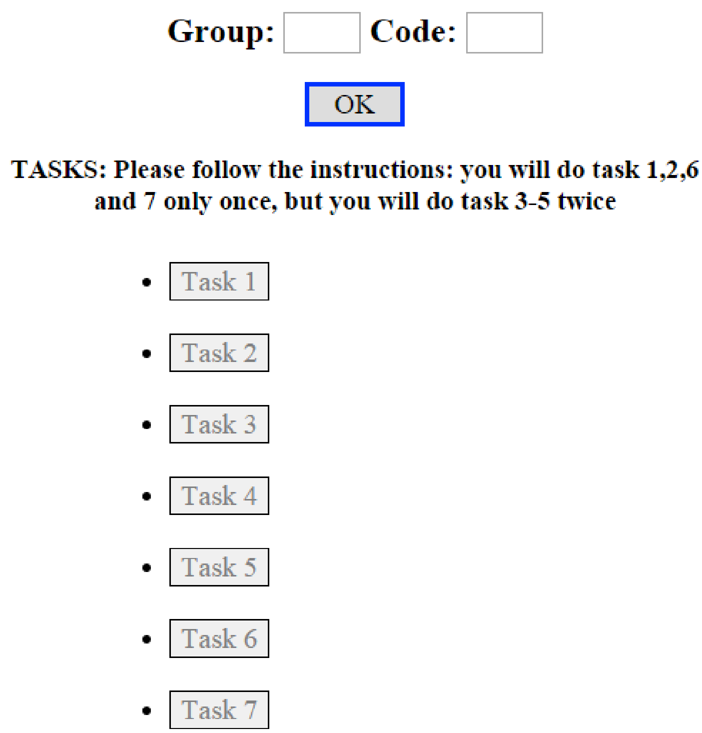


**Figure 5.6:** Experiment 2: A screen shot of experiment interface

that the experiment was a pre-post test design, nor the overall task sequence. They were informed only that the study was related to word games and they had to follow the task instructions on a computer screen indicating which games that they had to perform consecutively. The experiment interface is shown in Figure 5.6. They first completed the survey, the symmetry span task, and the reasoning task in PEBL. They did the anagram solving 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 and the anagram solving task as a post-test. The experiment timeline is shown in Figure 5.7.

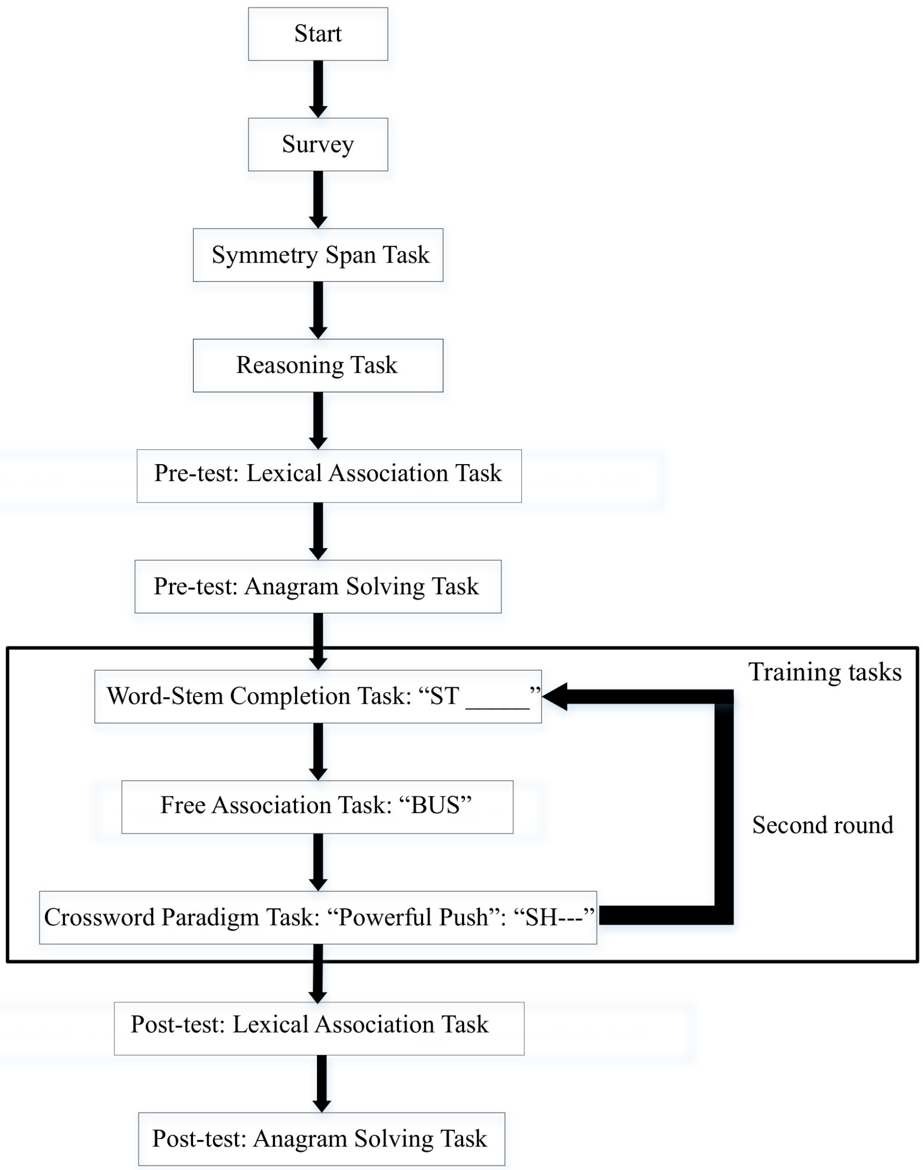


**Figure 5.7:** Experiment 2: Procedure

## 5.3 Results

Data from 77 participants were analyzed in this study. The number of participants for each group from A to D was 23, 17, 17, and 20, respectively.

### 5.3.1 Baseline Tasks

**Table 5.2**
Baseline results

| **Task** | | **Mean ± SD** | **Range** | **Skewness** | **Kurtosis** |
|---|---|---|---|---|---|
| Symmetry span | Accuracy (%) | 71.38 ± 20.79 | 0-100 | -1.35 | 4.9 |
| | Memory Span (Max:5) | 3.27 ± 0.86 | 1-5 | -0.5 | 3 |
| | Distraction: Accuracy (%) | 86.73 ± 12.11 | 46.43-100 | -1.22 | 4.34 |
| Reasoning: | Accuracy (%) | 43.05 ± 14.39 | 5-75 | -0.23 | 3.7 |

Descriptive statistics for the reasoning and symmetry span tasks are shown in Table 5.2. The results indicate that many participants performed the tasks very well, as demonstrated by the left skew. In the symmetry span task, the number of recognized positions and the accuracy of symmetry distractions were uncorrelated ($R = .09$, $t(75) = .85$, $p = .4$), while the correlation of accuracy between the reading span task and the symmetry task was 0.11 ($t(75) = .98$, $p = .33$). Significant correlations

($p < .05$) between baseline tasks and the other tasks' performance (either accuracy or response time) are shown in Figure 5.8 and Figure 5.9.

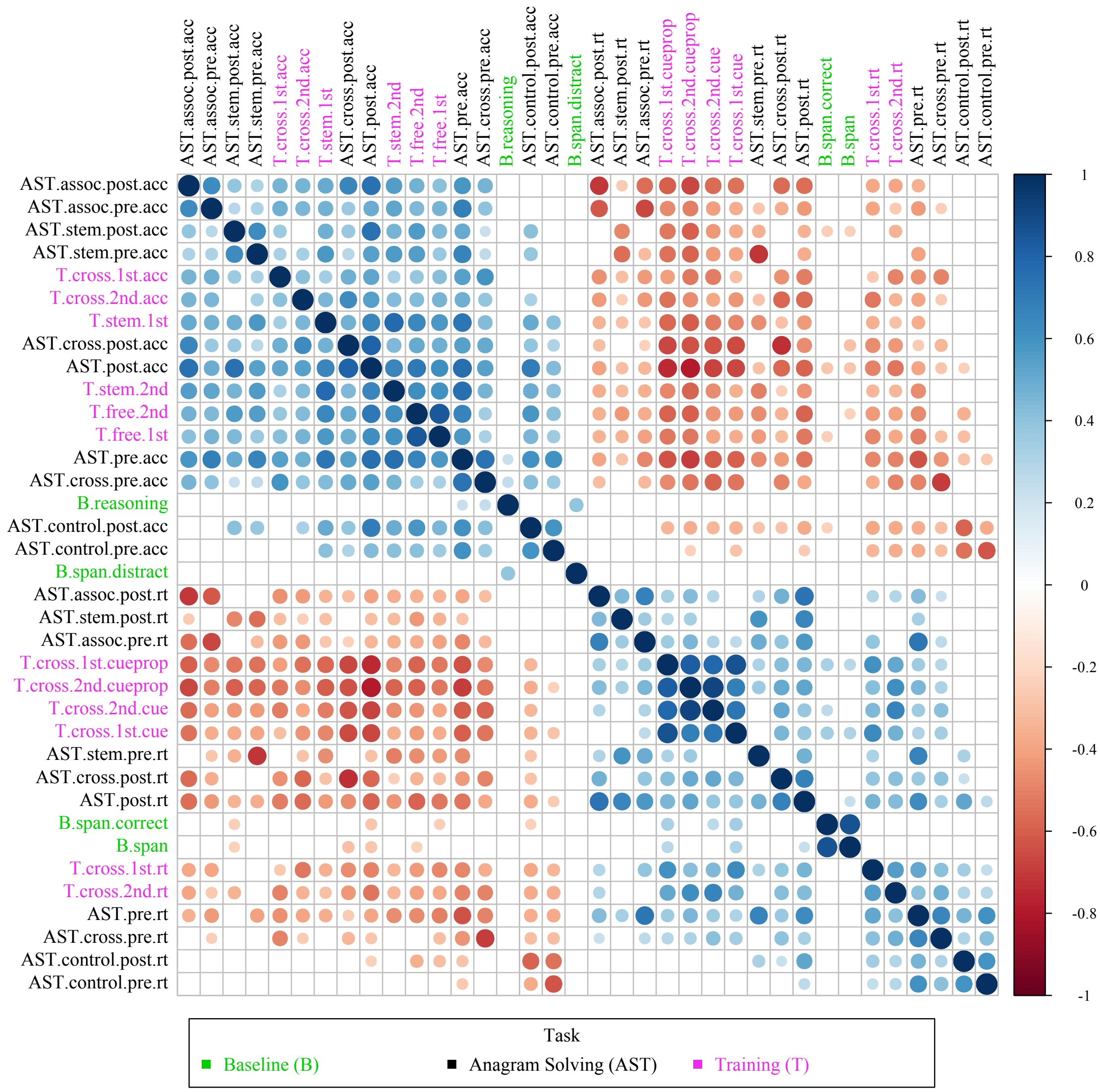


**Figure 5.8:** Correlation matrix of the anagram solving task: The empty spaces indicate non-significant correlations and the color scale from dark blue to dark red indicates the strength of correlations (1 to -1)[1].

[1] The results were arranged based on the Friendly (2002)'s angular order of the eigenvectors. Note: diff (difference), acc (accuracy: correct responses) and rt (response time)

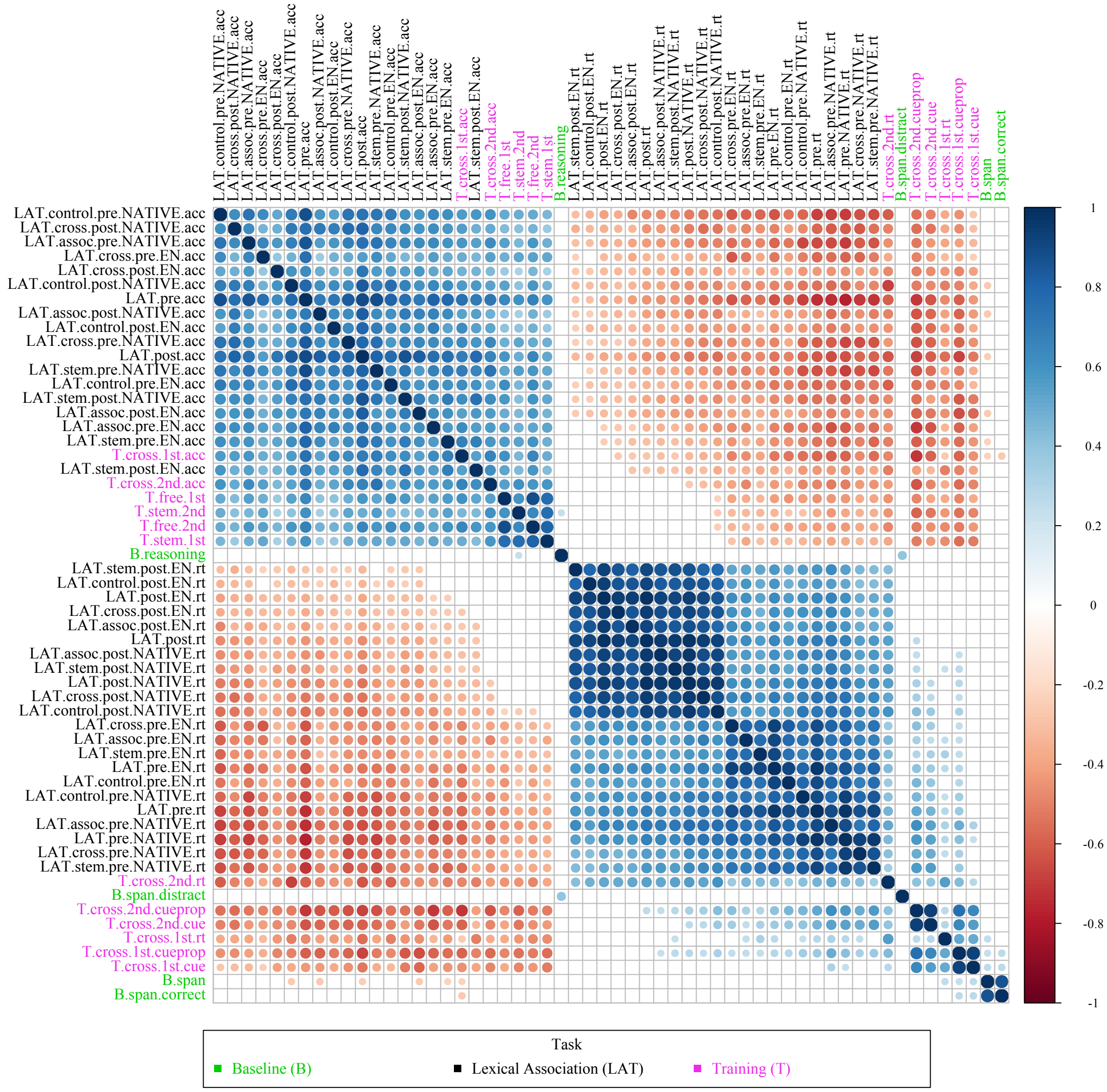


**Figure 5.9:** Correlation matrix of the lexical association task: The empty spaces indicate non-significant correlations and the color scale from dark blue to dark red indicates the strength of correlations (1 to -1)[1].

### 5.3.2 Training Tasks

The words from the two pre-test tasks were divided into two groups (44 words for the lexical association task and 20 words for the anagram solving task) for estimating training efficiency. Table 5.3 and Table 5.4 show results from the training games of those two groups. 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. I conducted paired Wilcoxon signed-rank tests (a non-parametric statistic test) to compare both iterations of the games. Results showed significant improvements in each measure, except for the number of crossword letter cues in Table 5.4. The average unique words generated for each target word from the free association task and the word-stem completion task were $39.08 \pm 12.5$ (mean $\pm$ standard deviation) and $39.48 \pm 14.53$, respectively.

According to Figure 5.8 and Figure 5.9, there were strong positive correlations between the training results and the pre-post tasks on the accuracy scores and response times. Therefore, participants who performed well in the pre-post tasks also did well during the training games.

**Table 5.3**
Lexical association task training results: Means and standard deviations of training tasks on first and second administration of test

| Task | | $1^{st}$ Test | $2^{nd}$ Test | Wilcoxon Test |
|---|---|---|---|---|
| Free Association[1] | | 2.68 ± 1.27 | 2.96 ± 1.49 | $Z = -3.56$* |
| Word-Stem Completion[1] | | 2.99 ± 1.16 | 3.49 ± 1.35 | $Z = -5.43$* |
| Crossword: | Accuracy | 6.43 ± 2.45 | 8.08 ± 3.18 | $Z = -5.74$* |
| | RT(s) | 11.98± 4.02 | 8.18 ± 3.96 | $Z = -6.56$* |
| | Letter cues | 2.97 ± 0.91 | 2.88 ± 1.01 | $Z = -2.1$* |
| | Cue Prop. | 0.51 ± 0.13 | 0.48 ± 0.16 | $Z = -3.5$* |

Note: [1]the number of legal words; * $p$-value < .001

**Table 5.4**
Anagram solving task training results: Means and standard deviations of training tasks on first and second administration of test

| Task | | $1^{st}$ Test | $2^{nd}$ Test | Wilcoxon Test |
|---|---|---|---|---|
| Free Association[1] | | 2.59 ± 1.24 | 3.04 ± 1.67 | $Z = -4.66$* |
| Word-Stem Completion[1] | | 3.56 ± 1.41 | 3.98 ± 1.49 | $Z = -3.75$* |
| Crossword: | Accuracy | 3.10 ± 1.21 | 3.99 ± 1.17 | $Z = -5.55$* |
| | RT(s) | 11.74 ± 5.24 | 8.48 ± 4 | $Z = -5.27$* |
| | Letter cues | 2.99 ± 1.03 | 3 ± 1.12 | $Z = -0.42$ |
| | Cue Prop. | 0.51 ± 0.16 | 0.5 ± 0.16 | $Z = -2.04$** |

Note: [1]the number of legal words; * $p$-value < .001; ** $p$-value < .05

### 5.3.3 Lexical Association Task

According to Figure 5.8, the accuracy (correct responses) of the lexical association task was negatively correlated with the response times of the task. For example, the correlations between the accuracy and response time of the pre-test and post-test were -0.73 ($t(75) = -9.32$, $p < .001$) and -0.47 ($t(75) = -4.56$, $p < .001$), respectively. This means participants responded to correct answers very fast and they were able to determine the answers immediately after they saw trials.

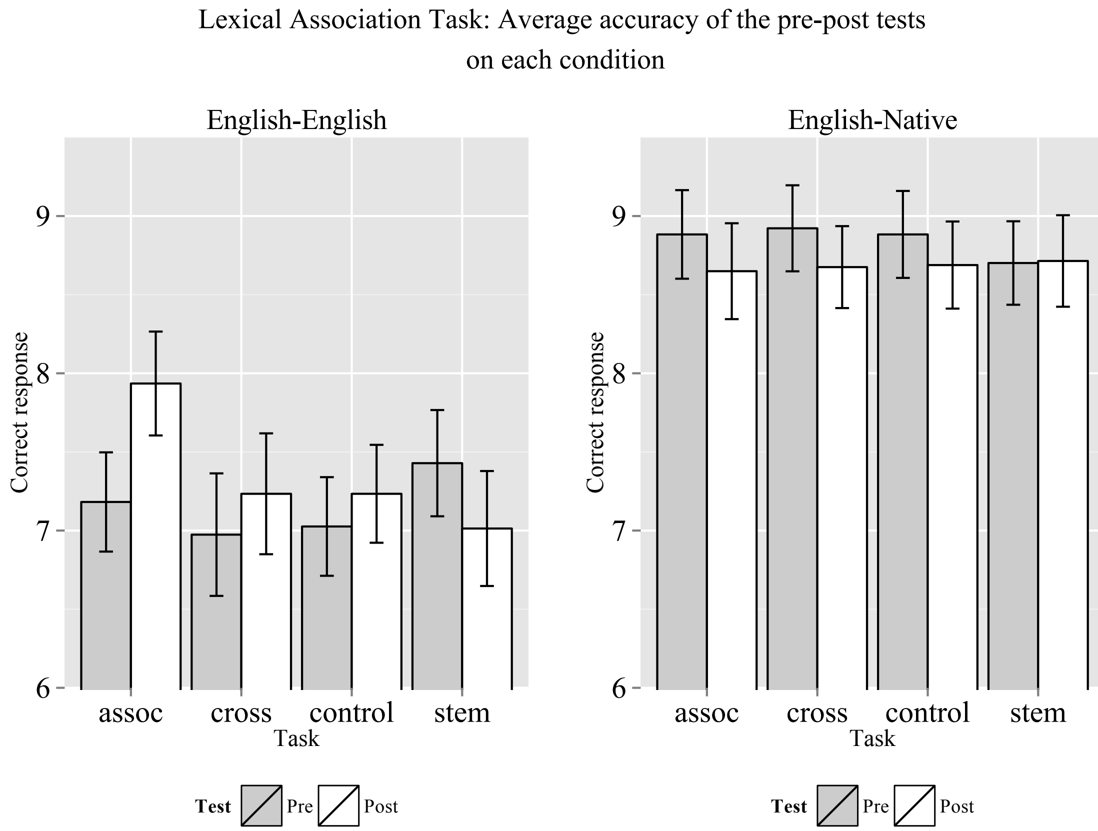


**Figure 5.10:** Lexical association task: Accuracy score between the pre-post tests for each game condition. Error bars indicate 95% confidence intervals (CI).

Since results were not normally distributed, paired Wilcoxon signed-rank tests (a non-parametric statistic test) was used to analyze the data. Accuracy or correct responses of the pre-post tests of the lexical association task of English-English word pairs significantly increased from 28.99 ± 6.66 to 29.08 ± 6.55 ($Z$ = -1.95, $p$ = .05). On the other hand, the accuracy or correct responses of English-native language word

[2]The confidence intervals of a within-subject design were computed based on Morey (2008).

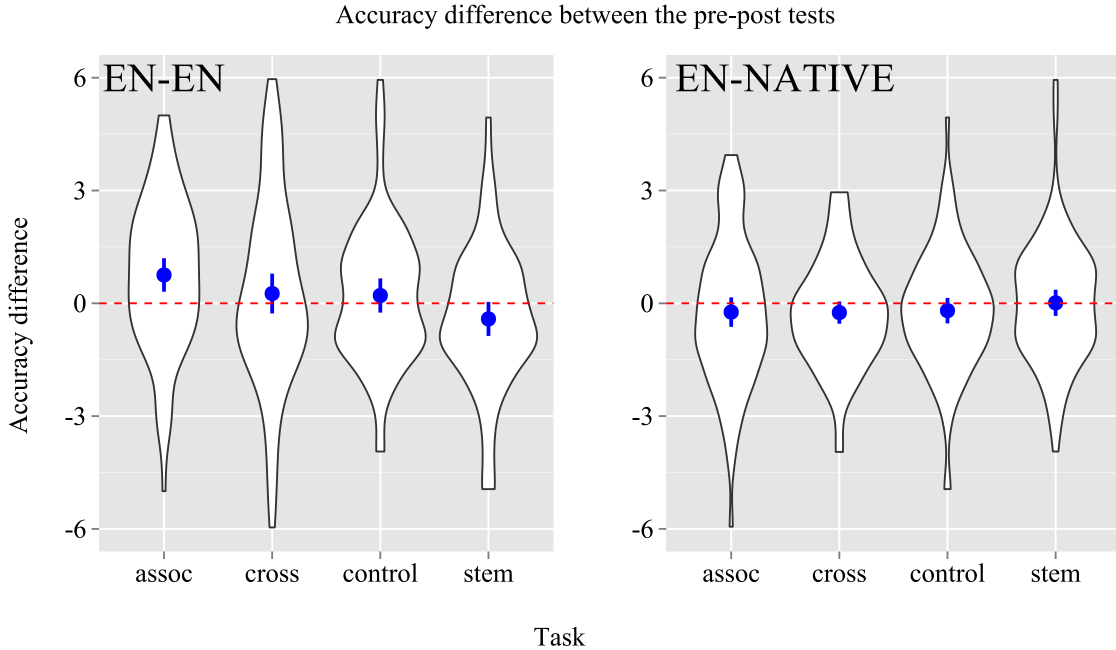


**Figure 5.11:** Lexical Association Task: Accuracy score difference between the pre-post tests. Dots and lines indicate means and 95% confidence intervals[2]of each game condition.

pairs decreased from 35.86 ± 6.73 to 35.18 ± 5.99, but not significantly ($Z$ = -1.56, $p$ = .12). Figure 5.10 shows the accuracy score of the pre-post tests of each game condition on both English-English and English-Native languages word pairs and it suggests that participants were better in translation than association. Figure 5.11 displays the accuracy score improvement of each participant from pre-test to post-test on the lexical association task in each game condition. Participants were able to improve between the tests with the words that they saw in the free association task more than the others. A two-way mixed (between and within subjects) Analysis of Variance (ANOVA) was conducted to compare accuracy differences among the effects of game conditions (a within-subject variable) and the participants' group (a between subject variable), as well as an interaction between these variables. The results suggested that there was a significant effect of the game conditions on the accuracy difference at the $p < .05$ ($F(3, 216) = 4.2$, $p = .007$). However, the effects of the participants' group and the interaction between the conditions and group were not significant ($F(3, 72) = 0.38$, $p = .77$ and $F(9, 216) = 1.61$, $p = .11$, respectively). Pairwise comparisons between the game conditions using a paired Wilcoxon signed rank test were also computed to confirm training efficiency. It indicated only a significant difference between the free association task and the stem completion task ($Z = -2.78$, $p = .005$). Furthermore, a mixed ANOVA was used to compare the same variables in the case of English-native language word pairs. The outputs showed that the effects of neither the game conditions ($F(3, 216) = 0.49$, $p = .69$) nor the participants' groups ($F(3, 72) = 0.49$, $p = .69$) were significant at .05 as well as the interaction between them ($F(9, 216) = 1.26$, $p = .26$).

Response times were estimated from correct and incomplete answers. Incorrect answers were excluded from the analysis. The average response times of English-English word pairs per participant improved, decreasing significantly from $14.32 \pm 5.63$ seconds to $8.57 \pm 4.56$ seconds ($Z = -7.56$, $p < .001$). Similarly, the average response times of English-native languages word pairs decreased significantly from $11.12 \pm 5.19$ seconds to $6.8 \pm 4.47$ seconds ($Z = -7.53$, $p < .001$). Participants were able to perform translation faster than association, which is shown in Figure 5.12. Figure 5.13 shows the response time difference of each participant from the pre-test to the

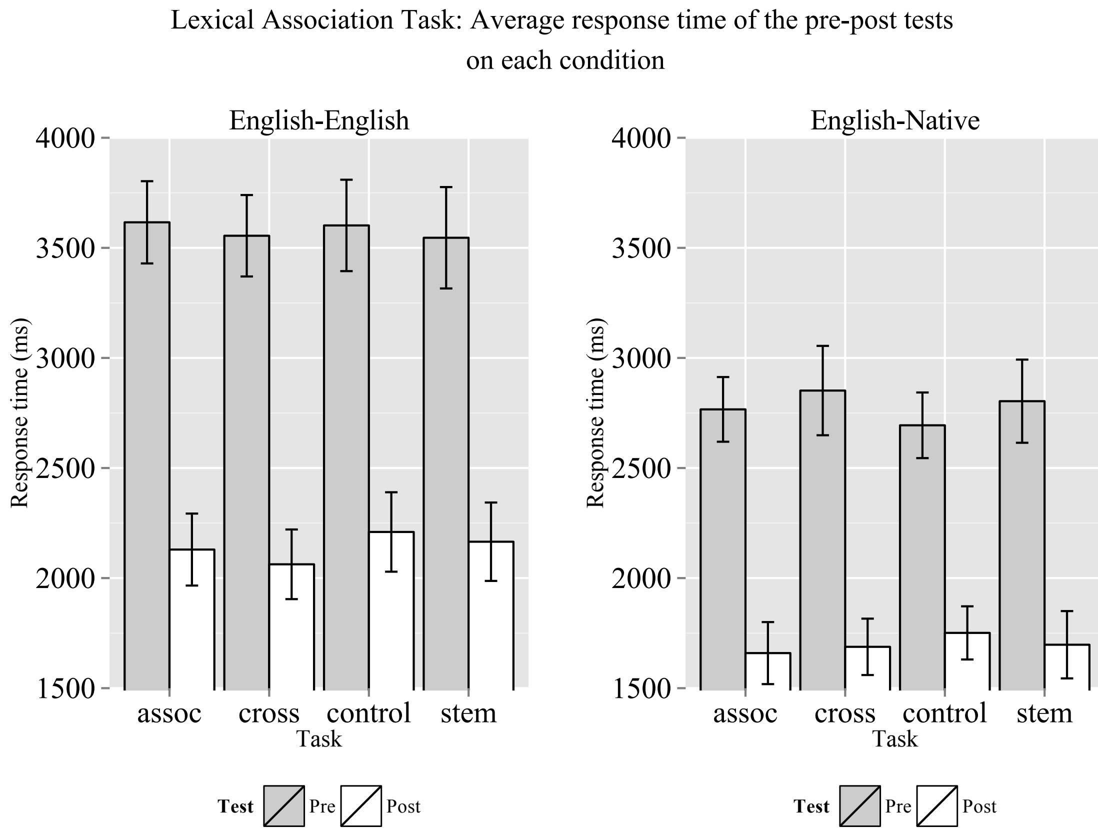


**Figure 5.12:** Lexical association task: Response time between the pre-post tests for each game condition. Error bars indicate 95% confidence intervals (CI).

post-test of the lexical association task in each game condition of both types of word pairs. The time differences were almost the same in both types. A two-way mixed (between and within subjects) ANOVA was conducted to compare the effects of the game conditions, the participants' groups on the response time differences between the pre-test and the post-test. The results in Table 6.4 indicated that there were no significant effects of the game conditions, the participants' groups, or their interactions on the time differences of either English-English or English-native languages

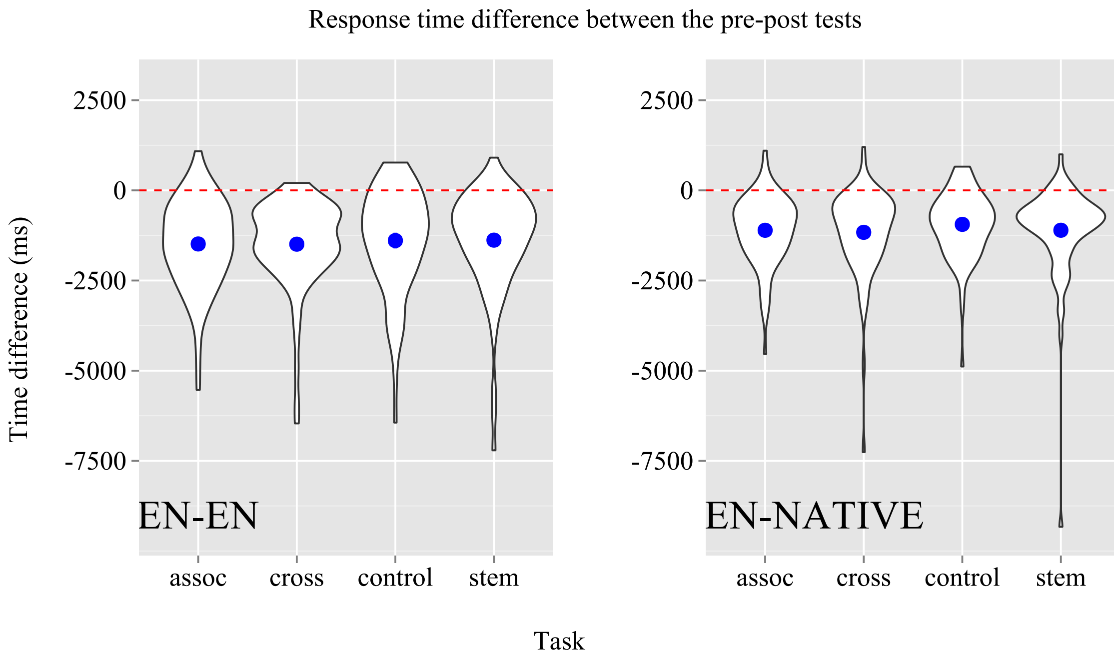


**Figure 5.13:** Lexical association task: Response time difference between the pre-post tests. Dots and lines indicate means and 95% confidence intervals of each game condition.

word pairs.

**Table 5.5**
ANOVA results: Response time difference of Lexical association task

| **Variable** | | ***F*-Test** | ***p*-value** |
|---|---|---|---|
| English-English: | Conditions | $F(3, 219) = 0.86$ | .46 |
| | Groups | $F(3, 73) = 1.01$ | .39 |
| | Interaction | $F(9, 219) = 1.51$ | .15 |
| English-Native: | Conditions | $F(3, 219) = 1.04$ | .38 |
| | Groups | $F(3, 73) = 0.95$ | .42 |
| | Interaction | $F(9, 219) = 0.65$ | .76 |

Overall, the results from the lexical association task suggest that the effect of the word games on the English-English word pairs was established, and the most powerful training game that efficiently assisted the lexical access and recognitional process was the free association task.

### 5.3.4 Anagram Solving Task

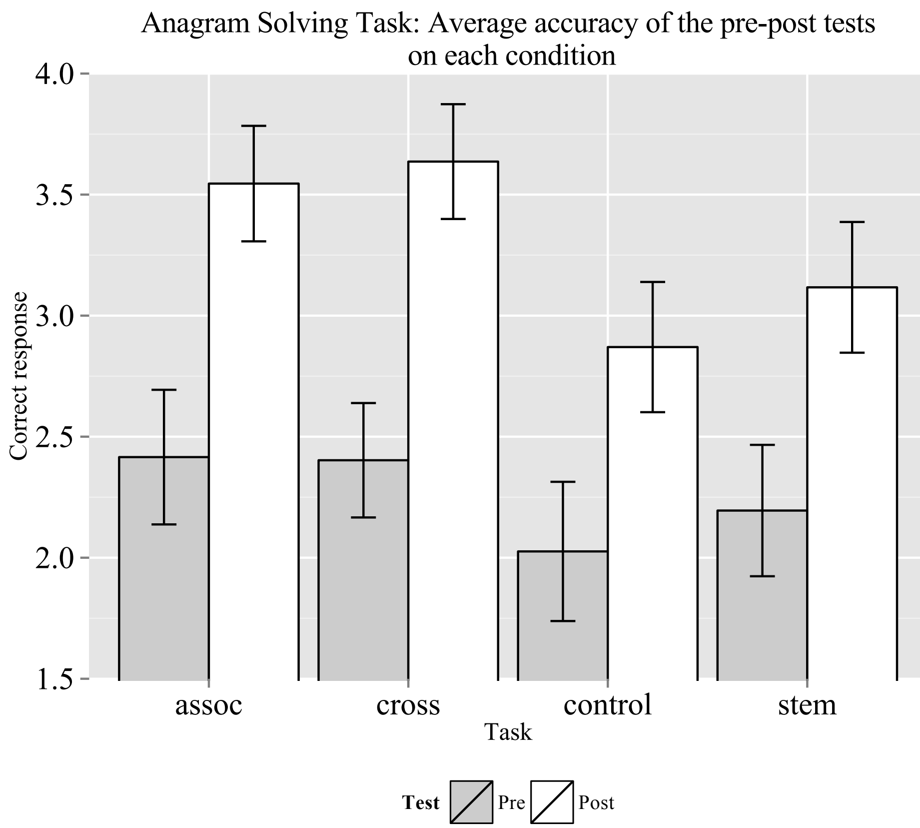


**Figure 5.14:** Anagram solving task: Accuracy score between the pre-post tests for each training condition. Error bars indicate 95% confidence intervals (CI).

The average accuracy of the anagram solving task significantly increased from 9.04 $\pm$ 3.8 to 13.17 $\pm$ 4.37 ($Z = -7.08$, $p < .001$) between the pre-post tests. Figure 5.14 reveals that the accuracy means of each game condition are similar. Figure

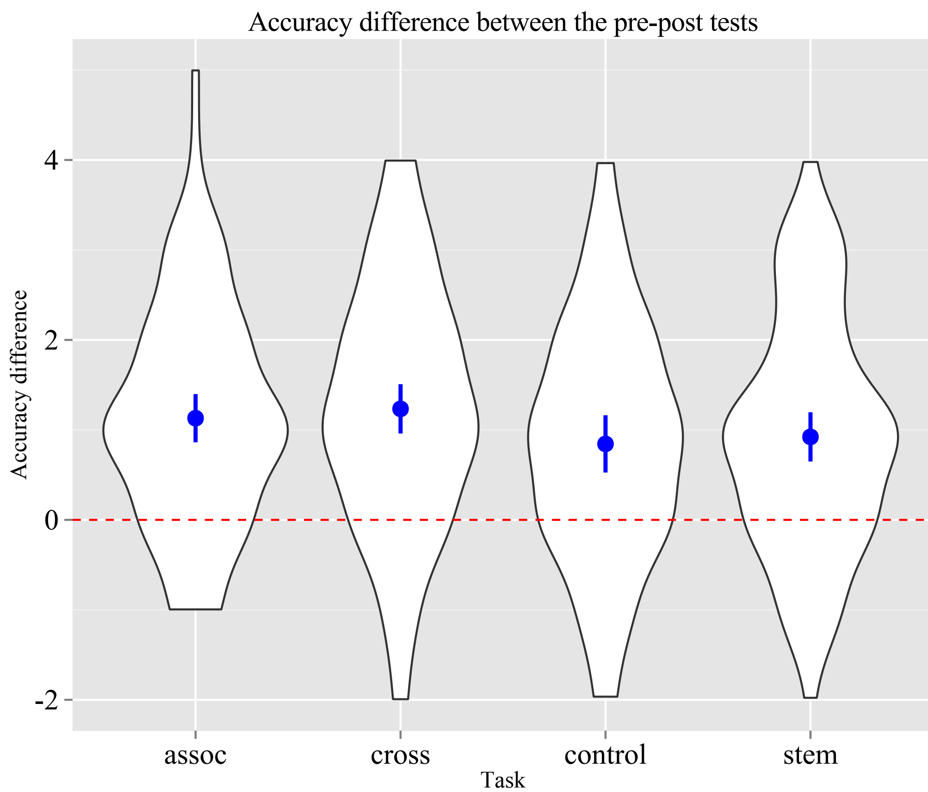


**Figure 5.15:** Anagram solving task: Accuracy score difference between the pre-post tests. Dots and lines indicate means and 95% confidence intervals of each game condition.

5.15 shows a further analysis of the accuracy difference between the pre-post tests of each game condition in a violin plot. A two-way mixed (between and within subjects) ANOVA was conducted to compare the effects of the game conditions, the participants' groups and an interaction between these variables on the accuracy improvement. The results suggested that there were no significant effects of the game conditions ($F(3, 219) = 1.57$, $p = .2$), the participants' groups ($F(3, 73) = 0.12$, $p = .95$) and the interaction ($F(9, 219) = 0.46$, $p = .9$).

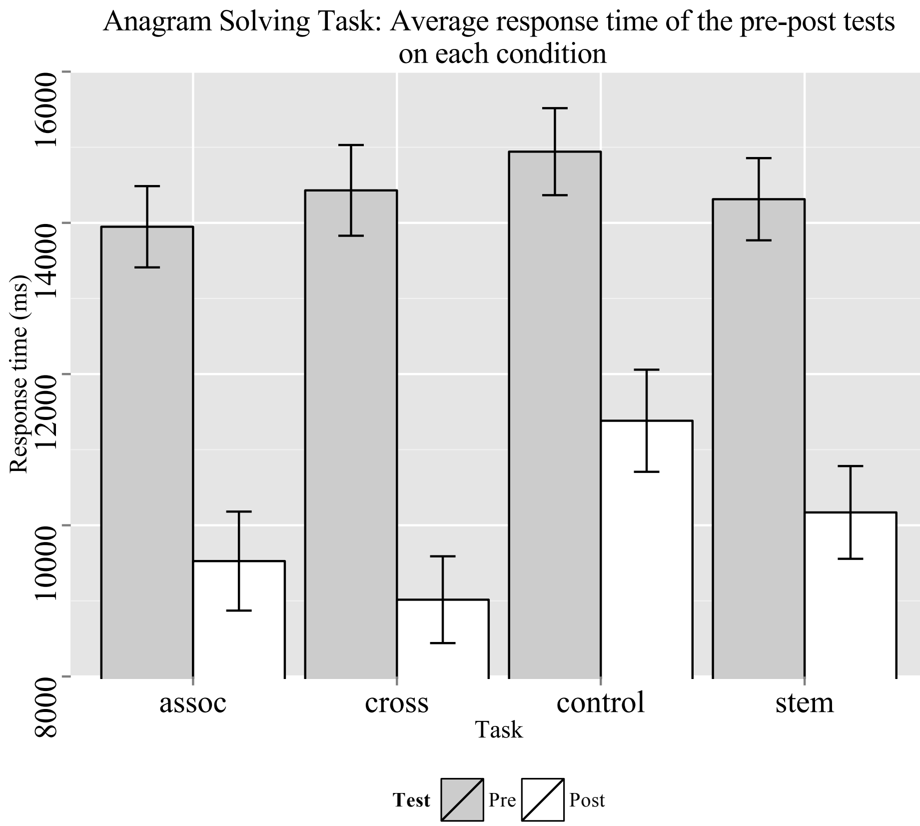


**Figure 5.16:** Anagram solving task: Response time difference between the pre-post tests for each training condition. Error bars indicate 95% confidence intervals (CI).

The response times of the anagram solving task were estimated from correct, incorrect and incomplete answers. The response times from only correct answers contained many missing values since there was no correct answer in some game conditions. The times significantly decreased from 14.41 ± 1.93 seconds to 10.02 ± 2.07 seconds between the pre-post tests ($Z = -7.53$, $p < .001$). Figure 5.16 reveals the means of response time of each training condition, and the crossword paradigm was the most effective game. Again, Figure 5.17 shows the response time difference between the

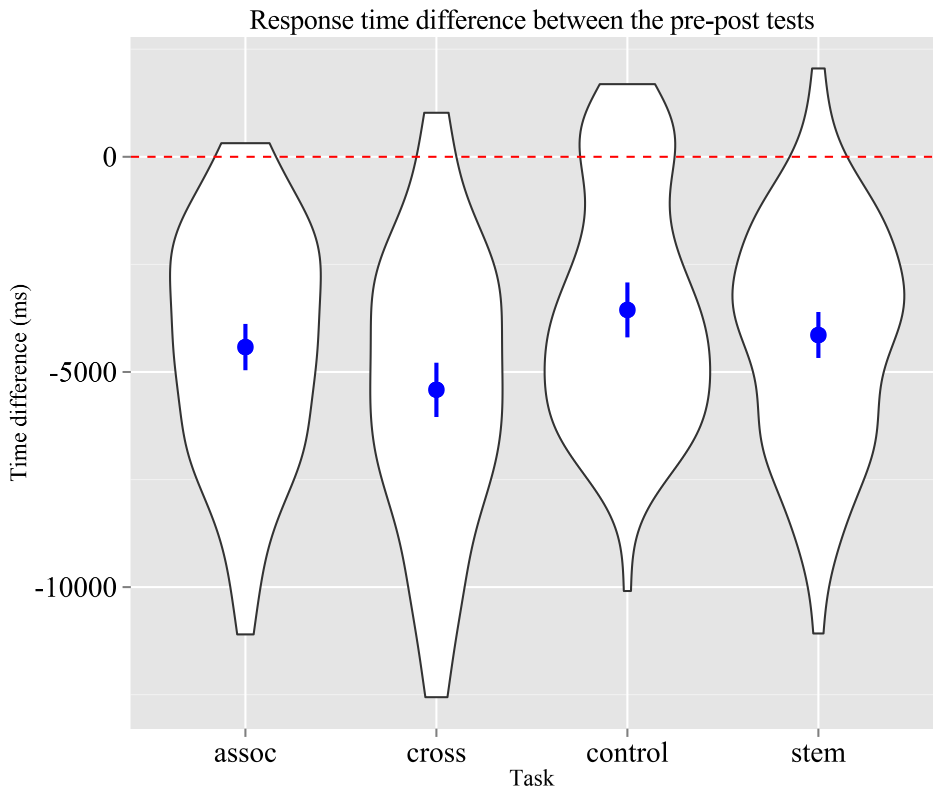


**Figure 5.17:** Anagram solving task: Response time difference between the pre-post tests. Dots and lines indicate means and 95% confidence intervals of each game condition.

pre-post tests of each game condition and the words that participants were presented in the crossword paradigm task during the training session assisted the anagram solving task performance greater than the other training conditions. A two-way mixed (between and within subjects) ANOVA was conducted to compare effects of the game conditions, the participants' groups and an interaction of them on the response time improvement. The results indicated that there was a significant effect of the game conditions on the time improvement ($F(3, 219) = 7.02$, $p < .001$). Pairwise comparisons between the game conditions using paired Wilcoxon signed-rank tests were also computed to compare training efficiency. It showed significant differences between the crossword paradigm task and the control condition ($Z = -3.29$, $p = .001$) as well as the crossword paradigm task and the word-stem completion task ($Z = -2.37$, $p = .018$). However, the effects of the participants' groups ($F(3, 73) = 0.98$, $p = .41$) and the interaction between the variables ($F(9, 219) = 1.45$, $p = .17$) were not significant.

In brief, the results suggest that there was a significant training effect on the anagram solving task and the most impressive game that was able to assist the solving performance was the crossword paradigm task.

## 5.4 Discussion

The goal of this experiment was to investigate non-native English speakers' short term learning effects of word games, including word-stem completion, free association and crossword paradigm. The assumption of this study was that after participants explored the training sessions, they would be able to improve L2 lexical decision performance and inhibit L1 translation processes. The results showed reliable progress from the pre-test to the post-test in the accuracy of the English word association task in the lexical association task and the response time of the anagram solving task. The most improved performance in the lexical association task was the free association task, whereas the most increased performance in the anagram solving task was the crossword paradigm task. The reasons that these two training tasks benefit the tests were that the lexical processes were similar. Specifically, the hypothesized route used during the lexical association task was the semantic route, which is the same as the strengthening process in the free association task; the routes that correspond to the anagram solving task were the orthographic and semantic associations, which were the routes strengthened in the crossword paradigm task.

The reason that the accuracy difference scores in the anagram solving task and the response time enhancement of the lexical association task had no substantial difference of the game conditions might be the small interval of the variables. For the anagram solving task, the total number of trials was 20 and they were divided into four different conditions. Thus, there were only five words for each training condition, which was a very small number to observe the training effect. Likewise, the limited time of the lexical association task was only 10 seconds per trial. Increasing the number of words in each training may solve these problems.

A ceiling effect was shown in bilingual word pair trials in the lexical association task. The accuracy means of these pre-test trials were almost perfect (about 85%), thus there was a little space for improvement in the post-test, and even though the accuracy decreased from the pre-test to the post-test, it was non-significant. Moreover, the results from both English-English word pairs and bilingual word pairs showed significant positive correlations between their accuracy means as well as their response times. Therefore, I was unable to conclude that the training games were able to inhibit the translation process in favor of the association route, or to establish that both processes were independent.

As a result of this study, I have learned that the response generation tasks were very difficult for non-native participants. The average number of generated words in each trial of the word stem completion task and the word association task was very low (less than four words for each target word or stem). Many participants had limited English vocabulary and poor English skills, so it was very difficult for them to generate answers. They came up with words that they knew or have seen before from prior trials, instead of associated words. For example, a participant answered "I, DONT, UNDERSTAND" to almost any target words that he saw during the training. Another person associated "BUS" with "BRIEF", perhaps because he saw the target word "BUS" during the practice session (before the training started). Some participants misspelled answers. For instance, they spelled "WIRED" instead of "WEIRD" to a target word "ODD" or "FARTER" instead of "FASTER" to a target word "QUICK". In the future, the game may be used to improve learners' word senses and as a spelling practice aid.

There was some positive feedback from participants to the study. After the experiment, some participants mentioned that they liked the study and it helped them refresh their English vocabulary. Accordingly, this study provides a basic understanding of using word games to improve second language (L2) vocabulary learning for English as a second language learners. To further develop the games for classroom purposes or to influence English proficiency, Experiment 3 was purposed to determine the game effect on comprehensive English reading tests.

# Chapter 6

# Experiment 3

The transfer of learning is the most critical objective of education and training. To be considered as a successful approach, practical tools need to be able to transfer human skills to other significant related tasks that are important for learners. Experiment 3 was proposed to investigate whether training games (crossword paradigm versus free association and stem completion) are able to help non-native English speakers improve their second language and vocabulary performance. Consequently, comprehensive English reading tests were added to this experiment in order to validate the effectiveness of the training games. In this study, participants performed both pre and post-tests. Between tests, they were taught 200 English words within a week of study via the online games. Three training conditions were examined, including a control group, a crossword group, and word stem completion and free association group, which were randomly assigned to each participant.

The online training games (the crossword paradigm, word stem completion and free association tasks) were the same as in the previous experiments. Participants who were assigned to the control group did not perform the games, but instead read 20 English online articles during a week of study. These articles selected by the experimenter, and were retrieved from news websites and English textbooks.

To further develop online games for using in a classroom, after the post-test, a user experience survey was given to participants to assess the games, the test and the website interface.

## 6.1 Hypotheses

The following hypotheses were tested in this study:

**Hypothesis 1** After one week of training with the games, participants will have a significant improvement in the English reading tests.

**Hypothesis 2** Participants who are assigned to practice with the word-stem completion and free association tasks will have a significant improvement in the English tests compared to the control group.

**Hypothesis 3** Participants who are assigned to practice with the crossword paradigm task will have a significant improvement in the English tests compared to the other training groups.

## 6.2 Method and Material

In this study, participants had to perform baseline tasks, the comprehensive English reading tests as pre-post tests and the online cognitive word games for a week. This differed from the previous two experiments in (1) the pre/post test measure; (2) the training conditions; (3) the amount of training (several sessions over a week instead of a single session) and (4) the use of a between-subject design. Each participant completed training using only one of the three training conditions for a week. The URL of the website contained their subject codes and was sent to them individually in order to track their progress. The game website was implemented using HTML, CSS, JavaScript and PHP. In addition, participants completed the baseline tasks including a symmetry span task and a reasoning task were implemented using PEBL. Two hundred English words were used in each training game and extracted from the English reading essays and questions. The study protocol was reviewed and approved by the Michigan Technological University Institutional Review Board (IRB).

### 6.2.1 Participants

Fifty-nine participants were recruited in this experiment. However, only 57 people completed all tasks. They were international students from the MTU community and undergraduate students from a university in Thailand. The participant's criteria were set up similar to the previous experiment. An additional criterion was that English was not one of official languages of participants' original countries. Their average age was 26.86 $\pm$ 4.05 years old (32 males and 25 females). Their native languages included Thai, German, Mandarin, Spanish, Persian, Arabic, Nepali and Saraiki. Eleven were undergraduate students. The experiment was separated to two sessions: a first session and a follow-up session. The first session contained the baseline tasks and the comprehensive English reading tests. It took one and a half hours and after participants completed it, they were compensated based on the minimum wage of country in which they participated. Participants in Thailand were paid 100 bath ($3) and participants in the US were paid $5. The second session was composed of the English reading tests and it took 1.5 hours. They were paid 300 bath ($11) in Thailand and $20 in the USA.

### 6.2.2 Demographic Survey

The goal of this survey was to determine cognitive factors and English proficiency of each participant that might influence English reading performance. They were asked about their personal information such as age, native language, level of education and their English experience. The questions were the same as in Appendix B. It took about five minutes to finish.

### 6.2.3 Baseline Tasks

Participants were asked to perform the symmetry span task and the reasoning task at the beginning of the study. The symmetry span task was used to measure participants' working memory ability, and the reasoning task was used to assess intelligence and reasoning ability. Both were non-verbal tasks, which were useful for assessing the abilities of non-native English speakers.

#### 6.2.3.1 Symmetry Span Task

The goal of the symmetry span task was to recall positions of red squares within a 4 x 4 matrix. Before the test, participants had to perform three practice phases. The first phase involved position recall, in which they saw red squares appearing continuously in various positions inside the matrix. Each red square appeared for 1000 ms. To recall the information, participants had to identify the red square locations by clicking at the empty matrix in the correct order. The next practice was symmetry-judgment. Participants were shown a matrix with some black squares and they had to determine whether the matrix was vertically symmetrical. The last practice combined the first two tasks. Participants were required to decide whether the matrix was vertically symmetrical and then were shown a randomly red square in a 4 x 4 matrix promptly after the judgment. They had to do these two tasks alternatively until the recall matrix appeared. The real test was similar to the last practice. There were two trials of each set size between two to five, and it took about 10 minutes to complete.

#### 6.2.3.2 Reasoning Task

Raven's progressive matrices (Raven & Court, 1998) were used to measure participant intelligence and reasoning ability in this study. The PEBL version of the Raven progressive matrices was developed based on the Matzen et al. (2010) problem sets. The types of shape transformation included 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. There was a total of 20 test problems and two practices at the beginning of the test. Participants had 5 minutes to complete all problems.

### 6.2.4 Training Tasks

One of three training conditions (the word-stem completion & free association tasks; the crossword paradigm task and the control reading task) was randomly selected for each participant. The word-stem completion and free association tasks were combined into one group in order to activate both semantic and orthographic routes, similar to the crossword paradigm task. The first condition composed of 30 game sets, 20 for the free association task and 10 for the word-stem completion task. The other conditions contained 20 sets.

#### 6.2.4.1 Free Association Task

In this task, participants were given a target word for each trial. Their goals 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 "BUS", they might answer "CAR, DRIVER, STATION". They had 30 seconds for each trial to give as many answers as possible. There was a total of 10 problems per one set and 20 sets in this task. After the time was up, the sample answers taken from Nelson et al. (1998) were shown in the screen for four seconds.

#### 6.2.4.2 Word-Stem Completion Task

The word-stem completion task is adapted from Mueller & Thanasuan (2014). In each trial, participants were given a word-stem with the first two filled letters and a blank space, such as "ST_____". Their task was to complete a word by typing the remaining letters in the blanks and answers from the given stem might be "STATION, STAR, STAY". They needed to generate as many unique words as they could in 30 seconds and there were 10 trial for each game set. There was a total of 10 game sets. When the time was up, the software showed the possible answers of the stem for four seconds. The sample answers were taken from Kucera & Francis (1967).

#### 6.2.4.3 Crossword Paradigm Task

The crossword paradigm task was originally conducted by Goldblum & Frost (1988), and was adapted by Mueller & Thanasuan (2013). In this task, each participant was given limited time to solve a series of crossword clues. Participants were shown a crossword clue and a word-pattern with two letters filled in. They then entered a guess in the blank spaces. If the answer was incorrect, the software randomly generated one more letter to the pattern. They had 30 seconds to generate a correct answer and for each game set, a total of 10 problems were given. The crossword clue-answer pairs in this study are from the same database as in Mueller & Thanasuan (2013) and Thanasuan & Mueller (2014).

#### 6.2.4.4 Control Task: Reading Articles

Reading articles in this study were taken from various sources such as English as a second language text books, New York Times and USA Today websites. There was a total of 20 articles given to participants to read for a week. Each article contained $423.25 \pm 224.20$ words in average.

### 6.2.5 English Reading Test

The purpose of English reading test use was to examine training efficiency, not to measure English proficiency. Thus, the practice essays were convenient and appropriate in this study since using a validated English test would increase the experiment's expense and all participants would have to complete the test on the same time. Six different reading essays were given to participants as the English reading tests. They were printed on paper and participants had to provide their answers directly on the test. Each essay contained roughly 300-400 words with eight to ten questions for each. They were taken from Model Test 1 and 2 of *How to Prepare for the TOEFL Test: Test of English As a Foreign Language* (Sharpe, 2001). For the pre-test, six English letters (A to F) were assigned to each essay and they were arranged into three groups (see Table 6.1) which were ABCD, CDEF and ABEF in order to balance the treatment conditions and essay difficulty. Then, one of these three groups were given to participants as the pre-test to do for an hour. In all conditions, all six essays were given to participants as the post test, in which they has one and a half hour to finish it. This design was used to reduce learning effects that might occur between the same pre-post tests.

### 6.2.6 Task Sequence

**Table 6.1**
Experiment design: Each participant was randomly assigned to one of nine groups at the beginning of the study.

| Participant group | Pre-Test | Training | Post-Test |
|---|---|---|---|
| 1 | ABCD | Word-Stem+Free | ABCDEF |
| 2 | CDEF | | |
| 3 | ABEF | | |
| 4 | ABCD | Crossword | |
| 5 | CDEF | | |
| 6 | ABEF | | |
| 7 | ABCD | Control: Reading | |
| 8 | CDEF | | |
| 9 | ABEF | | |

Participants were first requested to read and sign the consent form. They were assigned into one of nine groups showing in Table 6.1. They did the survey, the symmetry span task, the reasoning task and the English tests as the pre-test. Then, the experimenter sent an email containing game instructions and a website address to each participant individually. Participants performed the training tasks based on a group they were assigned at the beginning of the study for a week. Each training was composed of 20-30 task sets. Finally, they were asked to retake the English reading tests as the post-test, which contained the six reading essays with questions. After that, they did the post-survey. The experiment process is also shown in Figure 6.1.

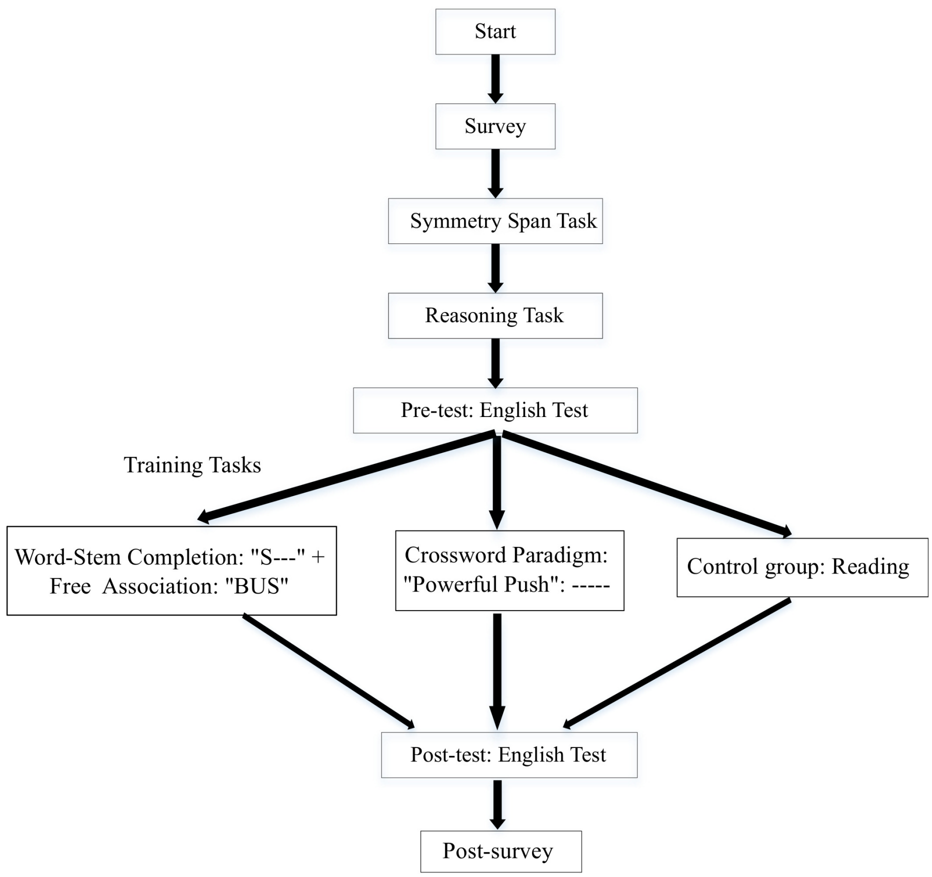


**Figure 6.1:** Experiment 3: Procedure

## 6.3 Results

**Table 6.2**
The number of participants for each group (1-9)

| Participant group | Pre-Test | Training | Participant |
|---|---|---|---|
| 1 | ABCD | | 7 |
| 2 | CDEF | Word-Stem+Free | 6 |
| 3 | ABEF | | 6 |
| 4 | ABCD | | 6 |
| 5 | CDEF | Crossword | 7 |
| 6 | ABEF | | 7 |
| 7 | ABCD | | 7 |
| 8 | CDEF | Control: Reading | 7 |
| 9 | ABEF | | 4 |

Data from 57 participants were analyzed in this study. The number of participants for each group (1-9) is shown in Table 6.2. The total number of participants for each training condition was 19 for the stem completion and free association group, 20 for the crossword paradigm group and 18 for the control (reading) group. Furthermore, the descriptive statistical data of this study is presented in Table 6.3. Most participants performed the tasks in this study very well (left-skewed).

**Table 6.3**
Descriptive results: Baseline tasks and English reading tests

| Task | | Mean ± SD | Range | Skewness | Kurtosis |
|---|---|---|---|---|---|
| Symmetry span | Accuracy (%) | 71.18 ± 22.04 | 10.71-100 | -0.83 | 3.16 |
| | Memory Span (Max:5) | 3.23 ± 1.03 | 1.5-5 | -0.08 | 1.74 |
| | Distraction: Accuracy (%) | 89.97 ± 11.87 | 42.86-100 | -1.52 | 5.73 |
| Reasoning: | Accuracy (%) | 48.3 ± 12.53 | 15-75 | -0.48 | 3.53 |
| Pre-test (4 essays) | A (Max:10) | 7.53 ± 1.68 | 3.75-10 | -0.54 | 2.61 |
| | B (Max:10) | 8.11 ± 1.43 | 3.75-10 | -1.26 | 5.53 |
| | C (Max:10) | 7.06 ± 1.99 | 3.33-10 | -0.35 | 2.3 |
| | D (Max:10) | 6.33 ± 2.03 | 1-10 | -0.6 | 3.09 |
| | E (Max:10) | 7.47 ± 1.83 | 3.75-10 | -0.55 | 2.46 |
| | F (Max:10) | 7.6 ± 2.09 | 0-10 | -1.75 | 6.69 |
| | Total (Max:40) | 29.32 ± 5.41 | 15.17-39 | -0.68 | 2.96 |
| Post-test (6 essays) | A (Max:10) | 8.25 ± 1.51 | 5-10 | -0.72 | 2.7 |
| | B (Max:10) | 7.98 ± 1.72 | 2.5-10 | -0.97 | 3.78 |
| | C (Max:10) | 7.29 ± 1.65 | 3.33-10 | -0.63 | 3.08 |
| | D (Max:10) | 6.7 ± 2.07 | 2-10 | -0.28 | 2.21 |
| | E (Max:10) | 7.37 ± 1.6 | 3.75-10 | -0.27 | 2.38 |
| | F (Max:10) | 7.54 ± 2.07 | 0-10 | -1.43 | 5.63 |
| | Total (Max:60) | 45.13 ± 7.91 | 22.1-59 | -0.99 | 3.73 |

### 6.3.1 Baseline Tasks

According to Table 6.3, most participants performed the reasoning and symmetry span tasks very well (left-skewed). The correlation between the accuracy of the symmetry span task and the accuracy of the reasoning task was .42 and significant($t(55) = 3.41$, $p = .001$). Figure 6.2 shows the correlation matrices for each game condition among the baseline tasks, the English reading tests and the training results. There

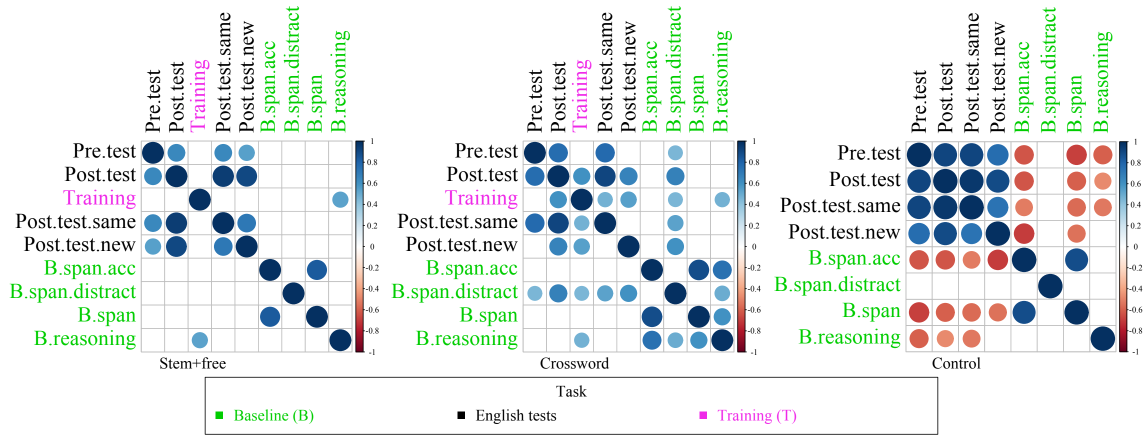


**Figure 6.2:** Correlation matrices of the training conditions: The empty spaces indicate non-significant correlations and the color scales from dark blue to dark red indicates the strength of correlations (1 to -1).

were significant negative correlations between the baseline results and the English reading tests in the control group.

### 6.3.2 Training Tasks

Participants completed 71.93 ± 39.68 (mean ± standard deviation) percent of the training tasks in average. The crossword paradigm training got the highest participation (84 ± 30.85 percent), following by the stem completion and free association training (72.11 ± 36.57 percent) and the control-reading group (58.33 ± 48.39 percent). A Microsoft Excel 2013 main dictionary was used as a spell checker for scoring answers that were generated from the word-stem completion task and the free association task. The means of generated words for each target word or stem in the word-stem and free association tasks were $4.42 \pm 1.69$ and $4.16 \pm 1.59$, respectively. The average correct answers of the crossword paradigm training were $7.46 \pm 1.43$ out of 10 per game set. Moreover, the average unique response words for each target word or stem in the free association task and the word-stem completion task were $35.4 \pm 7.17$ and $30.19 \pm 12.1$, respectively.

Figure 6.2 shows a strong correlation between the crossword training results and the post-test scores of both the same tests and the new tests, which means that the better participants performed on the games, the higher scores they achieved on the post-test. However, there was not a significant correlation between the free association and word-stem completion training results and the English reading test scores.

Furthermore, Figure 6.3 indicates average results of each training game. The means were estimated from five consecutive game sets, thus there were four groups for the free association task and the crossword paradigm task, and there were two groups for the word-stem completion game. For the crossword paradigm task, the average number of letter cues that participants needed in order to give correct responses was about 50 percent of the answer lengths, and 60 percent of the correct answers were solved on the first attempt—two letter cues presented in a pattern. An one-way within subjects Analysis of Variance (ANOVA) was conducted to compare group effects (1-5, 6-10, 11-15 and 16-20) in the free association task and the crossword

[1]The confidence intervals of a within-subject design were computed based on Morey (2008).

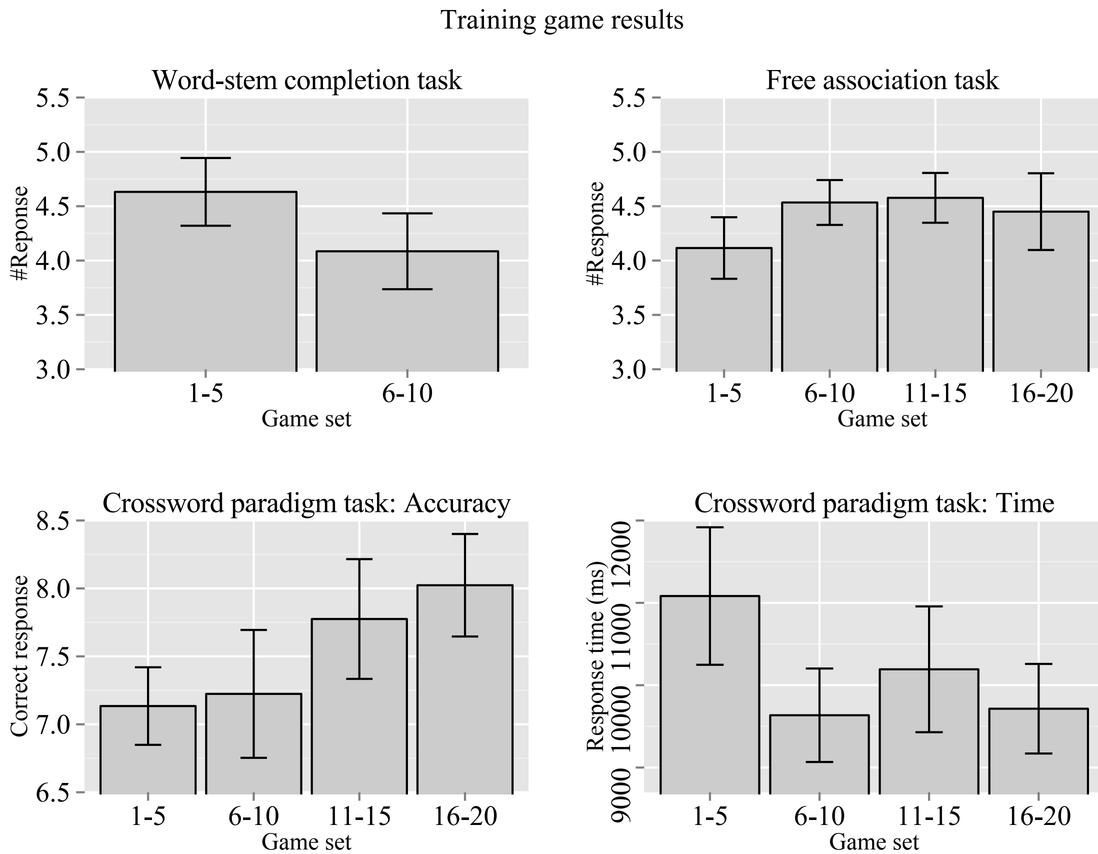


**Figure 6.3:** Training results: Plots of the word-stem completion task and the free association task show the average number of generated answers (Top). The average number of correct answers and the average response times of the crossword paradigm task are presented below. Error bars indicate 95% confidence intervals (CI)[1].

paradigm task on the training performance. The results suggested that there were the significant group effects on the accuracy ($F(3,48) = 4.57$, $p = .007$) and response time ($F(3,48) = 4.68$, $p = .006$) of the crossword paradigm task, but not on the number of generated words in the free association task ($F(3,38) = 0.39$, $p = .77$). A pairwise $t$-test also indicated significant improvement between the first and last groups of the crossword paradigm task on both accuracy ($t(16) = -3.52$, $p = .003$) and response time ($t(16) = 2.96$, $p = .009$). Similarly, a paired $t$-test was used to compare between two groups (1-5 versus 6-10) of the word-stem completion task results. It showed significant decrease from the first group to the second group ($t(14) = 2.61$, $p = .02$). Even though training words were not the same in each group, participants were able to gain benefits from the training games, especially the crossword paradigm task and the word-stem completion task.

### 6.3.3 English Reading Test

According to Table 6.3, essay B and F were the easiest tests (high left-skewed) and some test scores indicated that the results were not normal distribution. Therefore, the paired Wilcoxon signed-rank test was used to compare performance of the two tests. For the same test, participants improved significantly from 29.32 ± 5.41 in the pre-test to 30.47 ± 5.46 in the post-test ($Z = -2.65$, $p = .008$). Figure 6.4 shows the increases of mean accuracy of each training condition. Participants from the stem completion and free association group performed the tests better than the control group. Figure 6.5 reveals the accuracy score differences between the pre-post tests across the participant groups (1-9 from Table 6.1). A two-way between subject ANOVA was conducted to compare effects of the training conditions, the pre-test groups and the interaction between the conditions and the groups on the accuracy differences. The results from Table 6.4 suggested that only the interaction between the conditions and the groups was significant.

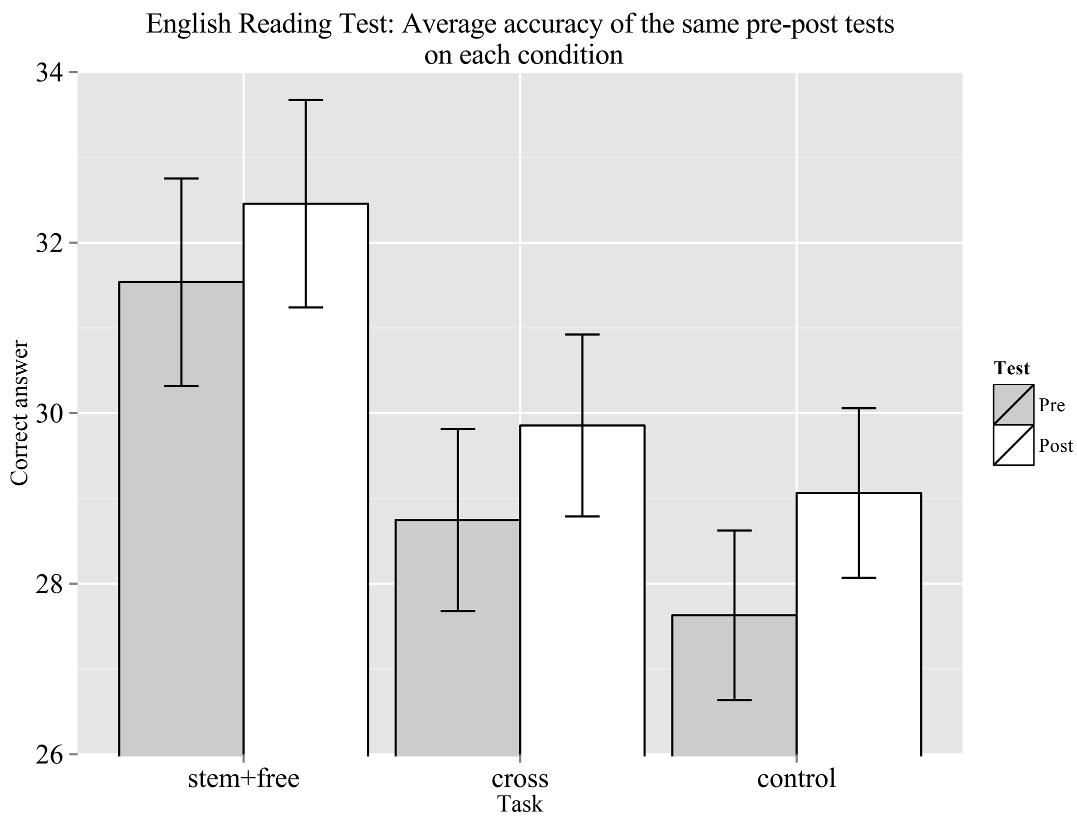


**Figure 6.4:** English reading test: Correct answers of the same pre-post tests on each game condition. Error bars indicate 95% confidence intervals (CI).

**Table 6.4**
ANOVA results: Accuracy difference of English reading tests

| **Variable** | ***F*-Test** | ***p*-value** |
|---|---|---|
| Training conditions | $F(2, 48) = 0.14$ | .87 |
| Test groups | $F(2, 48) = 2.71$ | .07 |
| Interaction | $F(4, 48) = 2.83$ | .03 |

Since the interaction effect was significant on the difference of the same pre-post scores, an one-way ANOVA was conducted to probe which game condition showed the test effect or which test group revealed the training effect. The results suggested

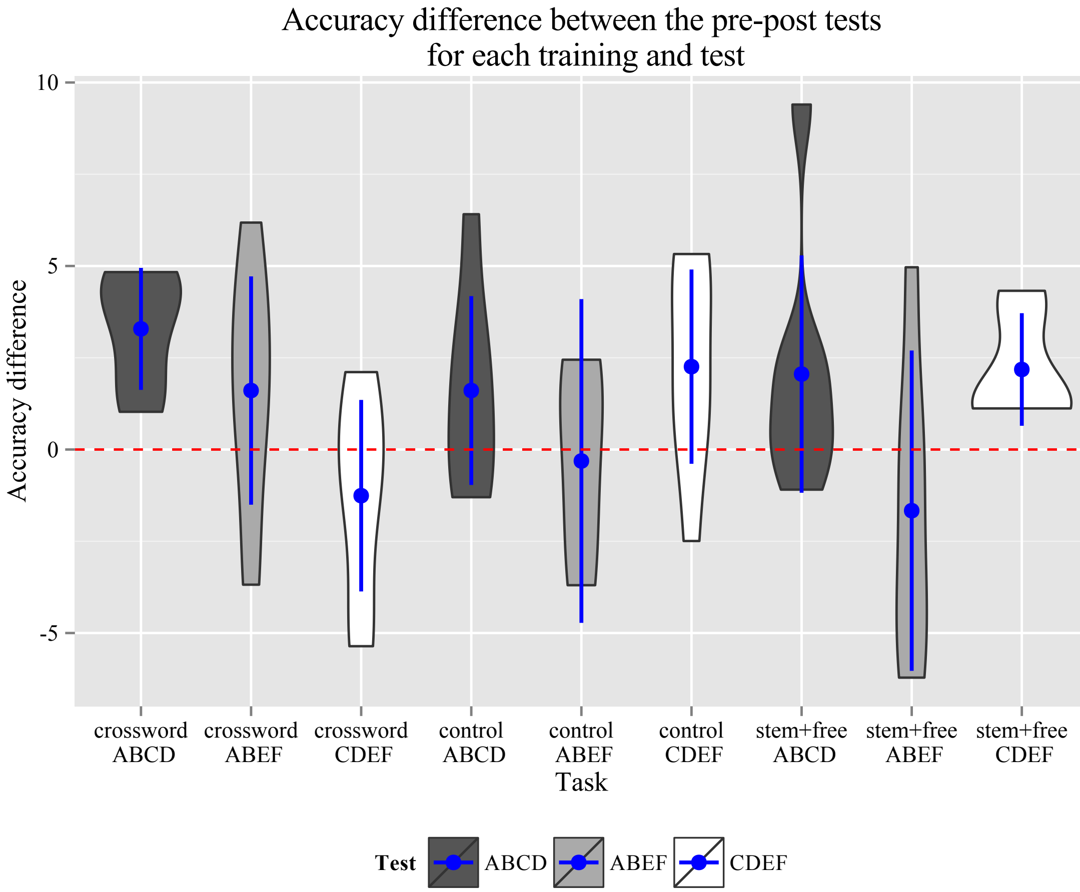


**Figure 6.5:** English reading test: Accuracy differences of the same pre-post tests on each game condition. Dots and lines indicate means and 95% confidence intervals.

that there was a significant test effect on the score difference in the crossword training group ($F(2, 17) = 4.6$, $p = .03$). Again, there was a reliable training effect on the score difference in the CDEF test group ($F(2, 17) = 4.36$, $p = .03$), but it was a difference between the crossword group and the stem completion plus free association group.

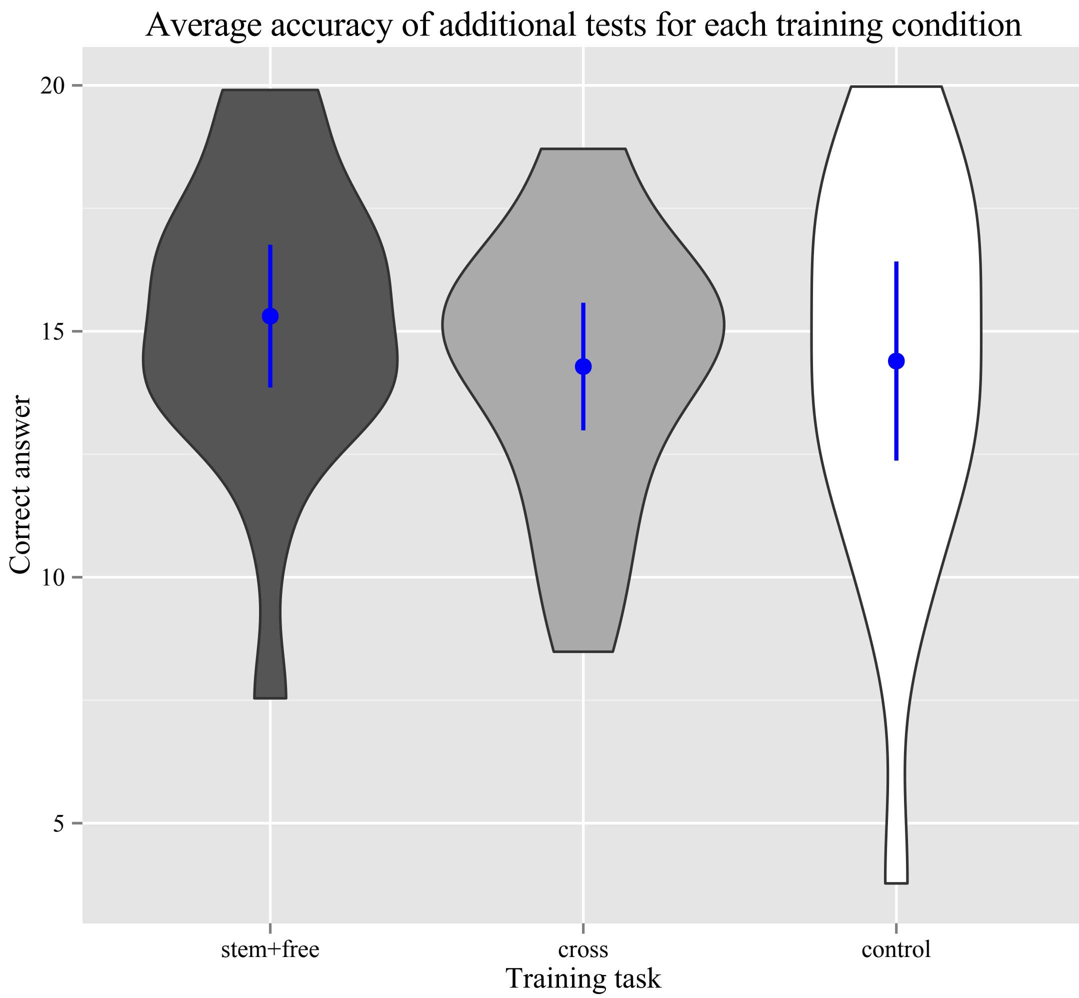


**Figure 6.6:** English reading test: Accuracy of additional tests on each game condition. Dots and lines indicate means and 95% confidence intervals.

Figure 6.6 indicates the new test scores on each training condition. Effects of the game conditions, the test groups and their interaction on the additional test scores were analyzed using a two-way ANOVA, which is shown in Table 6.5. However, there was a significant effect of the test group on the additional test. This again indicates that some tests were harder than others. Thus, a post-hoc Tukey's Honest Significant

Difference (HSD) test was conducted to compare between each two test groups. The outputs showed that only the groups with the additional tests CD and AB were significantly different from each other ($Z = -2.58$, $p$= .01).

**Table 6.5**
ANOVA results: Accuracy scores of additional English reading tests

| **Variable** | ***F*-Test** | ***p*-value** |
|---|---|---|
| Training conditions | $F(2, 48) = 0.63$ | .54 |
| Test groups | $F(2, 48) = 5.12$ | .01 |
| Interaction | $F(4, 48) = 0.71$ | .59 |

According to the training results, some participants fail to do the training tasks. They performed less than 50 percent of the assigned tasks, which may affect the test performance. Thus, the same two way ANOVA was conducted to explore the impact of training engagement. The participants who did less than 50 percent of all training tasks were removed from the analysis. However, the ANOVA output showed that there were not significant effects of either the game conditions ($F(2, 31) = 0.36$, $p = .7$) or the test groups ($F(2, 31) = 2.31$, $p = .12$). The interaction between the conditions and the groups was still well founded ($F(4, 31) = 3.77$, $p = .01$). Therefore, the overall results suggest that there was not a significant effect of the training games on the comprehensive English reading tests.

## 6.4 User Experience Survey

The goals of this survey were to evaluate how motivating and enjoyable the game and website was to use in reality along five components: fulfillment, usefulness, enjoyment, errors and positive emotions, and to validate the English reading tests. The survey was given to participants after the post-test of the experiment. The results may be useful as a design recommendation for the games and the website in the future, or to understand general attitudes toward the word games which may affect their performances.

The survey was measured using a Likert scale from 1-5 (strongly disagree-strongly agree) and short comments. Both reading and game post surveys are shown in Appendix C. The results from the survey are presented in three categories: training feedback, English reading test feedback, and website interface and other problems.

### 6.4.1 Training Feedback

Table 6.6 summarizes statements regarding to the online tasks that participants did. Figure 6.7 and 6.8 show the participants' feedback in the online training tasks, including the crossword paradigm task, the word-stem completion and free association

**Table 6.6**
Post Survey: Training statements

| **Statement** | **Games (Crossword and Stem+Free)** | **Control(Reading)** |
|---|---|---|
| S1 | The games helped me improve my vocabulary knowledge. | The articles helped me improve my vocabulary knowledge. |
| S2 | The games helped me improve my reading comprehension. | The articles helped me improve my reading comprehension. |
| S3 | The games encouraged me to learn English. | The articles encouraged me to learn English. |
| S4 | The games encouraged me to learn English vocabulary. | The articles encouraged me to learn English vocabulary. |
| S5 | The games are too hard. | The articles are too hard. |
| S6 | The games are too easy. | The articles are too easy. |
| S7 | The words that I saw in the games are from the English Reading tests. | The words that I saw in the articles are from the English Reading tests. |
| S8 | I liked the games I played. | I liked the articles I read. |
| S9 | I liked the game interfaces (e.g. layout, color, font size, etc.) I played. | I liked the article interfaces (e.g. layout, color, font size, etc.) I read. |
| S10 | I would like to play the games again. | I would like to read the articles again. |

task and the reading task. Sixty percent of participants commented that the games helped and encouraged them to learn English vocabulary. According to the plots, the participants who performed the online crossword paradigm task had higher positive reactions towards the training more than the others. A two-way ANOVA were conducted to compare effects of the training groups, the statements and the interaction between the two variables on the assessment. The results suggest that there were the significant effects of both training groups ($F(2, 459) = 5.47$, $p = .005$) and statements ($F(9, 459) = 19.68$, $p < .001$), but not the interaction ($F(18, 459) = 1.45$, $p = .1$) on

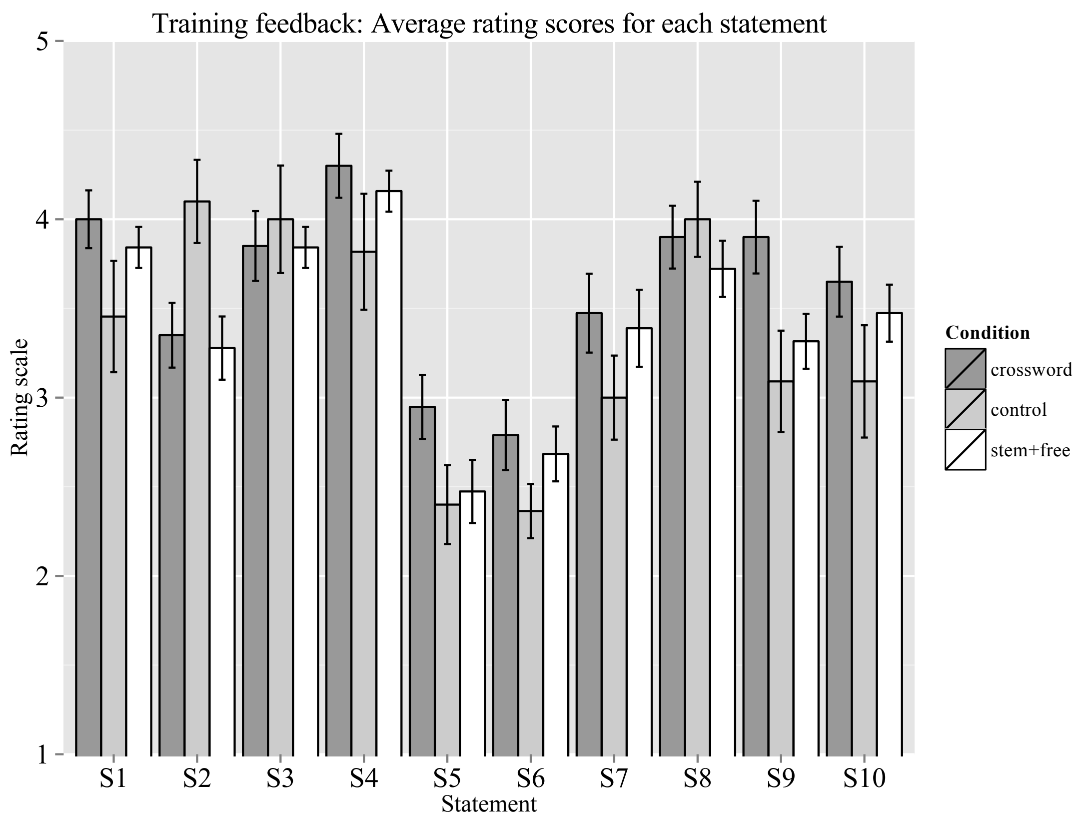


**Figure 6.7:** Post survey: Training games (average scores for each statement with error bars)

the game evaluation. A post-hoc Tukey's HSD test was applied to compare effects between the training groups. The findings show that there were significant effects of the reaction between the crossword paradigm training and the control which is the reading group ($t(195.08) = -2.4$, $p = .017$), and the crossword training and the stem completion plus free association group ($t(380.05) = -2.3$, $p = .022$).

Other feedback were also provided by participants. For example, participants from the crossword paradigm group commented that some semantic clues were unclear,

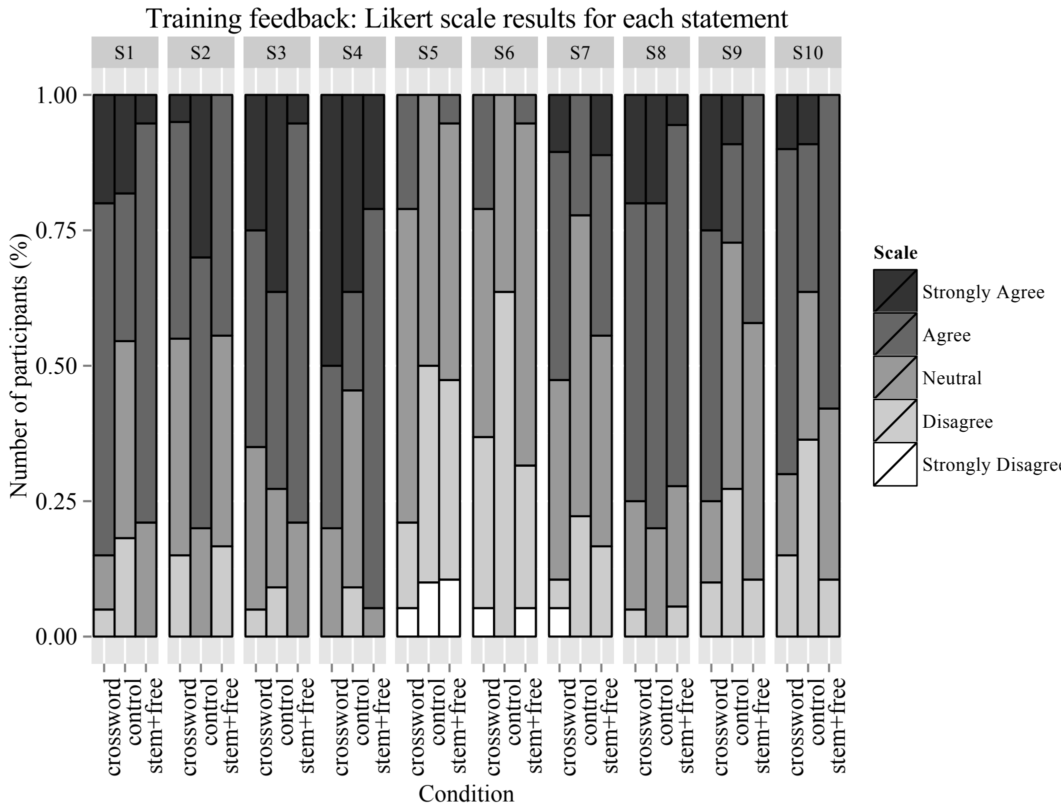


**Figure 6.8:** Post survey: Training games (Likert scale results for each statement)

and the time limited (i.e. 30 seconds) was too short for them to retrieve an answer. For the reading articles, some participants liked the news that they read. In brief, half of participants enjoyed the study and mentioned that the games motivated their English vocabulary learning.

**Table 6.7**
Post Survey: Test statement on Likest scale

| Number | Statement |
|---|---|
| S1 | The tests are appropriate for non-native English speakers (people who learn English as a second language). |
| S2 | The tests are too hard. |
| S3 | The tests are too easy. |

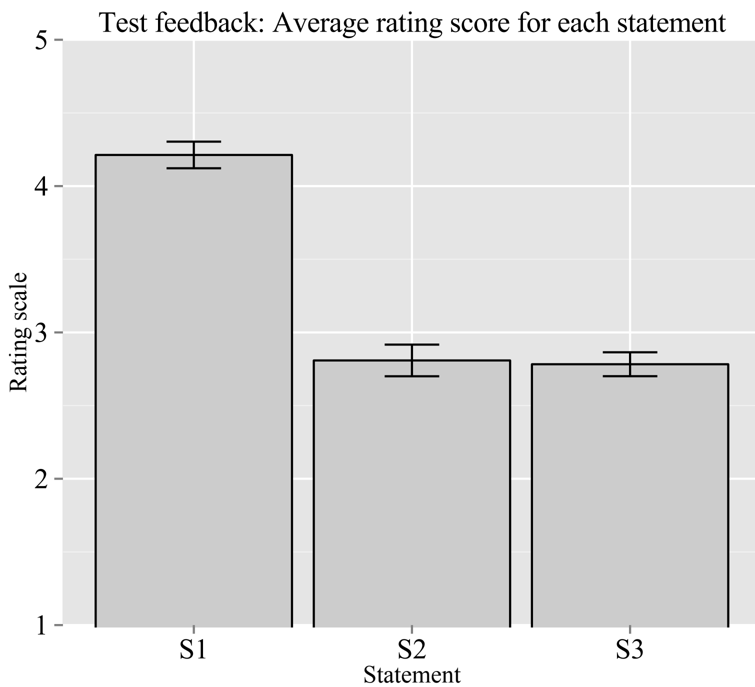


**Figure 6.9:** Post survey: English test feedback (average score for each statement with error bar)

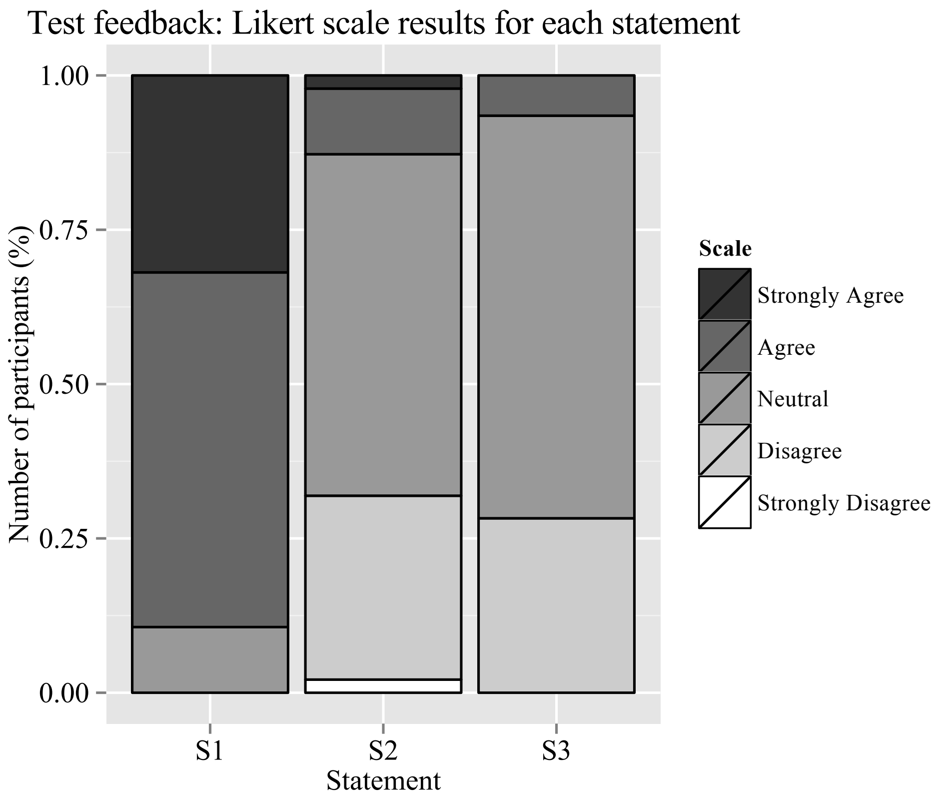


**Figure 6.10:** Post survey: English test feedback (Likert scale results for each statement)

### 6.4.2 English Reading Test Feedback

Table 6.7 shows statements of the test in the survey. Figure 6.10 and 6.9 indicate participants' evaluation on the test. Ninety percent of participants gave positive opinions for it. Some mentioned that the test was well-selected and it was not too hard or too easy.

### 6.4.3 Website Interface and Other Problems

Issues on the game interfaces were reported. For example, in the crossword paradigm task, one semantic clue overlapped and was presented on top of the answer space– primarily a technical problem. Other participants complained that when they pressed enter keys more than once, the software skipped a next trial, and they did not have a chance to answer the skipped questions. Another error was missing the last word-stem completion game set in the word-stem and free association training. However, all such problems that were reported during the study were fixed.

There was also some negative feedback from participants about the games and the study. For instance, some participants noted that there were a lot of tasks, or that they were boring, or that the interface was not colorful. Some participants commented that the experiment was not suitable for high English skill learners or students who have already studied in the USA.

## 6.5 Discussion

The aim of this study was to investigate the effect of language training games on English reading tests, which may involve skills required for using language in a real world setting. Overall, the findings did not support the hypotheses that training in these specific games would improve English language skills. Rather, it showed that with a between subject design, there was not a significant effect of the game conditions on the correct answers of either the same pre-post tests or the new post tests. Furthermore, an effect of English reading tests was detected in the analysis. Altogether, this indicates that the online training tasks, which composed of the crossword paradigm task, the stem completion task and the free association task did not help our participants improve the test scores.

Despite this finding, word games are widely used as a language study aid. They still may be effective in many situations, and there may be several reasons why I failed to find a significant impact. First possible reasons are participation and motivation. Some participants did not perform the online games. They commented on the post-survey that the games were boring and they disagreed that the games would help them improve English skills. The negative and unmotivated attitudes might impact the study. To solve this problem, increasing the number of participants or removing inattentive participants may improve the findings.

Another reason is the participant recruitment criteria. The sampling was limited only on age, education and participant's original countries, regardless of their English proficiency. Some participants were very fluent in English language, since they have been studying in the USA for a while. It seems that they did the pre-tests very well, so the training games did not affect or help them much. For a future study, participant's language ability should be concerned as a requirement and besides the English pre-post tests, a validated English proficiency test should be included in the study in order to measure participants' levels of English fluency. Moreover, the game mechanism might cause a failure to the experiment. At each trial, correct answers appeared automatically after time was up. They had been shown only for four seconds, so it was too fast to memorize or try to learn associations of all the words. The suggestion is that the time should be increased for future uses or studies.

The means of the generated words in each trial of the word-stem completion task and the free association task were very low as well as the number of unique words for each trial. The answers were distinct and inconsistent among participants. Many responses were from recent news, technology, entertainment or even from their fields of study. For example, participants majoring in science, technology, engineering, and mathematics tended to generate technical terms in particular areas such as "BIJECTION, TRIGONOMETRIC, EXPONENTIAL, LOGARITHM" related to "FUNCTION". Another type of responses is that some participants associated "FIX" to "COLDPLAY " or "SUBMARINE" to "YELLOW, BEATLES", which were from songs and music band. Furthermore, some participants were confused the word "INSTANCE" with "INSTANT", so they created wrong answers such as "READY, PROMPT".

According to the training results, it seems that the crossword paradigm task was more favorable than the others. It showed that participants were able to engage and complete all game sets as well as improve their performance in this training. That may be because the game was challenging and participants could finish each problem faster than the others. To improve the study, one of the best approaches may be redesigning the experiment to be a within-subject study and using other English test materials that involve not only comprehensive reading tests, but also vocabulary assessments. Another potential approach would be developing a training software that improves both breadth and depth of vocabulary knowledge. For example, it may be an application-based game in a tablet that allows a user to associate a word with other new words and creates a simple sentence from the words spontaneously.

# Chapter 7

# Conclusions and Future Work

Two main concepts have been investigated in this dissertation. First, I argue that second language (L2) skills are similar to other expertise skills, which means that specific deliberate practice is likely to improve the breadth (vocabulary size) and depth (fluency) of second language access. Thus, models inspired by expert decision making, especially in the context of verbal and linguistic knowledge, provided an important inspiration for this research. However, development of new models and simulations are beyond the scope of this dissertation. Second, I developed and tested cognitive word training games that are suitable for non-native English speakers in order to improve their vocabulary knowledge.

The goals of this dissertation were to investigate and to improve lexical access of non-native English speakers using the following English word games: a crossword game, a word-stem completion game and a free association game. The games were adapted from research on crossword experts who have fast and fluent access to orthographic and semantic language information. The training games attempt to strengthen these associations, but each one activates different aspects of the associations. Specifically, the free association training corresponds to the semantic route of language access, which is considered a critical mediator in proficient L2 speakers. On the other hand, the word-stem completion task tries to strengthen orthographic association directly. Finally, the crossword paradigm task attempts to strengthen both routes together.

The first experiment was designed to test the effectiveness of these methods mainly on native English speakers. The results showed that practice using the free association task produced faster knowledge access on a similar meaning comparison task. The main goal of the second experiment was similar to the first one, but was conducted with non-native English speakers. Again, the results indicated favorably significant effects of the training games on the accuracy of a lexical association task, as well as the response time of an anagram solving task. Together, these establish that such word games show promise in strengthening linguistic associations and may improve vocabulary and L2 access fluency.

The final experiment was designed to determine whether the same effects would occur after a week of extensive training on more complex and comprehensive English reading tests. The results showed non-significant effects across learning conditions in comparison to a control condition on correct answers of the reading tests. This suggests that word-game training might be very sensitive to learners' English proficiency, and the ways that the proficiency was being measured. However, the post-survey results indicated that many participants enjoyed the games, especially the crossword paradigm task, which may contrast with poorer engagement for rote memorization tasks.

In sum, these studies showed that cognitive word games were able to improve lexical memory access in several related tasks over a short period of time, but failed to demonstrate training effects for more complex English reading tests.

## 7.1 Future Directions

This research lays the groundwork for future projects that may lead to more effective L2 training.

### 7.1.1 Breadth versus Depth of Vocabulary Knowledge

The next version of the word games should be able to improve participants' lexical memory in L2 on both breadth and depth of vocabulary knowledge. The future experiment will not only focus on increasing vocabulary knowledge for less fluent L2 learners, but also enhance fluency and automaticity of word usages in English sentences in learners with more extensive L2 skills.

### 7.1.2 Matching L2 Proficiency with Appropriate Word Game Training

According to the experiment results, non-native participants, especially a group with less fluent in English, informed that they did not perform well and did not like the free association task. However, most participants preferred the crossword paradigm task over the others. That might be because the task was more challenging and spent less time to complete than the others. For a future study, the games should be assigned to participants based on their levels of L2 proficiency or ages (children or adults). This may increase learners' motivation, attention and engagement.

An adaptive training method may be another way to match appropriate word games to levels of language proficiency. The idea would be that different levels of fluency will receive different words based on word frequency. Another approach would be for a group of poorer language skills, the software will provide more cues or more time to play on each trial than the others. For example, the poorer group will receive more letter cues during the crossword paradigm session or more time to comprehend answer feedback when time is up.

### 7.1.3 Extensive Engaging Practice

Another approach to increase the training effect and to improve L2 proficiency for a future study would be extending the game training sessions and including many more vocabulary in the games. Extensive deliberate practices besides classroom activities may help L2 learners improve their language skills better than studying the language by themselves. However, the games need to be more challenging and noteworthy in order to attract learners' engagement.

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# Appendix A

# Experiment 1: Stimuli and Survey

This appendix shows the word stimuli that were used in Experiment 1 along with crossword clues, and some answers of the word-stem completion task and the free association task.

## A.1 Survey questions

1. How old are you?
2. What is your native language (primary language)?
3. If your native language is not English, how long have you been studying English language in years? (or answer NA)

4. What is your current level of education?

## A.2 Word stimuli

Forty words were taken from *Word for Students of English: A Vocabulary Series for ESL Vol. 1-7*, which have been classified into seven different levels from beginning to advanced learners: ADDRESS PIANO AUTHOR CELEBRATE LABOR CHALLENGE CRISIS ANALYZE DELICATE LEAN AIRPLANE PRINCE CULTURE CLIMATE NECESSARY DENY STRAIGHT ARTICLE DOMINATE QUARREL CHAIR STATION FREEZE DECREASE MEMORY SELFISH HARMONY PUNISH EMPIRE SCRUB COLLEGE DETERMINE SALARY ELEVATOR LUXURY QUICK PEST TRAIL NOVEL SPANK

**Table A.1**
Crossword paradigm task: Target words, orthographic cues and crossword clues

| **Target word** | **Stem** | **Crossword clue** |
|---|---|---|
| ADDRESS | AD- - - - - | STREET CITY AND ZIP CODE |
| AIRPLANE | AI- - - - - - | THE WRIGHTS' TRANSPORTATION |
| ANALYZE | AN- - - - - | EXAMINE IN DETAIL |
| ARTICLE | AR- - - - - | NEWSPAPER STORY |
| AUTHOR | AU- - - - | NOVELIST E.G. |

**Table A.1 – continued from previous page**

| Target word | Stem | Crossword clue |
|---|---|---|
| CELEBRATE | CE- - - - - - - | THROW A PARTY |
| CHAIR | CH- - - | COMMITTEE LEADER BRIEFLY |
| CHALLENGE | CH- - - - - - - | CALL INTO QUESTION |
| CLIMATE | CL- - - - - | REGIONAL WEATHER CONDITIONS |
| COLLEGE | CO- - - - - | PLACE OF STUDY |
| CRISIS | CR- - - - | EMERGENCY SITUATION |
| CULTURE | CU- - - - - | ANTHROPOLOGIST'S INTEREST |
| DECREASE | DE- - - - - - | DOWNWARD CHANGE |
| DELICATE | DE- - - - - - | EASILY BROKEN |
| DENY | DE- - | DECLARE UNTRUE |
| DETERMINE | DE- - - - - - - | FIGURE OUT |
| DOMINATE | DO- - - - - - | OVERSHADOW |
| ELEVATOR | EL- - - - - - | SKYSCRAPER NEED |
| EMPIRE | EM- - - - | _______ STATE BUILDING |
| FREEZE | FR- - - - | BECOME IMMOBILIZED |
| HARMONY | HA- - - - - | MUSIC MAJOR'S COURSE |
| LABOR | LA- - - | WORKERS COLLECTIVELY |
| LEAN | LE- - | FREE FROM FAT |
| LUXURY | LU- - - - | WHAT A FIVE-STAR HOTEL OFFERS |
| MEMORY | ME- - - - | COMPUTER CAPACITY |
| NECESSARY | NE- - - - - - - | OF VITAL IMPORTANCE |
| NOVEL | NO- - - | FICTIONAL WORK |
| PEST | PE- - | FLEA OR MOSQUITO |

**Table A.1 – continued from previous page**

| Target word | Stem | Crossword clue |
|---|---|---|
| PIANO | PI- - - | INSTRUMENT WITH 88 KEYS |
| PRINCE | PR- - - - | WILLIAM OR HARRY E.G. |
| PUNISH | PU- - - - | TAKE DISCIPLINARY ACTION |
| QUARREL | QU- - - - - | ANGRY DISPUTE |
| QUICK | QU- - - | FAST |
| SALARY | SA- - - - | WORKER'S PAY |
| SCRUB | SC- - - | WASH VERY HARD |
| SELFISH | SE- - - - - | ME-FIRST |
| SPANK | SP- - - | PUNISH A CHILD CORPORALLY |
| STATION | ST- - - - - | TRAIN STOP |
| STRAIGHT | ST- - - - - - | POKER HAND |
| TRAIL | TR- - - | HIKER'S PATH |

**Table A.2**
Word-stem completion task: Target words, orthographic cues (stem) and possible answers

| Target word | Stem | Possible answers |
|---|---|---|
| ADDRESS | AD_____ | ADDED, ADMINISTRATION, ADDITION, ADDITIONAL, ADD, ADDRESS, ADVANTAGE, ADEQUATE, ADVANCE, ADMINISTRATIVE, ADVANCED, ADVERTISING, ADVICE, ADAMS, ADOPTED |
| AIRPLANE | AI_____ | AIR, AID, AIRCRAFT, AIN, AIM, AIDS, AIMED, AIRPORT, AIMS, AIDED, AIRPLANE, AIA, AIRPLANES, AIDE, AIDING |
| ANALYZE | AN_____ | AND, AN, ANY, ANOTHER, ANYTHING, ANTI, ANSWER, ANYONE, ANALYSIS, ANNUAL, ANNOUNCED, ANODE, ANIMAL, ANCIENT, ANSWERED |
| ARTICLE | AR_____ | ARE, AROUND, AREA, AREAS, ART, ARMY, ARMS, ARM, ARTICLE, ARMED, ARTIST, ARTS, ARGUMENT, ARTISTS, ARRIVED |
| AUTHOR | AU_____ | AUDIENCE, AUTHORITY, AUGUST, AUTHOR, AUTOMOBILE, AUTHORITIES, AUTHORIZED, AUTOMATIC, AUTOMATICALLY, AUTO, AUG, AUTOMOBILES, AUTHORS, AUNT, AUSTIN |
| CELEBRATE | CE_____ | CERTAIN, CENTURY, CENTER, CENTRAL, CENT, CERTAINLY, CELLS, CELL, CENTERS, CENTURIES, CEILING, CENTS, CERTAINTY, CELLAR, CEASE |

**Table A.2 – continued from previous page**

| Target word | Stem | Possible answers |
|---|---|---|
| CHAIR | CH_____ | CHILDREN, CHURCH, CHANGE, CHILD, CHRISTIAN, CHANGES, CHANCE, CHARGE, CHIEF, CHARACTER, CHOICE, CHICAGO, CHRIST, CHARLES, CHURCHES |
| CHALLENGE | CH_____ | CHILDREN, CHURCH, CHANGE, CHILD, CHRISTIAN, CHANGES, CHANCE, CHARGE, CHIEF, CHARACTER, CHOICE, CHICAGO, CHRIST, CHARLES, CHURCHES |
| CLIMATE | CL_____ | CLASS, CLOSE, CLEAR, CLUB, CLEARLY, CLAIM, CLAY, CLOSED, CLASSES, CLAIMS, CLOTHES, CLOSELY, CLOCK, CLEAN, CLOSER |
| COLLEGE | CO_____ | COULD, COME, COURSE, COUNTRY, COMPANY, COLLEGE, COST, COURT, COMMUNITY, CONTROL, COMMON, COMPLETE, CONDITIONS, COSTS, COMMITTEE |
| CRISIS | CR_____ | CRISIS, CREATED, CROSS, CREDIT, CRITICAL, CREATE, CROWD, CREATION, CREATIVE, CRITICISM, CRY, CROSSED, CREW, CRIME, CRAZY |
| CULTURE | CU_____ | CUT, CURRENT, CUTTING, CULTURE, CULTURAL, CUBA, CURVE, CURIOUS, CUSTOMERS, CURT, CUP, CURRENTLY, CURE, CUSTOMER, CUTS |
| DECREASE | DE_____ | DEVELOPMENT, DEATH, DEPARTMENT, DEVELOPED, DEFENSE, DEAD, DEAL, DECIDED, DEGREE, DE, DETERMINED, DECISION, DEMOCRATIC, DESCRIBED, DEEP |

**Table A.2 – continued from previous page**

| Target word | Stem | Possible answers |
|---|---|---|
| DELICATE | DE_____ | DEVELOPMENT, DEATH, DEPARTMENT, DEVELOPED, DEFENSE, DEAD, DEAL, DECIDED, DEGREE, DE, DETERMINED, DECISION, DEMOCRATIC, DESCRIBED, DEEP |
| DENY | DE_____ | DEVELOPMENT, DEATH, DEPARTMENT, DEVELOPED, DEFENSE, DEAD, DEAL, DECIDED, DEGREE, DE, DETERMINED, DECISION, DEMOCRATIC, DESCRIBED, DEEP |
| DETERMINE | DE_____ | DEVELOPMENT, DEATH, DEPARTMENT, DEVELOPED, DEFENSE, DEAD, DEAL, DECIDED, DEGREE, DE, DETERMINED, DECISION, DEMOCRATIC, DESCRIBED, DEEP |
| DOMINATE | DO_____ | DO, DOWN, DOES, DON, DONE, DOOR, DOING, DOUBT, DOLLARS, DOESN, DOCTOR, DOUBLE, DOG, DOGS, DOMINANT |
| ELEVATOR | EL_____ | ELSE, ELEMENTS, ELECTION, ELECTRIC, ELECTRONIC, ELEMENT, ELECTIONS, ELSEWHERE, ELECTRICAL, ELEVEN, ELECTED, ELECTRONICS, ELABORATE, ELECTRON, ELECTRICITY |
| EMPIRE | EM_____ | EMOTIONAL, EMPLOYEES, EMPHASIS, EMPTY, EMPLOYED, EMPLOYMENT, EM, EMERGENCY, EMOTIONS, EMISSION, EMOTION, EMPLOYEE, EMPIRICAL, EMERGED, EMPEROR |
| FREEZE | FR_____ | FROM, FREE, FRONT, FRIENDS, FRENCH, FRIEND, FREEDOM, FREQUENTLY, FRANCE, FRESH, FRAME, FRANK, FRIDAY, FRIENDLY, FRANCISCO |

**Table A.2 – continued from previous page**

| Target word | Stem | Possible answers |
|---|---|---|
| HARMONY | HA_____ | HAD, HAVE, HAS, HAND, HALF, HANDS, HAVING, HARD, HAPPENED, HALL, HAIR, HARDLY, HAPPY, HADN, HANOVER |
| LABOR | LA_____ | LAST, LATER, LARGE, LAW, LAND, LATE, LABOR, LAY, LATTER, LARGER, LANGUAGE, LACK, LAWS, LADY, LAID |
| LEAN | LE_____ | LEFT, LESS, LET, LEAST, LEVEL, LEAVE, LETTER, LED, LEAD, LENGTH, LEARNED, LEADERS, LETTERS, LEADER-SHIP, LEARN |
| LUXURY | LU_____ | LUCY, LUCK, LUMBER, LUNCH, LUNCHEON, LUXURY, LUCKY, LUNG, LUNGS, LUMUMBA, LUCILLE, LUDIE, LUMI-NOUS, LUCIEN, LUGGAGE |
| MEMORY | ME_____ | ME, MEN, MEMBERS, MEANS, MEAN, MEDICAL, MEET-ING, METHOD, METHODS, MEET, MEMBER, MERELY, MET, MEANING, MEANT |
| NECESSARY | NE_____ | NEW, NEVER, NEXT, NEED, NECESSARY, NEAR, NEEDED, NEEDS, NEARLY, NEITHER, NEGRO, NEWS, NEVERTHE-LESS, NECK, NEGATIVE |
| NOVEL | NO_____ | NOT, NO, NOW, NOTHING, NORTH, NOR, NON, NORMAL, NOTE, NONE, NOTED, NOBODY, NOVEMBER, NOVEL, NO-TICE |
| PEST | PE_____ | PEOPLE, PER, PERHAPS, PERIOD, PEACE, PERSONAL, PERSON, PERSONS, PERFORMANCE, PERMIT, PERSON-NEL, PERFECT, PERMITTED, PERCENT, PERIODS |

**Table A.2 – continued from previous page**

| Target word | Stem | Possible answers |
|---|---|---|
| PIANO | PI_____ | PICTURE, PIECE, PIECES, PICKED, PICTURES, PICK, PILOT, PINK, PIKE, PIANO, PIP, PISTOL, PITTSBURGH, PILE, PITCH |
| PRINCE | PR_____ | PRESIDENT, PRESENT, PROGRAM, PROBLEM, PROBABLY, PROBLEMS, PROVIDE, PRESSURE, PROCESS, PRIVATE, PROPERTY, PRODUCTION, PROGRAMS, PROVIDED, PRESS |
| PUNISH | PU_____ | PUBLIC, PUT, PURPOSE, PURPOSES, PUBLISHED, PULLED, PUBLICATION, PULL, PURE, PUSH, PUTTING, PUSHED, PURCHASE, PULMONARY, PURELY |
| QUARREL | QU_____ | QUITE, QUESTION, QUESTIONS, QUALITY, QUICKLY, QUIET, QUICK, QUALITIES, QUIETLY, QUEEN, QUARTER, QUESTIONNAIRE, QUANTITY, QUARTERS, QUESTIONED |
| QUICK | QU_____ | QUITE, QUESTION, QUESTIONS, QUALITY, QUICKLY, QUIET, QUICK, QUALITIES, QUIETLY, QUEEN, QUARTER, QUESTIONNAIRE, QUANTITY, QUARTERS, QUESTIONED |
| SALARY | SA_____ | SAID, SAME, SAY, SAW, SAYS, SALES, SAT, SAYING, SAM, SAN, SATURDAY, SAVE, SAMPLE, SAFE, SAFETY |
| SCRUB | SC_____ | SCHOOL, SCHOOLS, SCIENCE, SCENE, SCIENTIFIC, SCALE, SCORE, SCREEN, SCOTTY, SCHEDULED, SCHEDULE, SCHOLARSHIP, SCIENTISTS, SCHEME, SCIENCES |
| SELFISH | SE_____ | SEE, SET, SECOND, SEVERAL, SERVICE, SENSE, SEEMED, SEEMS, SEEN, SELF, SEEM, SECRETARY, SECTION, SERVICES, SENT |

**Table A.2 – continued from previous page**

| Target word | Stem | Possible answers |
|---|---|---|
| SPANK | SP_____ | SPECIAL, SPACE, SPIRIT, SPRING, SPECIFIC, SPEAK, SPENT, SPEED, SPOKE, SPREAD, SPEAKING, SPIRITUAL, SPEECH, SPOT, SPEAKER |
| STATION | ST_____ | STATE, STILL, STATES, STUDY, STREET, STUDENTS, STRONG, STAGE, STARTED, STOOD, ST, STORY, START, STAND, STEP |
| STRAIGHT | ST_____ | STATE, STILL, STATES, STUDY, STREET, STUDENTS, STRONG, STAGE, STARTED, STOOD, ST, STORY, START, STAND, STEP |
| TRAIL | TR_____ | TRUE, TRAINING, TRIED, TRYING, TRADE, TRY, TRIAL, TREATMENT, TROUBLE, TRUTH, TRADITION, TREES, TRIP, TRADITIONAL, TREATED |

**Table A.3**
Free association task: Target words and associated answers

| Target word | Possible answers |
|---|---|
| ADDRESS | NAME, NUMBER, RETURN, NOTIFY |

**Table A.3 – continued from previous page**

| Target word | Possible answers |
|---|---|
| AIRPLANE | FLIGHT, STEWARDESS, FLYING, NAVIGATOR, CONTROLS, AIRCRAFT, FLY, CO-PILOT, HELICOPTER, MODEL, GLIDE, DEPART, HOBBY, PEANUTS, RESERVATION, KIT, HEIGHTS, TERMINAL, TRANSPORTATION, TRIP, AIR, DELAY, SOAR |
| ANALYZE | CRITIC, EVALUATE, CRITICAL, COMPUTE, DEFINE, PHILOSOPHER, SCIENTIFIC |
| ARTICLE | NEWSPAPER, MAGAZINE, ITEM, EDITORIAL, FEATURE, JOURNAL, PUBLICATION, ADVERTISEMENT |
| AUTHOR | WRITER, TITLE, POET, EDITOR, PUBLISHER, READER, CREATOR |
| CELEBRATE | REJOICE, TRIBUTE, BIRTHDAY, JOYOUS, FESTIVAL |
| CHAIR | TABLE, RECLINER, SEAT, STOOL, WICKER, DESK, COUCH, LOUNGE, SIT, FURNITURE, SOFA, BENCH, COMFORTABLE, SITTING, UNCOMFORTABLE, CUSHION, PATIO, COMFORT, THRONE, DIRECTOR, PORCH, LAWN, LIVING, ROCK, DENTIST, ARM, SWING, INCLINE, ROOM, ROW, DECK, DISCOMFORT, THING, WHEEL, ANTIQUE, HAMMOCK, PUT, TABLET, WOOD |
| CHALLENGE | DARE, OPPONENT, COMPETE, RISK, DARING, COMPETITION, CONQUEST, OBSTACLE, COMPLICATED, IMPOSSIBLE |
| CLIMATE | WEATHER, TEMPERATURE, ATMOSPHERE, TROPICAL |

Table A.3 – continued from previous page

| Target word | Possible answers |
|---|---|
| COLLEGE | UNIVERSITY, DEGREE, HIGH, CAMPUS, SCHOOL, EDUCATE, EDUCATION, GRADUATION, ADMISSION, GRADUATE, SCHOLARSHIP, STUDENT, JUNIOR, SEMESTER, PROFESSOR, CAREER, DORM, PROFESSIONAL, APPLICATION, FRATERNITY, PLACE, CLASS, COURSE, PROFESSION, RECOMMENDATION, SORORITY, UNDECIDED, AWAY, FACULTY, INTUITION, OPPORTUNITY, REALITY, RESPONSIBILITY, ROOMMATE, TERM, THESIS, ACHIEVEMENT, COMMUNITY, DIPLOMA, INSTRUCT, RING |
| CRISIS | IDENTITY, HOSTAGE, MISSILE, FEUD, TRAUMA |
| CULTURE | TRADITION, CUSTOM, SOCIETY, LIFESTYLE, HERITAGE, YOGURT, HISPANIC, GERM, EUROPE, LANGUAGE, LATIN, NORM |
| DECREASE | INCREASE, DIMINISH, DECLINE, REDUCE, DESCEND, DEPLETION, SHRINK |
| DELICATE | FRAGILE, PORCELAIN, CAREFUL, LACE, FRAIL, FEEBLE, BUTTERFLY |
| DENY | REFUSE, ACCEPT, REJECT, ADMIT, FORBID, PROHIBIT, CONFESS, DECLINE, RENOUNCE, REGRET, PERMIT, ACCUSE, PUNISH, ADMISSION, EXCUSE, DISPROVE, SUPPLY, REPRESS |
| DETERMINE | CALCULATE, DECIDE, EVALUATE, SET, PREDICT |
| DOMINATE | OVERPOWER, CONTROL, CONTROLS |
| ELEVATOR | ESCALATOR, STAIR, STAIRS, STAIRWAY, LOBBY, UP, LIFT, DOWN |
| EMPIRE | ROMAN, DYNASTY, KINGDOM, UMPIRE, BUILDING, BUILD |

**Table A.3 – continued from previous page**

| Target word | Possible answers |
|---|---|
| FREEZE | THAW, CHILL, DEFROST, MELT, FROZEN, SHIVER, BOIL, FRAME, SHUTTER, TAG, COLD |
| HARMONY | RAYS, MELODY, PEACE, AGREEMENT, PEACEFUL |
| LABOR | WORKER, UNION, WORK, MANAGEMENT, SLAVE, INDUSTRY, PAINTER, TOIL, FACTORY |
| LEAN | SHOULDER, TEND, CRUTCH, SWAY, TENDENCY, INCLINE, AGAINST, VEER, SLENDER |
| LUXURY | COMFORT, LIMOUSINE, YACHT, ELEGANT, HOTEL, PLEASURE, MONEY, WEALTH |
| MEMORY | REMEMBER, RECALL, REMINISCENCE, MEMORIAL, PICTURE, FORGET, REMIND, ELEPHANT, CEREMONY, MIND, RECOGNITION, BACKGROUND, GARDEN, HINDSIGHT, SAVIOR, RETAIN, THINK, ATTENTION |
| NECESSARY | URGENT, IMPORTANT, MUST, GOVERNMENT, ESSENCE, OBLIGATION, PROVISION |
| NOVEL | MYSTERY, ROMANCE, BOOK, WRITER, ROMANTIC, STORY, SPY, PLOT, FICTION, SUSPENSE, AUTHOR, CHAPTER, FAIRYTALE, PUBLICATION, DETECTIVE, POEM |
| PEST | ANNOYING, TERMITE, BOTHER, ANNOY, RODENT, FLY, ROACH, MOSQUITO, RAT, FLEA, INSECT, BULLY, SEAGULL, NOSY |
| PIANO | KEYBOARD, ORGAN, GRAND, INSTRUMENT, GUITAR, IVORY, TUNE, LESSON, HARP, PRACTICE, PLAYER, CONCERT, MUSIC, VIOLIN, FLUTE, TALENT |

**Table A.3 – continued from previous page**

| Target word | Possible answers |
|---|---|
| PRINCE | PRINCESS, FROG, ROYALTY, CASTLE, KING, PALACE |
| PUNISH | SCOLD, SPANK, DISCIPLINE, WHIP, CONDEMN, FORBID, SIN, GUILTY, PROSECUTE, REWARD, OBEY, PRISON, STRICT, THREAT, TORTURE, RENOUNCE |
| QUARREL | LOVERS, ARGUE, ARGUMENT, FIGHT, CONFLICT, FUSS |
| QUICK | SPONTANEOUS, RAPID, INSTANT, BRISK, URGENT, IMPULSE, RUSH, FAST, INSTANCE, HURRY, IMMEDIATE, BRIEF, EXPRESS, SWIFT, EASY, RESPONSE, DASH, EMERGENCY, REACTION, MICROWAVE, DART, INSTINCT, THRIFT, EASE, FURY, SOON, FOX, IMPATIENCE, SMART, SHARP, COMPULSION, DILIGENCE |
| SALARY | WAGE, INCOME, PAY, EARN, GROSS, RAISE |
| SCRUB | MOP, CLEANER, MILDEW |
| SELFISH | GREED, CONCEITED, MINE, SHARE, STINGY, CONCEIT, KEEP, RIGHTEOUSNESS, ARROGANT, TAKE |
| SPANK | PUNISH, PADDLE, PUNISHMENT, DISCIPLINE |
| STATION | SERVICE, RADIO, TRAIN, CHANNEL, GAS, CENTRAL, BUS, TELEVISION, TERMINAL, WAGON, NETWORK, RAILROAD, SHELL, SUBWAY |
| STRAIGHT | CURVE, CROOKED, LINE, BENT, CURVED, ERECT, DIRECT, LEVEL, ARROW, ANGLE, RULER, UNEVEN, FORWARD, SOBER, POISE, STIFF, AHEAD, BEND, DIRECTION, NARROW, FLAT, RIGID, WALL, TANGENT, BACKBONE, CORNER, EYEBROWS, SERIOUS, WINDING, ACCURATE, AWKWARD, PRIM, HAIR, TURN, ATTENTION, IRON, WRINKLE |

**Table A.3 – continued from previous page**

| Target word | Possible answers |
|---|---|
| TRAIL | PATH, HIKING, HIKE, TRACK, PASSAGE, FOLLOW, NATURE, CAMPAIGN, BLAZE, ROAD, RAIL, BIKE |

**Table A.4**

Lexical association task: Target words, correct answers and other word choices

| Target word | Correct answer | Word choices |
|---|---|---|
| ADDRESS | ZIPCODE | FROZEN, FAT, INCLINE, GRAND, PORCELAIN, CHANGE, FLAT, SCHOLARSHIP |
| AIRPLANE | TRANSPORTATION | FORWARD, MINE, DECLINE, WICKER, BOOK, EXAMINE, SHOULDER, WOOD |
| ANALYZE | EXAMINE | MINE, DENTIST, FIVE-STAR, TURN, STORY, SOAR, CAMPAIGN, RECLINER |
| ARTICLE | JOURNAL | FLAT, FLEA, STAIRWAY, IMMOBILIZED, MELT, NARROW, SHOULDER, REDUCE |
| AUTHOR | READER | HARD, DIPLOMA, SERIOUS, MUST, PHILOSOPHER, AWKWARD, DIPLOMA, MUST |
| CELEBRATE | FESTIVAL | DIMINISH, DECLINE, URGENT, HIGH, RUSH, DECLARE, POET, EDUCATE |

**Table A.4 – continued from previous page**

| Target word | Correct answer | Word choices |
|---|---|---|
| CHAIR | FURNITURE | STORY, RAISE, POISE, TRANSPORTATION, SHARE, MUSIC, PAY, REJOICE |
| CHALLENGE | COMPLICATED | EXPRESS, SUSPENSE, PUNISH, BOOK, SHOULDER, COMFORTABLE, DIRECTOR, EXPRESS |
| CLIMATE | TROPICAL | REMEMBER, LOBBY, RISK, REMEMBER, NAVIGATOR, CAREER, ARROW, SKYSCRAPER |
| COLLEGE | FACULTY | PHILOSOPHER, MONEY, SPONTANEOUS, UNCOMFORTABLE, DART, CASTLE, DARE, URGENT |
| CRISIS | TRAUMA | FRAME, TANGENT, PEACE, DEPLETION, AWKWARD, LOUNGE, WORKERS, STINGY |
| CULTURE | HERITAGE | FOX, BUTTERFLY, CAMPAIGN, WORKER, OVERSHADOW, BUILD, DEGREE, FEEBLE |
| DECREASE | DESCEND | SPANK, BOTHER, PASSAGE, PUNISH, WRITER, FRATERNITY, IVORY, FROG |
| DELICATE | FRAIL | HINDSIGHT, FOLLOW, ANGLE, PEANUTS, ANTIQUE, SMART, HINDSIGHT, FOLLOW |
| DENY | PERMIT | TELEVISION, INDUSTRY, POET, STEWARDESS, COMPULSION, MODEL, MYSTERY, EYEBROWS |
| DETERMINE | EVALUATE | TABLET, PRIM, ARGUMENT, DIRECT, INSTRUMENT, FUSS, BOOK, TABLET |
| DOMINATE | CONTROL | CEREMONY, COURSE, WAGE, HISPANIC, TRAUMA, POEM, FAST, NARROW |

**Table A.4 – continued from previous page**

| Target word | Correct answer | Word choices |
|---|---|---|
| ELEVATOR | DOWN | PEACE, FUSS, POKER, EVALUATE, SEAT, NUMBER, SCHOLARSHIP, TRANSPORTATION |
| EMPIRE | BUILD | BROKEN, OVERSHADOW, FAST, ORGAN, SKYSCRAPER, MUSIC, REDUCE, HINDSIGHT |
| FREEZE | SHIVER | PATIO, ANGRY, MUSIC, ROMANCE, TAKE, STATE, FLYING, CONCEIT |
| HARMONY | PEACEFUL | UNEVEN, ADMISSION, MEMORIAL, LEADER, HOTEL, PROFESSION, LOBBY, CONCEITED |
| LABOR | FACTORY | DORM, SCHOLARSHIP, COMMITTEE, TRACK, FOX, COMMUNITY, GRADUATE, FIVE-STAR |
| LEAN | SLENDER | STORY, FRAIL, TRIBUTE, THING, UNION, PLEASURE, REGIONAL, IMPOSSIBLE |
| LUXURY | PLEASURE | SMART, BRIEFLY, RECALL, WHEEL, DEFINE, RETURN, STUDENT, SKYSCRAPER |
| MEMORY | RECOGNITION | MOP, EXPRESS, CONTROLS, ACHIEVEMENT, SPONTANEOUS, DISPROVE, CURVE, CHANNEL |
| NECESSARY | OBLIGATION | STAIRS, REWARD, RETAIN, OFFERS, UNDECIDED, CONQUEST, CHILD, MANAGEMENT |
| NOVEL | CHAPTER | ACCUSE, PRINCESS, PROHIBIT, NEWSPAPER, KEEP, BECOME, DECLARE, TABLET |
| PEST | INSECT | PATH, CITY, UP, ACCEPT, WHEEL, REFUSE, WORKER, PATH |

**Table A.4 – continued from previous page**

| Target word | Correct answer | Word choices |
|---|---|---|
| PIANO | TUNE | ARROW, MYSTERY, OBEY, MOP, REFUSE, BACKBONE, DEFROST, DEPLETION |
| PRINCE | KING | EMERGENCY, COMPULSION, RAPID, SHOULDER, ATTENTION, RISK, MUST, HIKING |
| PUNISH | STRICT | INSTANCE, NAVIGATOR, NORM, CONTROLS, HAIR, STIFF, ATTENTION, FLIGHT |
| QUARREL | CONFLICT | NAVIGATOR, EASY, DASH, SOFA, STIFF, AWKWARD, ELEPHANT, HOTEL |
| QUICK | URGENT | ERECT, CAREER, SCOLD, ARROGANT, HIKING, FRAIL, CRITIC, CHILL |
| SALARY | RAISE | TRANSPORTATION, OVERSHADOW, NEWSPAPER, INSTINCT, WEATHER, DISCIPLINE, ACTION, LIFT |
| SCRUB | CLEANER | TITLE, PEACE, RUSH, STAIRWAY, SPANK, DARING, FROG, KEYBOARD |
| SELFISH | ARROGANT | AGREEMENT, ADMISSION, HURRY, PLACE, AIRCRAFT, ANGRY, MAGAZINE, TUNE |
| SPANK | DISCIPLINE | SORORITY, REFUSE, EMERGENCY, IMMOBILIZED, UNION, ERECT, REMEMBER, LATIN |
| STATION | TERMINAL | EMERGENCY, RETAIN, IMPORTANT, CORPORALLY, JOYOUS, WORK, ORGAN, FUSS |
| STRAIGHT | BEND | DIRECTOR, GRAND, FAIRYTALE, INSTRUMENT, NEWSPAPER, UNTRUE, LOVERS, BENCH |

**Table A.4 – continued from previous page**

| Target word | Correct answer | Word choices |
|---|---|---|
| TRAIL | BIKE | COUCH, HELICOPTER, FRAIL, PRINCESS, REJECT, ARGUE, HAMMOCK, COUCH |

# Appendix B

# Experiment 2: Stimuli and Survey

This appendix shows the word stimuli that were used in Experiment 2 along with crossword clues, and some answers of the word-stem completion task and the free association task.

## B.1 Survey questions

1. How old are you?

2. What is your gender?

3. What is your native language (primary language)?

4. If your native language is not English, how long have you been studying English language in years? (or answer NA)

5. Have you ever taken an English proficiency test such as TOEFL or IELTS?

6. If you have taken an English proficiency test, what is it? And what is your score? (or answer NA)

7. How long have you stayed or studied in the USA?

8. What basic English skills do you usually use? (You can choose more than one): Listening, Reading, Writing, Speaking

9. What is your current level of education?

10. What is your major?

## B.2 Word stimuli

Sixty-four words were taken from *Word for Students of English: A Vocabulary Series for ESL Vol. 1-7*, which have been classified into seven different levels from beginning to advanced learners: ADDRESS ANALYZE AUTHOR CELEBRATE

CHALLENGE CRISIS DELICATE DIRECT FAKE JOURNAL LABOR LEAN PIANO PROPER ROUGH STANDARD AIRPLANE ARTICLE CLIMATE CULTURE DENY DOMINATE FASHION LAWN MAGIC NECESSARY ODD POLICY PRINCE QUARREL SCREEN STRAIGHT BUTTON CHAIR COMEDY DECREASE EMPIRE FREEZE GARBAGE HARMONY MEMORY PUNISH RECIPE SCRUB SELFISH STATION TICKET WAITER BRIEF CHIEF COLLEGE DETERMINE ELEVATOR EXCHANGE INNOCENT LUXURY NOVEL PEST PREJUDICE QUICK SALARY SPANK TRAIL UNIFORM

**Table B.1**
Lexical association task: Target words, English (correct and incorrect associations) and Thai (correct and incorrect translations)

| Target word | English: Correct | English: Incorrect | Thai: Correct | Thai: Incorrect |
|---|---|---|---|---|
| ADDRESS | HOUSE | FAT | ที่อยู่ | อ้วน |
| AIRPLANE | DEPART | APPLAUSE | เครื่องบิน | การแสดงการสรรเสริญ |
| ANALYZE | EVALUATE | BROKEN | วิเคราะห์ | แตกสลาย |
| ARTICLE | MAGAZINE | COUGH | บทความ | การไอ |
| AUTHOR | PUBLISHER | AWKWARD | นักเขียน | อึดอัด |
| BRIEF | OUTLINE | FOOT | โดยย่อ | เท้า |
| BUTTON | ZIPPER | CURIOUS | ปุ่ม | อยากรู้อยากเห็น |
| CELEBRATE | BIRTHDAY | FOX | เฉลิมฉลอง | สุนัขจิ้งจอก |
| CHAIR | COUCH | MEET | เก้าอี้ | ประชุม |
| CHALLENGE | COMPETITION | PUNISH | ท้าทาย | ลงโทษ |

**Table B.1 – continued from previous page**

| Target word | English: Correct | English: Incorrect | Thai: Correct | Thai: Incorrect |
|---|---|---|---|---|
| CLIMATE | WEATHER | TRAIN | อากาศ | รถไฟ |
| COLLEGE | CAMPUS | TEMPT | วิทยาลัย | ล่อใจ |
| CRISIS | HOSTAGE | SHOULDER | ฉุกเฉิน | ไหล่ |
| CULTURE | CUSTOM | WAR | วัฒนธรรม | สงคราม |
| DECREASE | REDUCE | STIR | ลดลง | คนให้เข้ากัน |
| DELICATE | CAREFUL | SHOULDER | อย่างละเอียดอ่อน | ไหล่ |
| DENY | REJECT | STREET | ปฏิเสธ | ถนน |
| DETERMINE | DECIDE | ADDRESS | กำหนด | ที่อยู่ |
| DIRECT | FOCUS | CHECK | โดยตรง | ตรวจสอบ |
| DOMINATE | RULE | EMPLOYEE | ปกครอง | ลูกจ้าง |
| ELEVATOR | STAIRS | NOUN | ลิฟท์ | นาม |
| EMPIRE | KINGDOM | EXTREME | อาณาจักร | ที่สุด |
| FREEZE | CHILL | THINK | หยุด | คิดว่า |
| HARMONY | MELODY | IMITATE | ความสามัคคี | เลียนแบบ |
| LABOR | WORKER | ELEPHANT | แรงงาน | ช้าง |
| LEAN | TENDENCY | IMPOSSIBLE | ผอม | เป็นไปไม่ได้ |
| LUXURY | YACHT | MASTER | หรูหรา | ผู้เชี่ยวชาญ |
| MEMORY | FORGET | NEIGHBOR | ความทรงจำ | เพื่อนบ้าน |
| NECESSARY | IMPORTANT | EXPLODE | จำเป็น | ระเบิด |
| NOVEL | STORY | TOOL | นิยาย | เครื่องมือ |
| ODD | EVEN | IMPORTANT | แปลก | สิ่งสำคัญ |
| PEST | MOSQUITO | DAY | รบกวน | วัน |

**Table B.1 – continued from previous page**

| Target word | English: Correct | English: Incorrect | Thai: Correct | Thai: Incorrect |
|---|---|---|---|---|
| PIANO | INSTRUMENT | MYSTERY | เปียโน | ลึกลับ |
| PRINCE | PALACE | BRUSH | เจ้าชาย | แปรง |
| PUNISH | DISCIPLINE | TERRIBLE | ลงโทษ | น่ากลัว |
| QUARREL | ARGUE | PLATE | การทะเลาะ | จาน |
| QUICK | FAST | MEASURE | รวดเร็ว | ขนาด |
| SALARY | INCOME | PARCEL | เงินเดือน | พัสดุ |
| SCRUB | MOP | HEADACHE | การขัดถู | มีอาการปวดศีรษะ |
| SELFISH | GREED | MINUTE | เห็นแก่ตัว | ระยะเวลาอันสั้น |
| SPANK | PUNISH | LAWYER | ลงโทษ | ทนายความ |
| STATION | GAS | DISAGREE | สถานี | ไม่เห็นด้วย |
| STRAIGHT | RULER | DISREGARD | ตรงไปตรงมา | ความไม่เอาใจใส่ |
| TRAIL | HIKE | ACCOUNT | ทางเดิน | บัญชี |

**Table B.2**
Lexical association task: Target words, English (correct and incorrect associations) and Chinese (correct and incorrect translations)

| Target word | English: Correct | English: Incorrect | Chinese: Correct | Chinese: Incorrect |
|---|---|---|---|---|
| ADDRESS | HOUSE | FAT | 地址 | 肥胖的 |
| AIRPLANE | DEPART | APPLAUSE | 飞机 | 鼓掌 |
| ANALYZE | EVALUATE | BROKEN | 分析 | 破碎 |
| ARTICLE | MAGAZINE | COUGH | 文章 | 咳嗽 |
| AUTHOR | PUBLISHER | AWKWARD | 作者 | 笨拙的 |
| BRIEF | OUTLINE | FOOT | 简短 | 脚 |
| BUTTON | ZIPPER | CURIOUS | 按钮 | 好奇 |
| CELEBRATE | BIRTHDAY | FOX | 庆祝 | 狐狸 |
| CHAIR | COUCH | MEET | 椅子 | 遇见 |
| CHALLENGE | COMPETITION | PUNISH | 挑战 | 惩罚 |
| CLIMATE | WEATHER | TRAIN | 气候 | 火车 |
| COLLEGE | CAMPUS | TEMPT | 大学 | 诱惑 |
| CRISIS | HOSTAGE | SHOULDER | 危机 | 肩膀 |
| CULTURE | CUSTOM | WAR | 文化 | 战争 |
| DECREASE | REDUCE | STIR | 减少 | 搅拌 |
| DELICATE | CAREFUL | SHOULDER | 精巧的 | 肩膀 |
| DENY | REJECT | STREET | 否定 | 街道 |
| DETERMINE | DECIDE | ADDRESS | 决定 | 地址 |
| DIRECT | FOCUS | CHECK | 直接 | 检查 |
| DOMINATE | RULE | EMPLOYEE | 控制 | 雇员 |

Table B.2 – continued from previous page

| Target word | English: Correct | English: Incorrect | Chinese: Correct | Chinese: Incorrect |
|---|---|---|---|---|
| ELEVATOR | STAIRS | NOUN | 电梯 | 名词 |
| EMPIRE | KINGDOM | EXTREME | 帝国 | 极端 |
| FREEZE | CHILL | THINK | 冻结 | 想起 |
| HARMONY | MELODY | IMITATE | 和睦 | 模仿 |
| LABOR | WORKER | ELEPHANT | 劳工 | 大象 |
| LEAN | TENDENCY | IMPOSSIBLE | 瘦的 | 不可能 |
| LUXURY | YACHT | MASTER | 奢侈的 | 精通 |
| MEMORY | FORGET | NEIGHBOR | 记忆 | 邻居 |
| NECESSARY | IMPORTANT | EXPLODE | 必需 | 爆炸 |
| NOVEL | STORY | TOOL | 小说 | 工具 |
| ODD | EVEN | IMPORTANT | 古怪的 | 重要的 |
| PEST | MOSQUITO | DAY | 害虫 | 一天 |
| PIANO | INSTRUMENT | MYSTERY | 钢琴 | 神秘的 |
| PRINCE | PALACE | BRUSH | 王子 | 刷子 |
| PUNISH | DISCIPLINE | TERRIBLE | 惩罚 | 可怕 |
| QUARREL | ARGUE | PLATE | 吵架 | 盘子 |
| QUICK | FAST | MEASURE | 迅速的 | 测量 |
| SALARY | INCOME | PARCEL | 薪水 | 包裹 |
| SCRUB | MOP | HEADACHE | 擦洗 | 头痛 |
| SELFISH | GREED | MINUTE | 自私 | 分钟 |
| SPANK | PUNISH | LAWYER | 拍打 | 律师 |
| STATION | GAS | DISAGREE | 车站 | 不同意 |

Table B.2 – continued from previous page

| Target word | English: Correct | English: Incorrect | Chinese: Correct | Chinese: Incorrect |
|---|---|---|---|---|
| STRAIGHT | RULER | DISREGARD | 笔直的 | 忽视 |
| TRAIL | HIKE | ACCOUNT | 小径 | 账户 |

**Table B.3**

Anagram solving task: Target words and semantic clues

| Target word | Semantic clue |
|---|---|
| FAKE | Unreal |
| JOURNAL | Diary |
| LAWN | Grass in front of a home |
| PROPER | Suitable |
| ROUGH | Approximate |
| FASHION | Style |
| MAGIC | Wizard's skill |
| POLICY | Set of rules |
| SCREEN | TV display |
| STANDARD | Comparison basis |
| COMEDY | Humor |

**Table B.3 – continued from previous page**

| Target word | Semantic clue |
|---|---|
| GARBAGE | Trash |
| RECIPE | Kitchen reading |
| TICKET | Result of a parking violation |
| WAITER | Server as in a restaurant |
| CHIEF | Person in highest authority |
| EXCHANGE | Switch |
| INNOCENT | Undeserving of punishment |
| PREJUDICE | Unreasonable bias |
| UNIFORM | Always the same |

**Table B.4**

Crossword paradigm task: Target words, orthographic cues and crossword clues

| Target word | Stem | Crossword clue |
|---|---|---|
| ADDRESS | AD- - - - - | STREET CITY AND ZIP CODE |
| AIRPLANE | AI- - - - - - | THE WRIGHTS' TRANSPORTATION |
| ANALYZE | AN- - - - - | EXAMINE IN DETAIL |
| ARTICLE | AR- - - - - | NEWSPAPER STORY |
| AUTHOR | AU- - - - | NOVELIST E.G. |

**Table B.4 – continued from previous page**

| Target word | Stem | Crossword clue |
|---|---|---|
| BRIEF | BR- - - | SHORT |
| BUTTON | BU- - - - | CIRCLE ON A SHIRT |
| CELEBRATE | CE- - - - - - - | THROW A PARTY |
| CHAIR | CH- - - | COMMITTEE LEADER BRIEFLY |
| CHALLENGE | CH- - - - - - - | CALL INTO QUESTION |
| CHIEF | CH- - - | FIRE DEPARTMENT HEAD |
| CLIMATE | CL- - - - - | REGIONAL WEATHER CONDITIONS |
| COLLEGE | CO- - - - - | PLACE OF STUDY |
| COMEDY | CO- - - - | FUNNY BUSINESS |
| CRISIS | CR- - - - | EMERGENCY SITUATION |
| CULTURE | CU- - - - - | ANTHROPOLOGIST'S INTEREST |
| DECREASE | DE- - - - - - | DOWNWARD CHANGE |
| DELICATE | DE- - - - - - | EASILY BROKEN |
| DENY | DE- - | DECLARE UNTRUE |
| DETERMINE | DE- - - - - - - | FIGURE OUT |
| DIRECT | DI- - - - | STRAIGHTFORWARD |
| DOMINATE | DO- - - - - - | OVERSHADOW |
| ELEVATOR | EL- - - - - - | SKYSCRAPER NEED |
| EMPIRE | EM- - - - | _____ STATE BUILDING |
| EXCHANGE | EX- - - - - - | TRADE |
| FAKE | FA- - | NOT GENUINE |
| FASHION | FA- - - - - | KIND OF MODEL |
| FREEZE | FR- - - - | BECOME IMMOBILIZED |

**Table B.4 – continued from previous page**

| Target word | Stem | Crossword clue |
|---|---|---|
| GARBAGE | GA- - - - - | WHAT'S AT YOUR DISPOSAL? |
| HARMONY | HA- - - - - | MUSIC MAJOR'S COURSE |
| INNOCENT | IN- - - - - - | NOT GUILTY |
| JOURNAL | JO- - - - - | PERSONAL WRITINGS |
| LABOR | LA- - - | WORKERS COLLECTIVELY |
| LAWN | LA- - | MOWING SITE |
| LEAN | LE- - | FREE FROM FAT |
| LUXURY | LU- - - - | WHAT A FIVE-STAR HOTEL OFFERS |
| MAGIC | MA- - - | ILLUSIONIST'S ACT |
| MEMORY | ME- - - - | COMPUTER CAPACITY |
| NECESSARY | NE- - - - - - - | OF VITAL IMPORTANCE |
| NOVEL | NO- - - | FICTIONAL WORK |
| ODD | OD- | NOT EVEN |
| PEST | PE- - | FLEA OR MOSQUITO |
| PIANO | PI- - - | INSTRUMENT WITH 88 KEYS |
| POLICY | PO- - - - | CLUB RULE |
| PREJUDICE | PR- - - - - - - | UNREASONABLE BIAS |
| PRINCE | PR- - - - | WILLIAM OR HARRY E.G. |
| PROPER | PR- - - - | POLITE |
| PUNISH | PU- - - - | TAKE DISCIPLINARY ACTION |
| QUARREL | QU- - - - - | ANGRY DISPUTE |
| QUICK | QU- - - | FAST |
| RECIPE | RE- - - - | COOKING DIRECTIONS |

**Table B.4 – continued from previous page**

| Target word | Stem | Crossword clue |
|---|---|---|
| ROUGH | RO- - - | NOT AT ALL SMOOTH |
| SALARY | SA- - - - | WORKER'S PAY |
| SCREEN | SC- - - - | COMPUTER'S "FACE" |
| SCRUB | SC- - - | WASH VERY HARD |
| SELFISH | SE- - - - - | ME-FIRST |
| SPANK | SP- - - | PUNISH A CHILD CORPORALLY |
| STANDARD | ST- - - - - - | REFERENCE POINT |
| STATION | ST- - - - - | TRAIN STOP |
| STRAIGHT | ST- - - - - - | POKER HAND |
| TICKET | TI- - - - | BOX OFFICE PURCHASE |
| TRAIL | TR- - - | HIKER'S PATH |
| UNIFORM | UN- - - - - | MILITARY OUTFIT |
| WAITER | WA- - - - | RESTAURANT WORKER |

**Table B.5**
Word-stem completion task: Target words, orthographic cues (stem) and possible answers

| Target word | Stem | Possible answers |
|---|---|---|
| ADDRESS | AD_____ | ADDED, ADMINISTRATION, ADDITION, ADDITIONAL, ADD, ADDRESS, ADVANTAGE, ADEQUATE, ADVANCE, ADMINISTRATIVE, ADVANCED, ADVERTISING, ADVICE, ADAMS, ADOPTED |
| AIRPLANE | AI_____ | AIR, AID, AIRCRAFT, AIN, AIM, AIDS, AIMED, AIRPORT, AIMS, AIDED, AIRPLANE, AIA, AIRPLANES, AIDE, AIDING |
| ANALYZE | AN_____ | AND, AN, ANY, ANOTHER, ANYTHING, ANTI, ANSWER, ANYONE, ANALYSIS, ANNUAL, ANNOUNCED, ANODE, ANIMAL, ANCIENT, ANSWERED |
| ARTICLE | AR_____ | ARE, AROUND, AREA, AREAS, ART, ARMY, ARMS, ARM, ARTICLE, ARMED, ARTIST, ARTS, ARGUMENT, ARTISTS, ARRIVED |
| AUTHOR | AU_____ | AUDIENCE, AUTHORITY, AUGUST, AUTHOR, AUTOMOBILE, AUTHORITIES, AUTHORIZED, AUTOMATIC, AUTOMATICALLY, AUTO, AUG, AUTOMOBILES, AUTHORS, AUNT, AUSTIN |
| BRIEF | BR______ | BROUGHT, BROWN, BRING, BRITISH, BRIDGE, BRIGHT, BREAK, BROAD, BROTHER, BRIEF, BROKE, BRITAIN, BROKEN, BREATH, BRILLIANT |

**Table B.5 – continued from previous page**

| Target word | Stem | Possible answers |
|---|---|---|
| BUTTON | BU______ | BUT, BUSINESS, BUILDING, BUILT, BUILD, BUILDINGS, BUY, BUDGET, BUSY, BURDEN, BURNING, BUREAU, BURNED, BULL, BUS |
| CELEBRATE | CE_____ | CERTAIN, CENTURY, CENTER, CENTRAL, CENT, CERTAINLY, CELLS, CELL, CENTERS, CENTURIES, CEILING, CENTS, CERTAINTY, CELLAR, CEASE |
| CHAIR | CH_____ | CHILDREN, CHURCH, CHANGE, CHILD, CHRISTIAN, CHANGES, CHANCE, CHARGE, CHIEF, CHARACTER, CHOICE, CHICAGO, CHRIST, CHARLES, CHURCHES |
| CHALLENGE | CH_____ | CHILDREN, CHURCH, CHANGE, CHILD, CHRISTIAN, CHANGES, CHANCE, CHARGE, CHIEF, CHARACTER, CHOICE, CHICAGO, CHRIST, CHARLES, CHURCHES |
| CHIEF | CH______ | CHILDREN, CHURCH, CHANGE, CHILD, CHRISTIAN, CHANGES, CHANCE, CHARGE, CHIEF, CHARACTER, CHOICE, CHICAGO, CHRIST, CHARLES, CHURCHES |
| CLIMATE | CL_____ | CLASS, CLOSE, CLEAR, CLUB, CLEARLY, CLAIM, CLAY, CLOSED, CLASSES, CLAIMS, CLOTHES, CLOSELY, CLOCK, CLEAN, CLOSER |
| COLLEGE | CO_____ | COULD, COME, COURSE, COUNTRY, COMPANY, COLLEGE, COST, COURT, COMMUNITY, CONTROL, COMMON, COMPLETE, CONDITIONS, COSTS, COMMITTEE |

**Table B.5 – continued from previous page**

| Target word | Stem | Possible answers |
|---|---|---|
| COMEDY | CO_____ | COULD, COME, COURSE, COUNTRY, COMPANY, COLLEGE, COST, COURT, COMMUNITY, CONTROL, COMMON, COMPLETE, CONDITIONS, COSTS, COMMITTEE |
| CRISIS | CR_____ | CRISIS, CREATED, CROSS, CREDIT, CRITICAL, CREATE, CROWD, CREATION, CREATIVE, CRITICISM, CRY, CROSSED, CREW, CRIME, CRAZY |
| CULTURE | CU_____ | CUT, CURRENT, CUTTING, CULTURE, CULTURAL, CUBA, CURVE, CURIOUS, CUSTOMERS, CURT, CUP, CURRENTLY, CURE, CUSTOMER, CUTS |
| DECREASE | DE_____ | DEVELOPMENT, DEATH, DEPARTMENT, DEVELOPED, DEFENSE, DEAD, DEAL, DECIDED, DEGREE, DE, DETERMINED, DECISION, DEMOCRATIC, DESCRIBED, DEEP |
| DELICATE | DE_____ | DEVELOPMENT, DEATH, DEPARTMENT, DEVELOPED, DEFENSE, DEAD, DEAL, DECIDED, DEGREE, DE, DETERMINED, DECISION, DEMOCRATIC, DESCRIBED, DEEP |
| DENY | DE_____ | DEVELOPMENT, DEATH, DEPARTMENT, DEVELOPED, DEFENSE, DEAD, DEAL, DECIDED, DEGREE, DE, DETERMINED, DECISION, DEMOCRATIC, DESCRIBED, DEEP |
| DETERMINE | DE_____ | DEVELOPMENT, DEATH, DEPARTMENT, DEVELOPED, DEFENSE, DEAD, DEAL, DECIDED, DEGREE, DE, DETERMINED, DECISION, DEMOCRATIC, DESCRIBED, DEEP |

**Table B.5 – continued from previous page**

| Target word | Stem | Possible answers |
|---|---|---|
| DIRECT | DI______ | DID, DIDN, DIFFERENT, DIFFICULT, DIFFERENCE, DIRECTLY, DISTRICT, DIRECT, DIRECTION, DIVISION, DISTANCE, DIRECTOR, DISCUSSION, DISTRIBUTION, DINNER |
| DOMINATE | DO_____ | DO, DOWN, DOES, DON, DONE, DOOR, DOING, DOUBT, DOLLARS, DOESN, DOCTOR, DOUBLE, DOG, DOGS, DOMINANT |
| ELEVATOR | EL_____ | ELSE, ELEMENTS, ELECTION, ELECTRIC, ELECTRONIC, ELEMENT, ELECTIONS, ELSEWHERE, ELECTRICAL, ELEVEN, ELECTED, ELECTRONICS, ELABORATE, ELECTRON, ELECTRICITY |
| EMPIRE | EM_____ | EMOTIONAL, EMPLOYEES, EMPHASIS, EMPTY, EMPLOYED, EMPLOYMENT, EM, EMERGENCY, EMOTIONS, EMISSION, EMOTION, EMPLOYEE, EMPIRICAL, EMERGED, EMPEROR |
| EXCHANGE | EX______ | EXAMPLE, EXPERIENCE, EXPECTED, EXCEPT, EXTENT, EXISTENCE, EXPECT, EXACTLY, EXPLAINED, EXPRESSED, EXPRESSION, EXCHANGE, EXCELLENT, EXPERIMENTS, EXPERIMENT |
| FAKE | FA______ | FACT, FAR, FACE, FAMILY, FATHER, FALL, FARM, FAITH, FACTORS, FACILITIES, FAMOUS, FAST, FACTS, FAILURE, FAIR |

**Table B.5 – continued from previous page**

| Target word | Stem | Possible answers |
|---|---|---|
| FASHION | FA______ | FACT, FAR, FACE, FAMILY, FATHER, FALL, FARM, FAITH, FACTORS, FACILITIES, FAMOUS, FAST, FACTS, FAILURE, FAIR |
| FREEZE | FR_____ | FROM, FREE, FRONT, FRIENDS, FRENCH, FRIEND, FREEDOM, FREQUENTLY, FRANCE, FRESH, FRAME, FRANK, FRIDAY, FRIENDLY, FRANCISCO |
| GARBAGE | GA______ | GAVE, GAME, GAS, GAIN, GAMES, GARDEN, GAINED, GATE, GALLERY, GARDENS, GATHERED, GAY, GATHERING, GAVIN, GANG |
| HARMONY | HA_____ | HAD, HAVE, HAS, HAND, HALF, HANDS, HAVING, HARD, HAPPENED, HALL, HAIR, HARDLY, HAPPY, HADN, HANOVER |
| INNOCENT | IN______ | IN, INTO, INTEREST, INFORMATION, INDIVIDUAL, INCREASE, INDUSTRY, INCLUDING, INSTEAD, INSIDE, INDEED, INTERNATIONAL, INCREASED, INVOLVED, INDUSTRIAL |
| JOURNAL | JO______ | JOHN, JOB, JONES, JOBS, JOIN, JOINED, JOSEPH, JOURNAL, JOE, JOINT, JOHNSON, JOY, JOHNNY, JOHNNIE, JOURNEY |
| LABOR | LA_____ | LAST, LATER, LARGE, LAW, LAND, LATE, LABOR, LAY, LATTER, LARGER, LANGUAGE, LACK, LAWS, LADY, LAID |
| LAWN | LA______ | LAST, LATER, LARGE, LAW, LAND, LATE, LABOR, LAY, LATTER, LARGER, LANGUAGE, LACK, LAWS, LADY, LAID |

**Table B.5 – continued from previous page**

| Target word | Stem | Possible answers |
|---|---|---|
| LEAN | LE_____ | LEFT, LESS, LET, LEAST, LEVEL, LEAVE, LETTER, LED, LEAD, LENGTH, LEARNED, LEADERS, LETTERS, LEADERSHIP, LEARN |
| LUXURY | LU_____ | LUCY, LUCK, LUMBER, LUNCH, LUNCHEON, LUXURY, LUCKY, LUNG, LUNGS, LUMUMBA, LUCILLE, LUDIE, LUMINOUS, LUCIEN, LUGGAGE |
| MAGIC | MA______ | MAY, MAN, MADE, MANY, MAKE, MATTER, MAJOR, MAKING, MATERIAL, MAKES, MARKET, MAYBE, MAIN, MANNER, MARCH |
| MEMORY | ME_____ | ME, MEN, MEMBERS, MEANS, MEAN, MEDICAL, MEETING, METHOD, METHODS, MEET, MEMBER, MERELY, MET, MEANING, MEANT |
| NECESSARY | NE_____ | NEW, NEVER, NEXT, NEED, NECESSARY, NEAR, NEEDED, NEEDS, NEARLY, NEITHER, NEGRO, NEWS, NEVERTHELESS, NECK, NEGATIVE |
| NOVEL | NO_____ | NOT, NO, NOW, NOTHING, NORTH, NOR, NON, NORMAL, NOTE, NONE, NOTED, NOBODY, NOVEMBER, NOVEL, NOTICE |
| ODD | OD______ | ODDS, ODOR, ODYSSEY, ODDLY, ODORS, ODER, ODIOUS, ODDBALL, ODDBALLS, ODDER, ODDEST, ODDITIES, ODDITY, ODDITYS |

**Table B.5 – continued from previous page**

| Target word | Stem | Possible answers |
| --- | --- | --- |
| PEST | PE_____ | PEOPLE, PER, PERHAPS, PERIOD, PEACE, PERSONAL, PERSON, PERSONS, PERFORMANCE, PERMIT, PERSONNEL, PERFECT, PERMITTED, PERCENT, PERIODS |
| PIANO | PI_____ | PICTURE, PIECE, PIECES, PICKED, PICTURES, PICK, PILOT, PINK, PIKE, PIANO, PIP, PISTOL, PITTSBURGH, PILE, PITCH |
| POLICY | PO______ | POINT, POSSIBLE, POWER, POLITICAL, POSITION, POLICY, POLICE, POINTS, POPULATION, POOL, POST, POET, POOR, POPULAR, POETRY |
| PREJUDICE | PR_______ | PRESIDENT, PRESENT, PROGRAM, PROBLEM, PROBABLY, PROBLEMS, PROVIDE, PRESSURE, PROCESS, PRIVATE, PROPERTY, PRODUCTION, PROGRAMS, PROVIDED, PRESS |
| PRINCE | PR_____ | PRESIDENT, PRESENT, PROGRAM, PROBLEM, PROBABLY, PROBLEMS, PROVIDE, PRESSURE, PROCESS, PRIVATE, PROPERTY, PRODUCTION, PROGRAMS, PROVIDED, PRESS |
| PROPER | PR______ | PRESIDENT, PRESENT, PROGRAM, PROBLEM, PROBABLY, PROBLEMS, PROVIDE, PRESSURE, PROCESS, PRIVATE, PROPERTY, PRODUCTION, PROGRAMS, PROVIDED, PRESS |
| PUNISH | PU_____ | PUBLIC, PUT, PURPOSE, PURPOSES, PUBLISHED, PULLED, PUBLICATION, PULL, PURE, PUSH, PUTTING, PUSHED, PURCHASE, PULMONARY, PURELY |

**Table B.5 – continued from previous page**

| Target word | Stem | Possible answers |
|---|---|---|
| QUARREL | QU_____ | QUITE, QUESTION, QUESTIONS, QUALITY, QUICKLY, QUIET, QUICK, QUALITIES, QUIETLY, QUEEN, QUARTER, QUESTIONNAIRE, QUANTITY, QUARTERS, QUESTIONED |
| QUICK | QU_____ | QUITE, QUESTION, QUESTIONS, QUALITY, QUICKLY, QUIET, QUICK, QUALITIES, QUIETLY, QUEEN, QUARTER, QUESTIONNAIRE, QUANTITY, QUARTERS, QUESTIONED |
| RECIPE | RE______ | RE, REALLY, REAL, RESULT, REASON, RED, RECENT, REQUIRED, RESEARCH, RETURN, REPORT, RELIGIOUS, READ, RECEIVED, REACHED |
| ROUGH | RO______ | ROOM, ROAD, ROLE, ROUND, ROSE, ROCK, ROBERT, ROME, ROADS, ROMAN, ROOF, ROOMS, ROBERTS, ROUTE, ROUGH |
| SALARY | SA_____ | SAID, SAME, SAY, SAW, SAYS, SALES, SAT, SAYING, SAM, SAN, SATURDAY, SAVE, SAMPLE, SAFE, SAFETY |
| SCREEN | SC______ | SCHOOL, SCHOOLS, SCIENCE, SCENE, SCIENTIFIC, SCALE, SCORE, SCREEN, SCOTTY, SCHEDULED, SCHEDULE, SCHOLARSHIP, SCIENTISTS, SCHEME, SCIENCES |
| SCRUB | SC_____ | SCHOOL, SCHOOLS, SCIENCE, SCENE, SCIENTIFIC, SCALE, SCORE, SCREEN, SCOTTY, SCHEDULED, SCHEDULE, SCHOLARSHIP, SCIENTISTS, SCHEME, SCIENCES |
| SELFISH | SE_____ | SEE, SET, SECOND, SEVERAL, SERVICE, SENSE, SEEMED, SEEMS, SEEN, SELF, SEEM, SECRETARY, SECTION, SERVICES, SENT |

**Table B.5 – continued from previous page**

| Target word | Stem | Possible answers |
|---|---|---|
| SPANK | SP_____ | SPECIAL, SPACE, SPIRIT, SPRING, SPECIFIC, SPEAK, SPENT, SPEED, SPOKE, SPREAD, SPEAKING, SPIRITUAL, SPEECH, SPOT, SPEAKER |
| STANDARD | ST______ | STATE, STILL, STATES, STUDY, STREET, STUDENTS, STRONG, STAGE, STARTED, STOOD, ST, STORY, START, STAND, STEP |
| STATION | ST_____ | STATE, STILL, STATES, STUDY, STREET, STUDENTS, STRONG, STAGE, STARTED, STOOD, ST, STORY, START, STAND, STEP |
| STRAIGHT | ST_____ | STATE, STILL, STATES, STUDY, STREET, STUDENTS, STRONG, STAGE, STARTED, STOOD, ST, STORY, START, STAND, STEP |
| TICKET | TI______ | TIME, TIMES, TITLE, TINY, TILL, TIRED, TISSUE, TIED, TILGHMAN, TIM, TIGHT, TIE, TIRE, TIP, TIMBER |
| TRAIL | TR_____ | TRUE, TRAINING, TRIED, TRYING, TRADE, TRY, TRIAL, TREATMENT, TROUBLE, TRUTH, TRADITION, TREES, TRIP, TRADITIONAL, TREATED |
| UNIFORM | UN______ | UNDER, UNITED, UNTIL, UNIVERSITY, UNION, UNDERSTAND, UNDERSTANDING, UNIT, UNLESS, UNITS, UNITY, UNIVERSE, UNUSUAL, UNIQUE, UNDERSTOOD |

**Table B.5 – continued from previous page**

| Target word | Stem | Possible answers |
|---|---|---|
| WAITER | WA______ | WAS, WAY, WAR, WATER, WANT, WASHINGTON, WANTED, WALL, WASN, WALKED, WAYS, WAITING, WALK, WAIT, WATCH |

**Table B.6**
Free association task: Target words and associated answers

| Target word | Possible answers |
|---|---|
| ADDRESS | NAME, NUMBER, RETURN, NOTIFY |
| AIRPLANE | FLIGHT, STEWARDESS, FLYING, NAVIGATOR, CONTROLS, AIRCRAFT, FLY, CO-PILOT, HELICOPTER, MODEL, GLIDE, DEPART, HOBBY, PEANUTS, RESERVATION, KIT, HEIGHTS, TERMINAL, TRANSPORTATION, TRIP, AIR, DELAY, SOAR |
| ANALYZE | CRITIC, EVALUATE, CRITICAL, COMPUTE, DEFINE, PHILOSOPHER, SCIENTIFIC |
| ARTICLE | NEWSPAPER, MAGAZINE, ITEM, EDITORIAL, FEATURE, JOURNAL, PUBLICATION, ADVERTISEMENT |
| AUTHOR | WRITER, TITLE, POET, EDITOR, PUBLISHER, READER, CREATOR |
| BRIEF | SUMMARY, OUTLINE, OVERVIEW, SYNOPSIS, VAGUE |

**Table B.6 – continued from previous page**

| Target word | Possible answers |
|---|---|
| BUTTON | BELLY, ZIPPER, SHIRT, SNAP, SEW, SNOOZE, MUTTON, BLOUSE, LEVER, PRESS, HOLE, CALCULATOR, COLLAR, KNOB, PUSH, CUTE, ELEVATOR, SEAM, FASTEN |
| CELEBRATE | REJOICE, TRIBUTE, BIRTHDAY, JOYOUS, FESTIVAL |
| CHAIR | TABLE, RECLINER, SEAT, STOOL, WICKER, DESK, COUCH, LOUNGE, SIT, FURNITURE, SOFA, BENCH, COMFORTABLE, SITTING, UNCOMFORTABLE, CUSHION, PATIO, COMFORT, THRONE, DIRECTOR, PORCH, LAWN, LIVING, ROCK, DENTIST, ARM, SWING, INCLINE, ROOM, ROW, DECK, DISCOMFORT, THING, WHEEL, ANTIQUE, HAMMOCK, PUT, TABLET, WOOD |
| CHALLENGE | DARE, OPPONENT, COMPETE, RISK, DARING, COMPETITION, CONQUEST, OBSTACLE, COMPLICATED, IMPOSSIBLE |
| CHIEF | COMMANDER, EDITOR, INDIAN, BOSS, LEADER, MASTER, SUPERVISOR, CAPTAIN, MAYOR, POLICE, COLONEL, DEPUTY, EXECUTIVE, HAIL |
| CLIMATE | WEATHER, TEMPERATURE, ATMOSPHERE, TROPICAL |

**Table B.6 – continued from previous page**

| Target word | Possible answers |
|---|---|
| COLLEGE | UNIVERSITY, DEGREE, HIGH, CAMPUS, SCHOOL, EDUCATE, EDUCATION, GRADUATION, ADMISSION, GRADUATE, SCHOLARSHIP, STUDENT, JUNIOR, SEMESTER, PROFESSOR, CAREER, DORM, PROFESSIONAL, APPLICATION, FRATERNITY, PLACE, CLASS, COURSE, PROFESSION, RECOMMENDATION, SORORITY, UNDECIDED, AWAY, FACULTY, INTUITION, OPPORTUNITY, REALITY, RESPONSIBILITY, ROOMMATE, TERM, THESIS, ACHIEVEMENT, COMMUNITY, DIPLOMA, INSTRUCT, RING |
| COMEDY | SITUATION, HUMOR, DRAMA, TRAGEDY, FUNNY, DICE, HILARIOUS, COMEDIAN, MOVIE |
| CRISIS | IDENTITY, HOSTAGE, MISSILE, FEUD, TRAUMA |
| CULTURE | TRADITION, CUSTOM, SOCIETY, LIFESTYLE, HERITAGE, YOGURT, HISPANIC, GERM, EUROPE, LANGUAGE, LATIN, NORM |
| DECREASE | INCREASE, DIMINISH, DECLINE, REDUCE, DESCEND, DEPLETION, SHRINK |
| DELICATE | FRAGILE, PORCELAIN, CAREFUL, LACE, FRAIL, FEEBLE, BUTTERFLY |
| DENY | REFUSE, ACCEPT, REJECT, ADMIT, FORBID, PROHIBIT, CONFESS, DECLINE, RENOUNCE, REGRET, PERMIT, ACCUSE, PUNISH, ADMISSION, EXCUSE, DISPROVE, SUPPLY, REPRESS |
| DETERMINE | CALCULATE, DECIDE, EVALUATE, SET, PREDICT |
| DIRECT | INDIRECT, INSTRUCT, STEER, POINT, FOCUS, AIM, PRECISE, SIGNAL |

**Table B.6 – continued from previous page**

| Target word | Possible answers |
|---|---|
| DOMINATE | OVERPOWER, CONTROL, CONTROLS |
| ELEVATOR | ESCALATOR, STAIR, STAIRS, STAIRWAY, LOBBY, UP, LIFT, DOWN |
| EMPIRE | ROMAN, DYNASTY, KINGDOM, UMPIRE, BUILDING, BUILD |
| EXCHANGE | SWAP, TRADE, FOREIGN, REPLACE, RETURN, BARTER, STOCK, TRANSPLANT, SHARE, RECEIPT |
| FAKE | PHONY, REAL, PRETEND, FRAUD, UNNATURAL, BLUFF, WRESTLING, DISGUISE, FICTION, GENUINE, HYPNOTIZE, ILLUSION, PERJURY, MAGICIAN, PLASTIC, POLITICIAN, CON, IMITATE, MIMIC, SORORITY, MIRAGE, MAKE, LIAR, ORIGINAL, IDENTIFICATION, QUACK, REALITY, UNTRUTHFUL, SUPERMAN, DECEPTION, FAIRYTALE, HOROSCOPE, PREACHER, SINCERE, SLANDER, TEASE, TREND, COMMERCIAL, DISBELIEVE, NATURAL, POLYESTER, ROBOT, SUPERSTITION, GHOST, HEAL, MYTH |
| FASHION | TREND, STYLE, FAD, CLOTHES, DESIGNER, ORDERLY, DESIGN, MODERN, MODEL |
| FREEZE | THAW, CHILL, DEFROST, MELT, FROZEN, SHIVER, BOIL, FRAME, SHUTTER, TAG, COLD |
| GARBAGE | TRASH, DUMP, WASTE, JUNK, WASTED, LITTER, CAN, BAG, STINK, ALLEY, RACCOON, REFUSE, USELESS, ASHTRAY, CHORE, BASKET, MAGGOT, NONSENSE, SLOB, DECOMPOSE, MUCK, STUFF |
| HARMONY | RAYS, MELODY, PEACE, AGREEMENT, PEACEFUL |
| INNOCENT | GUILTY, PRESUME, NAIVE, PURE, VICTIM, PLEAD, VIRGIN, CHILDREN, VULNERABLE, HONEST, GULLIBLE |

**Table B.6 – continued from previous page**

| Target word | Possible answers |
|---|---|
| JOURNAL | DIARY, PUBLICATION, DAIRY, NEWSPAPER, WEEKLY, EDITORIAL, LOG |
| LABOR | WORKER, UNION, WORK, MANAGEMENT, SLAVE, INDUSTRY, PAINTER, TOIL, FACTORY |
| LAWN | MOWER, MOW, YARD, GRASS, LANDSCAPE, RAKE, WEED, HEDGE, MEADOW, SPRINKLE, PATIO, YAWN |
| LEAN | SHOULDER, TEND, CRUTCH, SWAY, TENDENCY, INCLINE, AGAINST, VEER, SLENDER |
| LUXURY | COMFORT, LIMOUSINE, YACHT, ELEGANT, HOTEL, PLEASURE, MONEY, WEALTH |
| MAGIC | WAND, MAGICIAN, VOODOO, TRICK, REAPPEAR, ILLUSION, SPELL, MARKER, KINGDOM, DISAPPEAR, CARPET, UNICORN, MUSHROOM, AMAZE, WITCH, CRYSTAL, MIGHT, ELF, LABYRINTH |
| MEMORY | REMEMBER, RECALL, REMINISCENCE, MEMORIAL, PICTURE, FORGET, REMIND, ELEPHANT, CEREMONY, MIND, RECOGNITION, BACKGROUND, GARDEN, HINDSIGHT, SAVIOR, RETAIN, THINK, ATTENTION |
| NECESSARY | URGENT, IMPORTANT, MUST, GOVERNMENT, ESSENCE, OBLIGATION, PROVISION |
| NOVEL | MYSTERY, ROMANCE, BOOK, WRITER, ROMANTIC, STORY, SPY, PLOT, FICTION, SUSPENSE, AUTHOR, CHAPTER, FAIRYTALE, PUBLICATION, DETECTIVE, POEM |

**Table B.6 – continued from previous page**

| Target word | Possible answers |
|---|---|
| ODD | EVEN, STRANGE, UNEVEN, BIZARRE, UNUSUAL, IRREGULAR, WEIRD, UNIQUE, FREAK, ABNORMAL, RARE, DIFFERENT, DIFFERENCE, UNCOMMON, UNNATURAL, COMMON, OBSCURE |
| PEST | ANNOYING, TERMITE, BOTHER, ANNOY, RODENT, FLY, ROACH, MOSQUITO, RAT, FLEA, INSECT, BULLY, SEAGULL, NOSY |
| PIANO | KEYBOARD, ORGAN, GRAND, INSTRUMENT, GUITAR, IVORY, TUNE, LESSON, HARP, PRACTICE, PLAYER, CONCERT, MUSIC, VIOLIN, FLUTE, TALENT |
| POLICY | INSURANCE, ATTENDANCE, HONESTY, COMPANY, RULE |
| PREJUDICE | BIAS, STEREOTYPE, PRIDE, MINORITY, EXTREME, UNFAIR, CONDEMN |
| PRINCE | PRINCESS, FROG, ROYALTY, CASTLE, KING, PALACE |
| PROPER | PRIM, ETIQUETTE, DECENCY, MANNERS, POISE, WHOM, ORDERLY, ATTIRE |
| PUNISH | SCOLD, SPANK, DISCIPLINE, WHIP, CONDEMN, FORBID, SIN, GUILTY, PROSECUTE, REWARD, OBEY, PRISON, STRICT, THREAT, TORTURE, RENOUNCE |
| QUARREL | LOVERS, ARGUE, ARGUMENT, FIGHT, CONFLICT, FUSS |
| QUICK | SPONTANEOUS, RAPID, INSTANT, BRISK, URGENT, IMPULSE, RUSH, FAST, INSTANCE, HURRY, IMMEDIATE, BRIEF, EXPRESS, SWIFT, EASY, RESPONSE, DASH, EMERGENCY, REACTION, MICROWAVE, DART, INSTINCT, THRIFT, EASE, FURY, SOON, FOX, IMPATIENCE, SMART, SHARP, COMPULSION, DILIGENCE |

**Table B.6 – continued from previous page**

| Target word | Possible answers |
|---|---|
| RECIPE | COOKBOOK, PRECIPICE, FORMULA, MIXTURE, ORIGINAL |
| ROUGH | SANDPAPER, SMOOTH, TOUGH, BUMPY, RIGID, GENTLE, HARSH, COURSE, CRUDE, BRISTLE, GRIT, HECTIC, ROUGE, AGGRESSIVE, FRIGID, BULLY, DRAFT, ROCKS, UNEVEN, LEATHER, SURFACE, VIOLENT, FLAT, FOOTBALL, FORCEFUL, HARDY, PLAYING, RAW, STERN, DELICATE, HOCKEY, UNEASY |
| SALARY | WAGE, INCOME, PAY, EARN, GROSS, RAISE |
| SCREEN | MOVIE, COMPUTER, DISPLAY, FILM, LINT, TELEVISION, THEATER, PATIO |
| SCRUB | MOP, CLEANER, MILDEW |
| SELFISH | GREED, CONCEITED, MINE, SHARE, STINGY, CONCEIT, KEEP, RIGHTEOUSNESS, ARROGANT, TAKE |
| SPANK | PUNISH, PADDLE, PUNISHMENT, DISCIPLINE |
| STANDARD | ROUTINE, NORM, DOUBLE, PRINCIPLE, COMMON, SHIFT, METRIC |
| STATION | SERVICE, RADIO, TRAIN, CHANNEL, GAS, CENTRAL, BUS, TELEVISION, TERMINAL, WAGON, NETWORK, RAILROAD, SHELL, SUBWAY |
| STRAIGHT | CURVE, CROOKED, LINE, BENT, CURVED, ERECT, DIRECT, LEVEL, ARROW, ANGLE, RULER, UNEVEN, FORWARD, SOBER, POISE, STIFF, AHEAD, BEND, DIRECTION, NARROW, FLAT, RIGID, WALL, TANGENT, BACKBONE, CORNER, EYEBROWS, SERIOUS, WINDING, ACCURATE, AWKWARD, PRIM, HAIR, TURN, ATTENTION, IRON, WRINKLE |

**Table B.6 – continued from previous page**

| Target word | Possible answers |
|---|---|
| TICKET | ADMISSION, VIOLATION, STUB, PARKING, SPEED, LOTTERY, BOOTH, RECEIPT, CLAIM, METER, COP, WARNING, MEAL, POLICE, BALLOT, OFFICER, PERMIT, THICKET, LICENSE, TAG |
| TRAIL | PATH, HIKING, HIKE, TRACK, PASSAGE, FOLLOW, NATURE, CAMPAIGN, BLAZE, ROAD, RAIL, BIKE |
| UNIFORM | MILITARY, POLICE, INFORM, WORKER, POLYESTER, MAID, OFFICER, SCOUT, STRIPES, AIR |
| WAITER | SERVER, WAITRESS, TIP, BUTLER, HOST, SERVANT, BARTENDER, HOSTESS, CHEF, DINER |

# Appendix C

# Experiment 3: Post Survey

The following pages show the post surveys that were given to participants after a week of study in Experiment 3. There are two different surveys for two game conditions and the control group.

**Post Survey** **Code**____________________

**Games**

- Which games did you play in this study? (crossword, word-stem, word-association)

- If you played more than one game, which one is the most helpful in term of improving your vocabulary knowledge?

- How many times did you play the games during a week of the study? (Please choose one)
    - Once for each game
    - Once for each game and more than once for some games
    - I have not started any games

- Please answer these questions by marking (X) on the following scale

| Question | Strongly agree | Agree | Neutral | Disagree | Strongly disagree | Not applicable |
|---|---|---|---|---|---|---|
| The games helped me improve my vocabulary knowledge. | | | | | | |
| The games helped me improve my reading comprehension. | | | | | | |
| The games encouraged me to learn English. | | | | | | |
| The games encouraged me to learn English vocabulary. | | | | | | |
| The games are too hard. | | | | | | |
| The games are too easy. | | | | | | |
| The words that I saw in the games are from the English Reading tests. | | | | | | |
| I liked the games I played. | | | | | | |
| I liked the game interfaces (e.g. layout, color, font size, etc.) I played. | | | | | | |
| I would like to play the games again. | | | | | | |

- Suggestions or comments about the games

**English Reading Tests**

- Please answer these questions by marking (X) on the following scale

| Question | Strongly agree | Agree | Neutral | Disagree | Strongly disagree | Not applicable |
|---|---|---|---|---|---|---|
| The tests are appropriate for non-native English speakers (people who learn English as a second language). | | | | | | |
| The tests are too hard. | | | | | | |
| The tests are too easy. | | | | | | |

- How many new words you have learned from the pre-test, post-test and the games? (approximately)

- Suggestions or comments about the tests

**Websites**

- Have you experienced any technical problems while performing the games?
  - No
  - Yes

What were the problems? :

**Suggestions or comments about the study**

**Post Survey** **Code___________________**

**Reading articles (you read them online)**

- How long did you spend on reading an article in average?

- How many times did you read the articles during a week of the study? (Please choose one)
  - Once for each article
  - Once for each article and more than once for some articles
  - I have not started any article.

- Please answer these questions by marking (X) on the following scale

| Question | Strongly agree | Agree | Neutral | Disagree | Strongly disagree | Not applicable |
|---|---|---|---|---|---|---|
| The articles helped me improve my vocabulary knowledge. | | | | | | |
| The articles helped me improve my reading comprehension. | | | | | | |
| The articles encouraged me to learn English. | | | | | | |
| The articles encouraged me to learn English vocabulary. | | | | | | |
| The articles are too hard. | | | | | | |
| The articles are too easy. | | | | | | |
| The words that I saw in the articles are from the English Reading tests. | | | | | | |
| I liked the articles I read. | | | | | | |
| I liked the article interfaces (e.g. layout, color, font size, etc.) I read. | | | | | | |
| I would like to read the articles again. | | | | | | |

- Suggestions or comments

**English Reading Tests**

- Please answer these questions by marking (X) on the following scale

| Question | Strongly agree | Agree | Neutral | Disagree | Strongly disagree | Not applicable |
|---|---|---|---|---|---|---|
| The tests are appropriate for non-native English speakers (people who learn English as a second language). | | | | | | |
| The tests are too hard. | | | | | | |
| The tests are too easy. | | | | | | |

- How many new words you have learned from the pre-test, post-test and the games? (approximately)

- Suggestions or comments about the tests

**Websites**

- Have you experienced any technical problems while reading the articles?
    - No
    - Yes

What were the problems? :

**Suggestions or comments about the study**

# Appendix D

# Policy on Journal Publication of Conference Papers

The following page shows the policy on journal publication of conference papers which was retrieved on November $10^{th}$, 2015 from the Cognitive Science Society website (`http://cognitivesciencesociety.org/conference_archival.html`). This documentation is for Chapter 4 and Figure 2.2.

COGNITIVE SCIENCE SOCIETY

Home | About the Society | Annual Conference | Journals | Resources | Calls | Employment | Funding | Study | Membership

## Annual Conference

Overview

CogSci 2016

Past Conferences/Videos

Future Meetings

Conference FAQ

Awards

Back to main menu

# Policy on Journal Publication of Conference Papers

Our Conference Proceedings are not considered archival for purposes of publication in either of the two Cognitive Science Society journals. The policy of the Society is that work published in a Proceedings paper may be considered for journal submission provided that the journal submission is substantially more elaborated than the Proceedings paper in terms of literature review, data analysis, and/or discussion.

We have no formal agreements with any other journals or societies. However, it is our experience that most journals and societies adopt the same position to Proceedings papers as we do. As far as we know this issue has only arisen twice in the first 30 years of the Society's existence, and both times the journal editor resolved the issue in favor of the author. A third case in 2007 was in reference to a paper submitted to Psychological Science. The Editor at the time concluded that, "...the CSS Proceedings meet the criterion of 'limited circulation' and I don't see any problem with our publishing this or any other manuscript that has appeared in those Proceedings. Of course, that view hinges on distribution remaining, for all intents and purposes, with conference attendees."

However, please remember that in all cases, it is the responsibility of the author to point out to the Editor that part or all of the manuscript is based on work previously presented at the Cognitive Science Conference and published in the Proceedings. If you fail to do so, you are in violation of CSS policy and your actions may be considered an ethical breach.

Annual Conference Back To Top