This is to certify that the
dissertation entitled

SECOND LANGUAGE ACQUISITION OF COMPLEX NOMINALS: THE ARCHITECTURE OF THE SECOND LANGUAGE LEXICON, INDIVIDUAL DIFFERENCES, AND SECOND LANGUAGE DEVELOPMENT

presented by

Junkyu Lee

has been accepted towards fulfillment
of the requirements for the

Ph.D. degree in Second Language Studies

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December 16, 2009

Date

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By

Junkyu Lee

A DISSERTATION

Submitted to
Michigan State University
In partial fulfillment of the requirements
For the degree of

DOCTOR OF PHILOSOPHY

Second Language Studies

2009

ABSTRACT

SECOND LANGUAGE ACQUISITION OF COMPLEX NOMINALS: THE ARCHITECTURE OF THE SECOND LANGUAGE LEXICON, INDIVIDUAL DIFFERENCES, AND SECOND LANGUAGE DEVELOPMENT

By

Junkyu Lee

This dissertation investigates the question of how the second language lexicon is functionally organized and how lexical information is processed in real-time. An answer to this question is pursued by looking at complex nominals (e.g., coffee cup), a rarely explored linguistic target in psycholinguistics-based SLA research. While taking into account first language backgrounds and individual cognitive abilities, the focus is on whether native speakers and non-native speakers interpret a complex nominal via retrieval and/or computational routes.

Three groups participated in this study: (1) an L2 English group whose L1 (Chinese and Korean) has a modifier-head complex nominal structure (e.g., orange-juice), (2) another non-native speaker group whose L1 (Spanish and Thai) has a head-modifier structure (e.g., juice-orange), and (3) an L1 English group as a control. All the participants completed three computer-based tasks: (1) a lexical sense decision task, (2) an inhibitory control test, and (3) a working memory test.

Results showed that native and non-native speakers relied on both retrieval and computational routes in the recognition of complex nominals taken from a large corpus. The L1 group tended to use more retrieval mechanisms whereas the L2 groups were

inclined to resort to computational routes. Also, the effects of cognitive abilities were confounded with processing costs and L1 background.

This study emphasizes that two key concepts (storage and computation) of the language faculty are integral to L2 lexical acquisition. The contribution of empirical L2 data to linguistic inquiry is also highlighted.

This dissertation is dedicated to my family.

ACKNOWLEDGEMENTS

This dissertation would not have been possible without the help and support of numerous people. Thus my sincere gratitude goes to all those people who have made this dissertation possible. I would like to start by acknowleding each member of my dissertation committee who has offered constant support and encouragement throughout the processes of this dissertation: Eve Zyzik, who always gave me insightful comments that have improved this dissertation in numerous ways; Rebecca Foote, whose extremely helpful feedback made this dissertation psycholinguistically sound and substantial; Shawn Loewen, whose constructive guidiances on quantitative methods made this dissertation far more professional; finally my chair to whom I am most deeply indebted, Susan Gass, who did not only support me intellectually and academically throughout my Ph.D. studies but also supported me at every single step of my doctoral research.

Special thanks must be made to my friends and colleagues who helped me in my revisions and material development, including Marthe Russell, Jennifer Behney, Luke Plonsky, Mark Shea, Jamie Thomas, and Robin Roots.

I gratefully acknowledge Joan Reid, Russ Werner, and Anna Davis, the staff of the Second Language Studies program, for giving me all necessary assistance during my studies.

The support and encouragement of many friends and colleagues helped me overcome setbacks and stay focused on my graduate study; I am grateful to all the SLS students including Shaofeng Li, Tomoko Okuno, Seongmee Ahn, Ben White, Xiaoqing (Andy) Chen, Chien-Hsiung (Scott) Chiu, Amy Thompson, Fei Fei, Hyewon Lee, Sun Yi

Hong, Soo Hyon Kim, Grace Lee Amuzie, Jimin Kahng, Hyojung Lim, Yeon Heo, Susan Berendes Wood, Hiep Chau, Ching-Ni Hsieh, Nobuhiro Kamiya, Kimi Nakatsukasa, Maren Schierloh, Tetyana Sydorenko, Emma Trentman , Solene Inceoglu, Sara Hillman, Wen-Hsin Chen, and Baburhan Uzum; I am also thankful to my colleagues at Yale and Seoul National for their constant encouragement, including Hosung Nam, Hyoungbae Lee, Seunghun Lee, Youngjoo Lee, and Yoonshin Kim.

Also, I would like to express my appreciation to the many professors in Korea and the US who have led my academic life fruitful and successful, including Sungbom Lee, Chungmin Lee, Jong-bok Kim, Seungho Nam, Maria Piñango, Larry Horn, Stephen Anderson, Louis Goldstein, Maria Babyonyshev, Seungja Choi, Debra Friedman, Senta Goertler, Debra Hardison, Charlene Polio, Diana Pulido, Patti Spinner, Paula Winke and Patricia Paulsell.

I wish to express my gratitude to my parents (Min-soo Lee & Haeng-ja Lee) who always supported and encouraged me during this period. I would also like to thank my parents-in-laws (Myungho Ko & Haejung Byun) and my sister (Jisun Lee) and her family for their endless support and love. Last but not least I am deeply indebted to my son, Rich (Jonghyun) Lee and my wife, Yoojung Ko, whose love and support provided me with the energy to attain my goals.

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CHAPTER ONE - INTRODUCTION

In this dissertation, I will investigate the question of how the second language lexicon is organized and how lexical information is processed in real-time. I pursue an answer to this question by looking at complex nominals (e.g., *coffee cup*), which are rarely explored within the psycholinguistic context of second language acquisition; specifically, I focus on how native and non-native speakers interpret the meaning of complex nominals. At the same time, I take into account other potential variables that may affect complex nominal processing by second language learners, including the learners' first language backgrounds, their individual cognitive abilities, and item-frequency effects.

One might claim that words are the building blocks of language and language learning. Within the context of second language (L2) acquisition, as Gass and Selinker (2008) go so far as to state, the lexicon is presumably the most significant component of second language acquisition (p. 449). L2 lexical knowledge is, therefore, of inevitable importance in both production and comprehension of an L2 (e.g., Bogaards & Laufer, 2004; Gass, 1988; Nation, 2001; Read 2000).

The second language lexicon has been investigated in relation to retention (e.g., Hulstijn & Laufer, 2001), incidental learning paradigms (e.g., Pulido, 2003), receptive and productive knowledge (e.g., Webb, 2005), L2 phonetics (e.g., Barcroft & Sommers, 2005), and writing (e.g., Barcroft, 2004). Despite the wide range of L2 lexicon studies to date, relatively little attention is paid to the issue of L2 lexical representation (Jiang, 2000;

Wolter, 2001). Jiang (2004) correctly pointed out that "more basic and specific issues related to the acquisition process, such as how lexical knowledge is represented in the learner's mind ... what stages a word goes through before it becomes an integrated part of the learner's lexicon, have received little attention" (p. 416). Given that the mental representations are related to L2 learners' performance, research into the L2 lexicon should pay more attention to the architecture of the L2 lexicon.

In order to understand the mental architecture of the second language lexicon, I pay attention to the dual functions of the language faculty (e.g., Jackendoff, 1997; Pinker, 1999). The dual functions include storage (i.e., memorizing lexical units) and computation (i.e., manipulating lexical units through rules). In the L1 literature, both storage and computation underlie many explanations regarding the functional organization of the lexicon or mental dictionary (e.g., Clashen, 1999; Ullman, Pancheva, Love, Yee, Swinney, & Hickok, 2005). In other words, L1 studies suggest that an appropriate characterization of the lexicon is likely to combine both computation and storage.

The organization of the L2 lexicon is presumably similar to that of the L1 lexicon, which implies that both storage and computation should be considered as integral to the study of L2 lexical acquisition. To date, however, in L2 vocabulary research, the consideration of this dual function is rarely applied. L2 vocabulary learning focuses mainly on the storage of words (e.g., de Bot, Paribakht, & Wesche, 1997; Jiang, 2002) and large lexical units such as formulaic sequences (e.g., Schmitt, 2004; Wray, 2002)[1].

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[1] See Abel (2003) for a notable application of the dual functions in examining L2 idioms.

Given that both storage and computation are integral in the lexicon, the computations of lexical information should be as important as the storage of words.

In order to explore the dual functions in the second language lexicon, I chose complex nominals as the linguistic target of this study. Complex nominals in this dissertation refer to the combination of two nouns such as *coffee cup*. Complex nominals provide an informative clue to understanding functional organization of the lexicon. A theoretical question regarding the representation and processing of complex nominals is whether a complex nominal such as coffee cup is represented as a single word (i.e., *coffee-cup*) or as two words (i.e., *coffee* and *cup*) or as three words (*coffee*, *cup*, and *coffee-cup*). This question corresponds to the theoretical ramifications of complex nominals: (1) full-listing models in support of holistic representations, (2) full-parsing models in favor of discrete representation, and (3) dual-route models integrating full-listing and full-parsing models.

Complex nominals in English have been used as a key linguistic target in L1 research literature to reveal the structure of the mental lexicon, including L1 acquisition (e.g., Clark, 1993; Nicoladis, 2003), L1 psycholinguistics (e.g., Gagné, 2001; Libben, 1998), L1 neuro-imaging studies (e.g., Fiorentino & Poeppel, 2007), and L1 aphasia studies (e.g., Badecker, 2001). One reason for the importance is related to the linguistic productivity of complex nominals in English. An intriguing aspect of complex nominals is that English native speakers interpret the meaning of novel complex nominals such as *beach beverage* easily and rapidly (Gerrig & Murphy, 1992; Murphy, 1990; Potter & Falconer, 1979; Springer & Murphy, 1992). The high productivity of complex nominals also entails that there always co-exist both familiar and novel complex nominals, which provides a good venue to examine the dual functions in the lexicon.

Insofar as the computations of complex nominals are concerned, previous L1 literature (e.g., Gagné, 2002) suggests that the semantic integration of a complex nominal involves two processes: (1) the meaning activation of each constituent in complex nominals and (2) the establishment of meaningful relations to combine each constituent. When interpreting *coffee cup*, for example, one activates not only the meaning of *coffee* and the meaning of *cup* but also one search for a meaningful relationship of the two words as a whole. This semantic integration would yield greater processing loads than a simple retrieval of the stored lexical representation. Given that L2 processing is less efficient than L1 processing, exploring the semantic integration process can provide an important insight as to how L1 and L2 speakers differ in terms of processing complex nominals.

At the same time, individual differences in how complex nominals are stored and/or computed may be related to diverse factors including the learners' first language backgrounds and their individual cognitive abilities. First, the headedness of the mother tongue may affect the recognition processes of L2 complex nominals because languages differ with respect to the headedness of compounds (right-headed compounds such as orange-juice vs. left-headed compounds such as juice-orange). Thus, L2 learners whose first language has a left-headed structure may find it more difficult to process right-headed L2 complex nominals than L2 learners whose compound structure in the first language is right-headed. Secondly, linguistic cognitive abilities including working memory capacity and linguistic inhibitory control ability may play a role in processing

L2 complex nominals. Individuals differ in terms of their cognitive ability to inhibit or suppress irrelevant information among competing sources. This ability is related to inhibitory control ability and working memory capacity, which are both an important part of executive functioning that controls and manages cognitive processes (Anderson & Green, 2001; Gass & Lee, in press; Green, 1998; Norman & Shallice, 1986). From the perspective of the functional architecture of the L1 and L2 lexicon, cognitive abilities such as working memory capacity and inhibitory control ability are likely to be associated with computational mechanisms, but not with retrieval systems. A reason for the potential effects of the cognitive abilities on computing complex nominals is that the cognitive abilities are observable in higher-order cognitive processes (e.g., Daneman & Carpenter, 1980; Waters & Caplan, 1996; Juffs, 2004). As illustrated above, semantic integration involves the resolution of competing information, which is related to higher processing costs than a simple retrieval of information from long-term memory. Thus, those who are better at inhibiting irrelevant information or in maintaining relevant information might be more efficient in semantic integration processes associated with complex nominal processing than those who are not. Within the broader psycholinguistic context, the importance of individual variables in general language processing research has been well-documented (e.g., Daneman & Carpenter, 1980; Just & Carpenter, 1992). However, the roles of individual cognitive factors have rarely been explored in L1 complex nominal processing, presumably because L1 processing of complex nominals is too efficient and automatized to be observed. In this regard, L2 processing of complex nominals could offer one way to examine the function of cognitive variables in L2 processing, given that L2 processing is generally less efficient.

Within the domain of second language acquisition, research needs to account for the interpretive processes of complex nominals by L2 learners, which includes not only how word meanings are accessed, but also how meanings are retrieved or created by the concepts of known words. In other words, L2 vocabulary research should integrate into the research agenda both computation and storage, a key in characterizing the attributes of complex nominals.

Beyond the domain of second language acquisition, researching L2 complex nominals has great potential for enriching the research basis of the mental lexicon. Particularly, interlanguage complex nominal data has certain methodological (e.g., the use of "authentic" or "real" complex nominals) and theoretical advantages (i.e., the less efficient/automatized processing system of L2 learners), which are difficult to examine through native speakers' performance in normal circumstances.

This dissertation is the first attempt, to the best of my knowledge, (1) to examine the representation and processing of complex nominals by second language learners, (2) to investigate complex nominal processing by native and non-native speakers within the context of an interference paradigm[2], and (3) to explore the effect of cognitive abilities (e.g., working memory capacity and inhibitory control capacity) on complex nominal

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[2] I hypothesize that the processing costs of semantic integration would differ in accordance with the number of meanings in each constituent. In this regard, I put forward four logically possible combinations of complex nominals; (1) single meaning – single meaning (e.g., coffee cup), (2) single meaning – multiple meanings (e.g., violin bow), (3) multiple meanings – single meaning (e.g., well water), and (4) multiple meanings – multiple meanings (e.g., lead mine). In general, I expect that the interferences related to each condition would differ. See Task 1 for more details.

processing, with two L2 learner groups whose L1 differs in terms of the headedness of compound structure.

The structure of this dissertation is as follows. Chapter 2 will give the necessary background for the various issues related to complex nominal processing. Chapter 3 consists of three tasks: Task 1 examines the representation and processing of complex nominals via an interference paradigm; Tasks 2 and 3 are concerned with the effect of two cognitive variables (i.e., inhibitory control ability and working memory capacity) on L2 complex nominal processing. Each task includes specific tasks, research questions, and results. Chapter 4 discusses the results of the three tasks in relation to the architecture of the second language mental lexicon. Chapter 5 concludes the dissertation not only with future research directions but also with the contributions of this dissertation to language science and to second language acquisition.

CHAPTER TWO - BAKGROUND

2.1. Linguistic Target: Complex nominals

This dissertation is concerned with how native speakers and non-native speakers interpret a combination of two nouns (i.e., complex nominals) in English with a special reference to the dual functions in the lexicon. Particularly, the focus of this study is familiar compounds such as *orange juice* and *coffee cup*. The familiarity of compounds is operationalized as the existence of compounds in a large English corpus containing spoken and written data.

In English, complex nominals are one of the most well known examples of linguistic productivity as the creation of complex nominals is a highly productive morphological process (e.g., Adams, 1973; Bolinger & Sears, 1981; Bauer, 2001; Clark, 1993; Katamba, 1993; Stockwell & Minkova, 2001). The high productivity of complex nominals using two nouns implies that there always exist novel complex nominals that are understood in a language community (e.g., Downing, 1977; Levi, 1978). Thus, complex nominals are a shortcut to enriching the lexicon in the sense that single words in the lexicon are used to create a new complex nominal.

In what follows, I first narrow the scope of the targets of this study with respect to terminology and writing conventions and then, I describe some linguistic characteristics of complex nominals that are relevant to the focus of this study: (1) headedness, (2) the semantic transparency of each noun in compounds, and (3) the semantic relation between the two nouns.

Terminology. Various names for complex nominals have been used in the literature. In linguistics, complex nominals (e.g., Levi, 1978) are called noun-noun compounds (e.g., Clark, 1993; Warren, 1978), root-root compounds (e.g., Nicoladis, 2007), nominal compounds (e.g., Zimmer, 1972; van Jaarsveld & Rattink, 1988; Blanken, 2000), or nominal compounding (e.g., Bauer, 1978; Downing, 1977; Zimmer, 1971, 1972). In cognitive psychology, complex nominals often refer to concept combination (e.g., Costello & Keane, 2001; Estes & Glucksberg, 2000). For the sake of ease of exposition, I will consistently use "complex nominals" to encompass all the names in the literature and will not make any theoretical distinction among the various terms.

Writing conventions. English complex nominals have typically three forms: (1) a space between two nouns (e.g., coffee cup), (2) a hyphen between two nouns (e.g., tape-record), and (3) no space between two nouns (e.g., football). A common account of how these three forms develop over time is that an English complex nominal tends to begin with a space between two nouns, and then the complex nominal appeared to be hyphenated when the complex nominal became recognized as a single word, and finally the complex nominal does not have a space or a hyphen when it became a single word (Börjars & Burridge, 2001; Quirk, Greenbaum, Leech, & Svartvik, 1985)[3]. For example, Jesperson (1968) pointed out that the word *today* originated from *to* and *day*, and also in

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[3] Yet, the historical explanation of the writing conventions of English complex nominals is not always clear. Rather, many linguists pointed out that the writing conventions are a random process (Adams, 1973; Katamba, 1993; Napoli, 1996; Wardhaugh, 1995). For example, Quirk, Greenbaum, Leech, and Svartvik (1985) demonstrated that some words in English can be used in the three forms such as *flower pot*, *flower-pot*, and *flowerpot*.

the 1920's the hyphenated form *to-day* was used. The evolutionary account suggested that open compounds that do have a space are less likely to be stored as a single word in the lexicon, considering that compounds without a space are likely to be lexicalized. Thus, this dissertation limits the scope of linguistic targets to open compounds which have a space between two nouns.

Headedness. Complex nominals (e.g., *coffee cup*) consist of a modifier noun (i.e., *coffee*) and a head noun (i.e., *cup*). A head inherits the basic attributes of a complex nominal such as syntactic and semantic information, whereas a modifier functions as a quality adjective (Dressler, 2006). For example, a *coffee cup* is a type of cup and inherits its syntactic and semantic attributes of being an inanimate concrete noun from the head (i.e., cup); the modifier *coffee* offers a more detailed meaning such as "a cup used for coffee".

Interestingly, languages differ with respect to the headedness of complex nominals (Dressler, 2006; Jarema, 2006). In many languages such as Chinese, English, and Korean, the head is positioned on the right (e.g., apple-juice) and thus complex nominals in these languages are in the order of a modifier and a head. Some languages such as Hebrew, Spanish, Thai, and Vietnamese are left-headed (e.g., juice-apple), although Romance languages tend to insert a preposition between two nouns (e.g., sugo di mele 'juice of orange' in Italian)[4]. In these left-headed languages, complex nominals have the order of a head and a modifier.

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[4] See 2.4.1.1. for a more detailed description of compound structures of Romance languages.

Semantic transparency of two constituents. In English, most complex nominals are endocentric (Bauer, 2001; Plag, 2003). In an endocentric complex nominal in English, the meanings of each constituent are semantically transparent and contribute to the interpretation of the complex nominal as a whole. Put differently, the meaning of the whole compounds can be clearly guessed from its constituents. In a word such as *coffee cup*, for example, both the meaning of *coffee* and the meaning of *cup* are semantically transparent and contribute to the interpretation of *coffee cup* as a cup used for coffee[5]. In this dissertation, I focus on endocentric complex nominals in which both constituents in the complex nominals are semantically transparent (e.g., coffee cup) because it is more interesting to see how one interprets the whole meanings based on each constituent, which he or she knows the meanings of both.

Diverse relations between two nouns. Random selections of two nouns cannot lead to the creation of a complex nominal. Complex nominals can be interpreted only when the relation of a modifier and a head in a complex nominal is established in a meaningful way. There exist diverse semantic relations between two nouns embedded in complex nominals. For example, *coffee cup* is a cup used for drinking coffee, whereas *paper cup* refers to a cup made of paper. Indeed, the analysis of diverse semantic relations of complex nominals has been one of the most demanding tasks for linguists (Downing, 1977; Jespersen, 1942; Levi, 1978; Marchand, 1960; Shoben, 1991; Warren, 1978).

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[5] In English there are also exocentric compounds such as *skinhead* and *hatchback* do not have a head, and the meaning of the whole compounds cannot be clearly guessed from its constituents (Bauer, 1983, p. 203). In many cases, exocentric compounds do not have a space between two nouns.

Table 1. Levi (1978)'s categorizations of semantic relations in complex nominals[6]

Predicates	Examples	Subject/Object
CAUSE1	tear gas	Object
CAUSE2	drug deaths	Subject
HAVE1	apple cake	Object
HAVE2	lemon peel	Subject
MAKE1	silkworm	Object
MAKE2	snowball	Subject
USE	steam iron	Object
BE	soldier ant	Object
IN	field mouse	Object
FOR	horse doctor	Object
FROM	olive oil	Object
ABOUT	price war	Object

Several earlier linguistic approaches have been contradictory regarding how relations are used to combine individual constituents in compounds (e.g., Downing, 1977; Gleitman & Gleitman, 1970; Kay & Zimmer, 1976; Levi, 1978). Some linguists (Gleitman & Gleitman, 1970; Levi, 1978) claimed that there is a finite set of relations when a modifier and head are combined. For example, Levi (1978) proposed that a set of 12 relations can explain the majority of the interpretation of complex nominals, as illustrated in Table 1. In contrast, other linguists (Downing, 1977; Kay & Zimmer, 1976) argued that complex nominals could have an infinite set of interpretations. In sum, although there was divergence on the number and characteristics of the relations embedded in complex

[6] The distinction between Subject and Object is based on the role of a modifier (i.e., the first constituent). Levi argued that the relationship between a modifier and a head can be characterized in terms of a two-place predicate (subject-predicate-object). For example, *tear gas* means *gas* CAUSES *tear*, in which the modifier *tear* is in the position of object.

nominals, various linguistic approaches have agreed that the relation between modifiers and heads plays an important role in interpreting complex nominals.

Lexicalized versus novel complex nominals. As mentioned earlier, complex nominals are highly productive in English. The high productivity entails the new addition of complex nominals to the mental lexicon. A useful way to conceptualize the mental representation of complex nominals is a distinction between lexicalized and novel complex nominals (Fiorentino & Poeppel, 2007; Gagné, 2002; Gagné & Spalding, 2006; Jaarsveld, Coolen, & Schreuder, 1994; Jaarsveld & Rattink, 1988; Libben, 2006; Nicoladis, 2003; Plag, 2003). A lexicalized complex nominal (e.g., orange juice) refers to a complex nominal that language users are familiar with because it is frequently used or encountered. In contrast, a novel complex nominal (e.g., sand pie) refers to a complex nominal that language users rarely or never encounter, but still understand the meaning of.

However, the distinction is not always clear-cut. Frequency is widely used as an indicator of whether a complex nominal is lexicalized; the more frequently a word is used, the more likely the word is lexicalized. The frequency-based assumption is a probabilistic statement but not an absolute criterion. Gagné (2002: 724) notes that a continuum between lexicalized and novel complex nominals could be a better way to characterize the distinction between them.

2.2. L1 psycholinguistic models of compounds

Complex nominals, the target of this study, a type of multimorphemic word, have been a linguistic focus in trying to broaden the understanding of the structure of the mental lexicon. As described in 2.1., the recognition[7] of a complex nominal can be achieved (1) not only when language users know the meanings of each constituent in the complex nominal (2) but also when they are able to establish the meaningful relationship between the two constituents.

These two characteristics of complex nominals provide us a good rationale to examine the dual functions in the lexicon. Psycholinguistically speaking, the comprehension of complex nominals involves an interpretive process where (1) the single meaning of the whole complex nominal exists in the mind or (2) the concepts of each constituent are combined to express a single notion of a complex nominal. The two interpretive processes of complex nominals allow us to examine an important insight not only as to how word meanings are assessed, but also as to how meanings are created by virtue of known familiar meanings (see Libben, 2006 for more theoretical importance of complex nominals). In this regard, complex nominals provide a good venue to examine the dual functions in the lexicon.

A theoretical question regarding the processing and representation of a complex nominal such as *orange juice* is whether it is (1) stored as a whole, (2) stored discretely, or (3) stored as three lexical entries (i.e., *orange, juice,* and *orange-juice*). There is a theory in favor of whole-word representations (e.g., Bybee, 1995; McClelland, Rumelhart, & the PDP research group, 1986; Rumelhart, McCelland, & the PDP Group, 1986); there is also a theory in support of computations (e.g., Clahsen, 1999; Marslen-Wilson, Tyler,

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[7] I use "recognition", "interpretation", and "comprehension" interchangeably. In this study, I do not make any theoretical distinctions among them.

Waksler, & Older, 1994; Rastle & Davis, 2008; Rastle, Davis, & New, 2004; Taft, 1979 , 2004); there is a theory that bolsters both whole-word representations and computations (e.g., Baayen, Dijkstra, & Schreuder, 1997; Caramazza, Laudanna, & Romani, 1988; Pinker & Ullman, 2002). Interestingly, the different models of complex nominals seem to be related to the theoretical backgrounds of researchers in such a way that, in general, psychologists prefer retrieval mechanisms associated with memory structures whereas linguists favor computations in conjunction with the internal structures of complex nominals. Although both the whole-word accounts and the computation-based accounts appear plausible, insights from both linguistics (in favor of computation) and psychology (in support of retrieval) seem necessary in order to examine the dual functions associated with complex nominals.

In what follows, I sketch the theoretical background for the representation and processing of complex nominals. The first three accounts, as briefly mentioned above, are concerned with how the meaning of each constituent in a complex nominal is activated or accessed: (1) a full-listing account, (2) a full parsing account, and (3) a dual-routes account. The last two psycholinguistic accounts (the Competition-Among-Relations-In-Nominals model and the schema-based model) are concerned with how each constituent is integrated to obtain a meaningful interpretation.

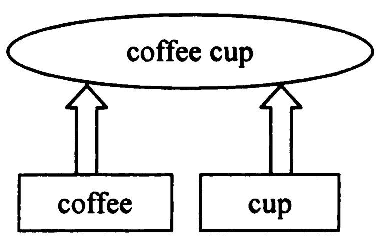
2.2.1. Activation of the whole word versus activation of each constituent versus both

2.2.1.1. Full-listing accounts versus Full-parsing accounts

In the L1 literature, there are two positions for the representations of multi-morphemic words. The first position supports the idea that the words are fully listed whereas opponents of this position claim that compound words are interpreted by a compositional process of separate lexical entries.

According to the full-listing or full-storage accounts (e.g., Bybee, 1995; Butterworth, 1983; Manelis & Tharp, 1977; Monsell, 1985; Rumelhart, McCelland, & the PDP Group, 1986), multimorphemic words such as complex nominals do not involve compositional processes of morphemes, but rather they are stored as a "chunk" and therefore directly retrieved from long-term memory. That is, these accounts see complex nominals in terms of whole-word representations without resorting to complex internal structures of the compound. Figure 1 illustrates how a complex nominal may be represented in a full-listing model, in which the whole meaning of a complex nominal is present in the long-term memory.

Figure 1. An illustration of a full-listing model

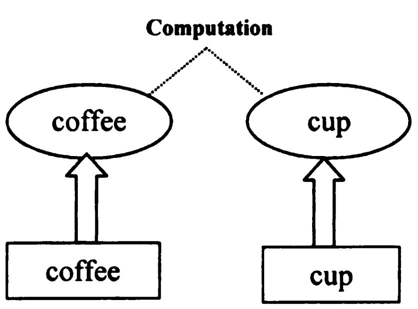


There are two main pieces of evidence in support of the full-listing account. First, the formation of complex nominals is not fully rule-driven. Butterworth (1983), for example, argued that compounds are stored and processed as whole words because morphological rules cannot provide a full account for the productivity of compounds. Secondly, the structures of complex nominals are characterizable in terms of frequency.

Bybee (1995), for instance, claimed that compounds are fully stored without abstract representations of their complex structure. Her model argues that a constituent structure is the effect of frequency-mediated associative activations of related forms. According to her model, each individual word in a low-frequency compound will be recognized more strongly as an independent constituent because they have stronger lexical activations. Overall, the full-listing account claims that the meaning of a complex nominal is represented as a whole word.

On the other extreme, compounds are assumed to be fully and invariably parsed. This full-parsing approach claims that compounds are automatically and obligatorily parsed into constituents via a decompositional route (e.g., Clahsen, 1999; Giraudo & Grainger, 2000; Marslen-Wilson, Tyler, Waksler, & Older, 1994; Rastle, Davis, & New, 2004; Taft, 1979, 2004). Figure 2 illustrates how a complex nominal may be represented and processed in a full-parsing model.

Figure 2. An illustration of a full-parsing model



The main argument in support of the full-parsing models comes from the constituent activation. That is, the meanings of each constituent in a complex nominal are accessed during the processing of complex nominals. An early study by Taft and Forster (1976) using a lexical decision task found that compounds undergo online decomposition, arguing for the existence of morphological constituents in compounds. Furthermore, a dense body of recent L1 psycholinguistic research has indicated that the constituent activation is related to semantic transparency in recognizing complex nominals (McQueen & Cutler, 1998). That is, the constituent activation in compound processing emerges at least when a constituent is semantically transparent. Priming for compounds, for example, has identified that the interpretation of compounds is related to the recognition of constituents in compounds, particularly with compounds having semantically transparent constituents (Andrews, 1986; Inhoff, Briihl, & Schwartz, 1996; Libben, Gibson, Yoon, and Sandra, 2003; Lima & Pollatsek, 1983; Sandra, 1990; Taft, 1994; Taft & Forster, 1976; Zwitserlood, 1994). Sandra (1990) found the priming effect only with semantically transparent constituents but not with opaque constituents. Zwitserlood (1994) reported that total and partial transparent compounds in Dutch are associated with a priming effect. Libben, Gibson, Yoon, and Sandra (2003) examined four types of compounds classified by semantic transparency: TT (transparent-transparent, e.g., car-wash), OT (opaque-transparent, e.g., strawberry), TO (transparent-opaque, e.g., jailbird) and OO (opaque-opaque, e.g., hogwash). They found morphological constituency in all four types of compounds, regardless of semantic transparency.

A strong piece of evidence in favor of the full-parsing account is that people can understand a novel compound without difficulty. Libben, Derwing, and de Almeida (1999) examined the prelexical parsing of ambiguous novel compounds such as *clamprod*, which could be interpreted either as clam + prod or as clamp + rod. Specifically, they tested the two possibilities: (1) a first possible parse where the first possible constituent is always parsed (i.e., clam + prod) and (2) a last possible parse where the constituent is parsed until the parser reached the maximally possible constituent (i.e., clamp + rod). They found that both interpretations emerged in a morpheme recall task and in a semantic priming task, suggesting that morphological parsing yields multiple representations.

Recent studies suggest that even lexicalized complex nominals may undergo an obligatory parsing process (e.g., Fiorentino & Poeppel, 2007; Gagné and Spalding, 2004). Fiorentino and Poeppel (2007) examined the morphological processing of lexicalized compounds (e.g., airplane), using visual lexical decision with MEG (Magnetoencephalography). They found the effect of early decomposition of lexicalized compounds, suggesting that morphologically complex words have internally structured representations. Gagné and Spalding (2004) claimed that familiar compounds such as *snowball*, which are likely to be lexicalized, seem to behave like novel compounds in the sense that the familiar compounds get involved in computational processes. They found that the interpretation of familiar compounds (e.g., snowball), patterned with that of novel compounds when relation availability was manipulated. Specifically, participants responded faster to target combinations (e.g., *snowball,* 'a ball made of snow') after seeing a prime combination with the same relation (e.g., *snowfort*, 'a fort made of snow') than that with the different relation (e.g., *snowshovel* 'a shovel for snow'). The findings do not necessarily contradict the presence of lexicalized complex nominals, while indicating that even a lexicalized complex nominal is not irrelevant to a computational process.

Overall, the full-parsing account claims that the meanings of each constituent are accessed and combined via a computation.

2.2.1.2. Dual-routes accounts

Instead of taking such an extreme position as full-listing models and full-parsing models, dual-route models use both a compositional route and a whole-word access route, although there is divergence on how the two routes are utilized (e.g., Baayen, Dijkstra, & Schreuder, 1997; Bertram, Schreuder, & Baayen, 2000; Caramazza, Laudanna, & Romani, 1988; Frauenfelder & Shreuder, 1992; Laudanna & Burani, 1985; Pinker & Ullman, 2002). That is, when a complex nominal is encountered, the language parser tries to find a unified representation of the complex nominal, as well as to construct the meaning of the complex nominal using each of the constituents[8]. For example, the Morphological Race (MR) Model, a parallel dual-route model, suggests that both compositional and whole-word mechanisms are available and the two routes race in processing complex nominals (Baayen, Dijkstra, & Schreuder, 1997). In general, the MR model claims that familiar compounds are accessed as a whole-word because whole-word access routes tend to win the race in processing familiar compounds. Figure 3 illustrates how a dual-route account represents a complex nominal in its model. As in Figure 3, the dual-route models not only search for the stored complex nominals (e.g., *coffee-cup*) but also attempt to combine two constituents (*coffee* and *cup*).

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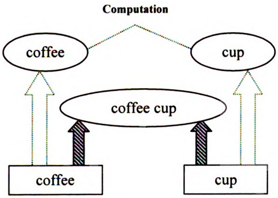
[8] It should be also noted that the idea of dual function models are closely related to the characterization of past tense in English. For example, Pinker (1999) claims that irregular forms are stored as wholes while regular forms are computed/generated by rules (see Pinker and Ullman, 2002 for a review).

Much empirical evidence seems to support dual-route models in the L1 literature (e.g., Andrew, Miller, & Rayner, 2004; Inhoff, Radach, & Heller, 2000; Juhasz, Inhoff, & Rayner 2005; Pollatsek, Hyönä, & Bertram 2000). Inhoff, Radach, and Heller (2000) found that German compounds are associated with a facilitative effect when there are spaces between the constituents of compounds. However, the spaces in compounds had interfering effects on the creation of an overall meaning of compounds. They interpreted the findings as the involvement of both access to constituents and combining the constituents together. Using an eye-tracking technique, Andrew, Miller, and Rayner (2004) found that the frequency of the first-constituent influenced first fixation, the frequency of the second-constituent affected gaze duration, and the frequency of the whole-word has a significant effect on gaze duration and total looking time. They proposed a process of segmentation-through-recognition, in which compounds are accessed via both constituent and whole-word representation.

Figure 3. An illustration of a dual-route model



Of relevance is the earlier discussion on characterizing complex nominals as a continuum between lexicalized and novel complex nominals. Gagné and Spalding (2006b) proposed that the presence of two independent parallel processes such as direct retrieval from memory and an algorithmic route should be the most direct explicit methods of viewing compound processing as a continuum from lexicalized to novel compound. For example, Gagne & Spalding (2006c) claimed that while admitting the possibility of storing familiar compounds, the even familiar compounds are fully parsed. They explain the dual functions related to compound processing in terms of "availability" and "familiarity". A general assumption of compounds in the L1 literature is that a high frequent compound (estimated by a corpus) is likely to be stored as a single lexical item in memory. Gagne and Spadling named this possibility the "availability" in the sense that the item is available in the memory and can be retrieved. However, they argue that high frequency compounds may not simply mean holistic representations; rather, the high frequency could mean "familiarity" in the sense that compounds that are encountered very frequently could lead to easier computations.

In summary, the dual-route accounts incorporate both full-listing and full-parsing models into their models.

2.2.2. The activation of relation: The locus of computation

The L1 psycholinguistic models in 2.2.1 questioned whether L1 speakers activate a unified representation or separate representations of each constituent or both, when processing complex nominals. Regarding the full-paring and the dual-function models, however, the meaning activations of each constituent does not necessarily imply the computations of the activated meanings of each constituent. As seen in 2.1., an appropriate interpretation of a complex nominal requires the establishment of combinations of two nouns in a meaningful relation. Thus, the integration of each constituent in a meaningful way is as important as the activation of each constituent and/or the whole word representation, in order to explain the recognition of complex nominals in real-time. It is the obligatory combinatorial processes of each constituent in complex nominals that provide use a rationale for the presence of computation in processing complex nominal.

L1 cognitive psychology research has paid attention to the psycholinguistic mechanisms of establishing the relations of two nouns in novel complex nominals (Estes & Glucksberg, 2000; Gagné, 2002; Gagné & Shoben, 1997, 2002; Murphy, 1988, 1990; Wisniewski, 1996), suggesting that there is an obligatory process of selecting the interpretable relation between two nouns to establish a unified representation. Overall, the interpretation of complex nominals can be characterized either in terms of thematic relations, for example 'IN' for the complex nominal *mountain cloud* (Gagne & Shoben, 1997) or with respect to property attribution, for example, 'mushroom-shaped' for the complex nominal *mushroom cloud* (Estes & Glucksberg, 2000).

In the L1 psycholinguistic literature, the activation of a relationship between two nouns has been tested by examining whether previous exposure to a complex nominal (e.g., orange juice) facilitated the interpretation of a subsequent complex nominal (e.g., strawberry juice) which has the same semantic relation as the previous one. Two major lines of psycholinguistic research have developed which depend on whether either modifiers or heads in complex nominals play a key role in establishing a relation between two nouns in complex nominal processing: A schema-based theory (Murphy, 1988, 1990; Wisniewski, 1996) versus CARIN (competition among relations in nominals) theory (Gagné & Shoben, 1997, 2002). In general, the schema-based theory proposes that head nouns in complex nominals are responsible for activating the relational structures while the CARIN theory claims that modifier nouns in complex nominals activate the relational structures of the complex nominals.

According to the schema-based theory (a slot-filling approach), the head noun in a complex nominal is represented by a structural set of slots and fillers. The schema-based theory claims that, in the course of concept combination (i.e., the interpretations of complex nominals), the modifier (the first noun in English complex nominals) serves as a filler for a slot in the head noun (the second noun). For example, *paper cup* (a cup made of paper) is interpreted by taking the modifier *paper* into the MATERIAL slot within the schema for *cup*. The head noun (i.e., cup) provides a slot where a modifier (i.e., paper) can be inserted. Therefore, the head noun plays a key role in interpreting a complex nominal. In this theory, more availability of the slot in a head will lead to easier interpretations of complex nominals. Conversely, no appropriate slot in the head noun will result in nonsensical interpretations of complex nominals. For example, the reason that a complex nominal *air cup* is nonsensical or difficult to interpret without a context is that the head noun *cup* does not have an appropriate slot for the modifier noun *air*.

In contrast, the CARIN theory does not assume the replacement of a modifier inside the head noun's schema. Instead, the CARIN theory emphasizes the role of the modifier (i.e., the first noun) in complex nominal processing. It argues that the modifiers trigger/activate the competition of possible semantic relations with the heads (the second noun). Through the competition, the most appropriate semantic relation is selected and used to connect the modifier and head noun concepts. In the CARIN theory, the more available the required relation, the easier it is to interpret complex nominals For example, when *mountain* is a modifier, the relation used to interpret a complex nominal is likely a LOCATION relation (e.g., mountain lake) but less likely an ABOUT relation (e.g., mountain magazine).

When connecting the relation activation models to the previously discussed constituent activation models, the relation activation models are compatible with the full-parsing account and the dual-routes account because relation activation assumes compositional processes. For example, Gagné (2002: 733) claimed that two routes might be available for selecting a relation during conceptual combination: (1) an algorithmic route that combines the two constituents based on information in the modifier's relational distribution and (2) the retrieval route.

This dissertation will not test whether the schema-based theory or the CARIN theory is more plausible. Rather, the reason that I introduce the two models is that, when computational routes are assumed to be used, the recognition of complex nominals requires the inhibitions of irrelevant relational structures among many possible relations. Put differently, the interpretations of complex nominals are not a simple union of two constituents in a complex nominal. What both the schema-based and the CARIN theories have in common is that there are not only the activations of relational structures that semantically connect each constituent in a complex nominal but also an obligatory selection process of relationships between two nouns. Therefore, I assume that, during the selection processes, computations should be a part of complex nominal processing.

Figure 4 illustrates how computational processes may occur during the recognitions of complex nominals by taking the processes of relation selection into account. Figure 5 is a modified version of a dual-route model where computational processes are a search for an appropriate relation between each constituent.

Figure 4. A revised illustration of a full-parsing model

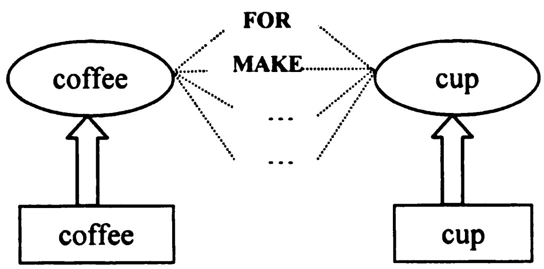
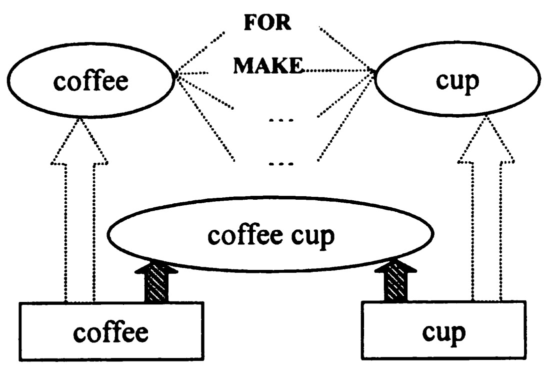


Figure 5. A revised illustration of a dual-route model



2.3. The theoretical importance of examining L2 complex nominal data in understanding the structure of the mental lexicon

2.3.1. Within SLA research

The psycholinguistic attributes of complex nominals (i.e., storage and computation) are closely analogous to the architecture of the mental lexicon proposed in the L1 literature, where it has been suggested that both computation and storage are necessary for an appropriate characterization of the lexicon (e.g., Clashen, 1999; Jackendoff, 1997; Pinker, 1999; Ullman, Pancheva, Love, Yee, Swinney, & Hickok, 2005). For example, Libben (2006) claimed that the lexicon may be functionally structured to maximize both computation and storage in the mental representation. Therefore, the notions of computation and storage in the lexicon may not be mutually exclusive; but complementary, reflecting behavioral patterns of language users, and therefore, the individualized architecture of lexicons.

However, the role of computation in the lexicon has not been highlighted in L2 vocabulary learning (see Abel, 2003 for a notable application of dual functions in L2 idiom research). Much L2 vocabulary research tends to be storage-based (e.g., de Bot, 1992; de Bot, Paribakht, & Wesche, 1997). For example, one of the most common research areas in L2 vocabulary learning is the study of formulaic sequences such as *as soon as* and *on the contrary*. The formulaic sequences refer to "a sequence, continuous or discontinuous, of words or other meaning elements, which is, or appears to be, prefabricated" (Wray, 2000: 465). In general, the formulaic-sequence studies support the holistic representations of formulaic sequences; that is, formulaic sequences are stored as whole words and retrieved from long-term memory (Altenberg, 1998; Jiang & Nekrasova, 2007; Raupach, 1984; Schmitt & Carter, 2004; Weinert, 1995; Wray, 2002). The holistic representations of formulaic sequences seem plausible considering that the whole meaning of a formulaic sequence such as *as soon as* is more important in production and comprehension than the meanings of individual words in a formulaic sequence.

There are two important differences between the current study and the previous studies of formulaic sequences: (1) The semantic transparency of constituents in multi-words and (2) the productivity. First, a study of formulaic sequences such as *as soon as* is concerned not with how each constituent in the formulaic sequence is combined. That is, each constituent in a formulaic sequence such as *as soon as* is not necessarily semantically transparent in the sense that the meaning of the whole formulaic sequence may not be guessed from the constituents made up of the formulaic sequence. In contrast, the current study is concerned with a case where two words are semantically transparent (e.g., apple juice) while the formulaic-sequence literature is mostly based on a case where the meaning of the whole phrase (e.g., as soon as) is useful. Note that, as mentioned in 2.2.1., the meaning activation of each constituent is a key idea of investigating the validity of either full-parsing or dual-route models of complex nominals. A clear point in Section 2.2. is that the interpretation of complex nominals involves lexical access to both the modifier and head noun concepts and/or to the whole-phrase concepts as well as computational or retrieval processes. The understanding of complex nominals must include not only how word meanings are accessed, but also how meanings are retrieved or created by the concepts of known words. Contrary to the formulaic-sequence studies, therefore, this study is in a better position to examine the role of both computations and retrievals in L2 lexical, morphological processing.

The second difference between the current study and the previous studies of formulaic sequences is that the current study is concerned with a highly productive morphological process while the studies of formulaic sequences deal with prefabricated or ready-made lexical items.

Novel complex nominals are less likely to be stored as a whole in the lexicon because the creation of a new complex nominal implies the absence of the complex nominal in the lexicon. An intriguing aspect of complex nominals is that English native speakers interpret the meaning of novel complex nominals easily and rapidly (Gerrig & Murphy, 1992; Murphy, 1990; Potter & Falconer, 1979; Springer & Murphy, 1992). Thus, if non-native speakers know the meanings of each word, they may not show difficulty in understanding the nominal. This, in turn, suggests that they can produce meaningful computations using the known meanings of each word, which is not the part of research questions of formulaic-sequence study.

While highlighting the importance of computations in the L2 lexical processing, this study would provide empirical support for researching stored chucks because it handles both computations and retrievals. A general assumption of the usage-and-storage based account of formulaic sequence is that the more proficient an L2 learner, the more words stored in their mental lexicon (e.g., Ellis, 2005; Schmitt, 2004). In the current study, L2 learners may be more likely to rely more on computational routes in processing even familiar complex nominals because familiar complex nominals may function as novel complex nominals. The more reliance on computational routes by L2 learners would indicate that L2 learners are less efficient in using retrieval routes or have less number of stored lexical information, providing a good rationale to examine the role of stored lexical information.

In summary, complex nominals allow us to examine the role of computation and storage in the lexicon. I do not argue against the usage-and-storage based L2 vocabulary accounts, dominant in second language acquisition research. However, the accounts should accommodate another key aspect of the lexicon, that is, the mental computation of words. L2 vocabulary research becomes more balanced by integrating two key aspects (i.e., storage and computation) of L2 vocabulary acquisition.

2.3.2. Beyond SLA research

Complex nominals have been used as a key linguistic target in the L1 research literature to reveal the structure of the mental lexicon in relation to dual functions, including L1 acquisition (e.g., Clark, 1993; Nicoladis, 2003), L1 psycholinguistics (e.g., Gagné, 2001; Libben, 1998), L1 neuro-imaging studies (e.g., Fiorentino & Poeppel, 2007) and L1 aphasia studies (e.g., Badecker, 2001). However, second language research has not been reflected in the mainstream of complex nominal studies.

Empirical research, as Juffs (2001, p. 311) noted, enables SLA researchers to contribute to L1 and L2 theoretical literature through the testing and validating of theoretical constructs. Researching L2 complex nominal processing will enrich the research basis of the mental lexicon. Methodologically, L2 research is able to use "authentic" or "real" complex nominals that can be found in a large corpus because the real complex nominals may not be stored in L2 learners' minds. L1 research has heavily relied on novel compounds to examine how conceptual information is combined because familiar compounds are likely to be stored in memory, yet novel compounds must involve combinatorial processes to be interpreted (e.g., Gagné & Shoben, 1997; Gagné, 2001). A methodological issue of using novel compounds is related to the familiarity and plausibility of the novel compounds, as pointed out by Wisniewski and Murphy (2005). That is, the use of novel compounds leads to difficulty in controlling the familiarity and plausibility of the stimuli, which is well-known for significant variables for online studies. In this regard, the L2 data based on the responses to "real" complex nominals are appealing and provide an important clue of the continuum between lexicalized and unlexicalized complex nominals.

Theoretically, the less efficient processing system of L2 learners could provide a better understanding of the continuum between lexicalized and novel complex nominals, enriching the research base on the mental lexicon. Morphological processing by native speakers (NS) tends to be too efficient and quick to observe the mechanism, and therefore the processing is typically invisible. For example, Gagne and Spalding (2006c, p.13) state that the relation selection process in complex nominal processing cannot be observed in a normal circumstance with native speakers. Rather, the processing of complex nominals is observable when the meaning is difficult to access, as in aphasia (e.g., Badecker, 2001; Blanken, 2000; Delazer & Semenza, 1998; Dressler & Denes, 1989; Libben, 1998; Rochford & Williams, 1965) or when the relation selection process is accelerated via priming paradigms (e.g., Estes & Jones, 2006; Gagné, 2001, 2002; Gagné & Shoben, 2002; Raffray, Pickering, & Branigan, 2007). In this regard, the less efficient processing ability of non-native speakers as compared to native speakers could provide an important clue to complex nominal processing.

2.4. Compounding Factors that affect L2 complex nominal processing

In this section, I outline the variables that may influence L2 learners' performance when they process complex nominals. Specifically, I put forward two learner variables (i.e., the headedness of L1 compounds and cognitive ability) and one item variable (i.e., frequency).

2.4.1. Learner variables

2.4.1.1. L1 influence: Headedness

L1 influence is a perennial, interesting topic in second language research. As described in Section 2.1., languages differ with respect to the headedness of compounds. In Chinese and Korean, compounds are always right-headed and thus have an identical compound structure in terms of the position of the head. In Korean, for example, the English translation of *math teacher* is swuhak 'math' + senseeyngnim 'teacher', where the head 'teacher' is in the same right-position as in English (see Sohn 1999 for more details about complex nominals in Korean). Thus, the compound structure of English and Korean are identical at least on the surface, in terms of the position of the head and modifier, although detailed linguistic analyses will differ.

Table 2. Examples of complex nominals in Thai

Complex nominals Thai	English translations
/aahǎan dèk/	'baby food' > food + child
/caan khâaw/	'rice plate' > plate + rice
/ŋən dūan/	'monthly money' > money + month
/thǔŋ tháaw/	'socks' > bag + foot

In contrast to English, Chinese, and Korean, compounds in Thai and Spanish are left-headed, although there are some right-headed compounds in Thai and Spanish. For example, a corresponding expression of an English word 'house key' in Thai is /kuncɛɛ/ 'key' + /bâan/ 'house', in which the head of the compound is the first constituent[9]. Other left-headed compounds in Thai can be seen in Table 2 (Iwasaki, Ingkaphirom, and Horie, 2005, p. 37).

Spanish is somewhat different from Thai in terms of the productive forms of complex nominals, although both the languages share the left-headed structure of complex nominals. In Spanish, a simple combination of noun and noun is less productive. Table 3 shows a handful of examples for noun-noun compounds without a preposition (Bradley & Mackenzie, 2004, p 304).

Table 3. Less productive forms of complex nominals in Spanish

Complex nominals in Spanish	English translations
Página web	Web page
Horno microondas	Microwave
Video juego	Computer game
Satellite espía	Spy satellite
Placa madre	Motherboard

9 According to Iwaski, Ingkaphirom, and Horie (2005), Thai has a limited number of right-headed complex nominals. An example of right-head compounds is /muu thuu/ 'hand-held telephone', in which /muu/ means 'hand' and /thuu' refers to 'carry'.

A more common case of compounds in Spanish is that two constituents in a compound are linked by a preposition (Bradley & Mackenzie, 2004, p 304), as in Table 4.

Table 4. Productive forms of complex nominals in Spanish

Complex nominals in Spanish	English translations
Jugo de piña	Pineapple juice
Ropa de playa	Beachwear
Hoja de cálculo	Spreadsheet

A handful of studies have examined L1 influence on the production and comprehension of L2 complex nominals with respect to the headedness of L1 complex nominals. Slabakova (2002) tested whether the differences in L1 morphological structure influence L2 performance, by comparing French learners of Spanish and English learners of Spanish. In Spanish, a language with left-headed compounds, as described above, a productive morphological process of compounding is to insert an obligatory preposition, typically *de*, into two nouns in a compound, as in *zapatos de tango* (tango shoes); thus, ungrammatical is a compound without the preposition such as *zapatos tango*. The patterns are also true in French. Importantly, in English, both noun-noun compounds (e.g., tango shoes) and their phrasal counterparts (e.g., shoes for tango) are allowed. In forced multiple choice questions, Slabakova (2002) found that French learners of Spanish outperformed significantly English learners of Spanish in rejecting ungrammatical noun-noun compounds and complex predicates, when both NNS groups have comparable low levels of Spanish proficiency. She claimed that the findings indicate the L1 influence of morphological structures on comprehending the L2 constructions because the constructions are not used or ungrammatical in French (as in Spanish) whereas they are available in English.

Also, Liceras and Díaz (2000) have examined whether the headedness of L1 complex nominals affects the production of L2 complex nominals. In picture-naming tasks, they examined learners of Spanish with different levels of L2 proficiency, in terms of (1) noun-noun compounding strategies and (2) the trigger of the L2 acquisition of noun-noun compounding. They argued that noun-noun compounding is not a marked option because both intermediate and advanced learners of Spanish produced noun-noun compounds frequently, which are not a productive process in Spanish. Also, they claimed that directionality (changing from a right-headed to a left-headed word order) triggers the L2 acquisition of Spanish noun-noun compounds because all learners, regardless of their L1 backgrounds and L2 proficiency, did make mistakes in producing gender-marking patterns, in which only the head is supposed to bear gender-marking morphemes in Spanish.

Some bilingual child studies also have identified compound reversals, in which the order of a head and a modifier is reversed. Nicoladis (1999) reported that, in spontaneous speech, a three-year old French-English bilingual child reversed the order of French compound approximately 60 % and that of English compounds about 20%. Also, Nicoladis (2002) found that in a production task, French-English bilingual children reversed compounds in English more often than monolingual English-speaking children. However, she did not find the performance difference between the bilingual children and the monolingual children in a comprehension task.

The aforementioned L2 and bilingual studies suggest that the headedness of the L1 may affect the processes of L2 complex nominals. Yet, the previous studies are based on off-line measures of comprehending complex nominals or on less controlled production tasks. Thus, this study examines the role of L1 influence on the processing of L2 complex nominals via online elicitation tasks.

In general, the difference in the headedness among these languages offers an interesting opportunity to examine the L1 effect on L2 complex nominal processing during second language acquisition. The L1 influence is that there may be differential interference effects, depending on the convergence and divergence between mother and target languages. If the headedness of the L1 compounding structures plays a role, for example, I expect that Korean learners of English may encounter less interference in processing English compounds than Thai learners of English because English and Korean are right-headed whereas Thai is left-headed.

2.4.1.2. Cognitive abilities

2.4.1.2.1. Working memory Capacity

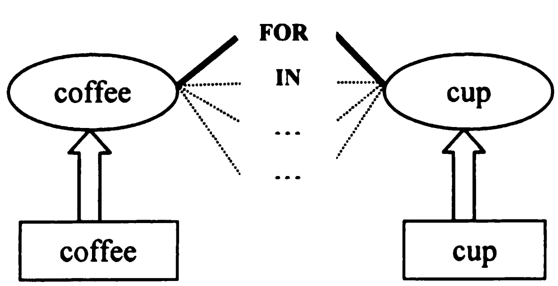
Numerous empirical studies suggest that working memory (WM) capacity is the locus of individual variations in various high-order cognitive tasks including language processing. Individuals with high WM capacity are suggested to be more efficient than individuals with low WM capacity in highly-demanding cognitive tasks including L1 (e.g., Daneman & Carpenter, 1980; Waters & Caplan, 1996) and L2 language processing (Harrington & Sawyer, 1992; Juffs, 2004). Assuming that complex nominal processing involves computation, it is possible that high WM individuals may be faster at combining the meanings of complex nominals than their low WM counterparts.

Working memory (WM) capacity involves the cognitive processes required to perform mental operations on chunks of information and the temporary storage of those chunks (Baddeley & Hitch, 1974; Cowan, 2005; Hasher, Lustig, & Zacks, 2007; Kane & Engle, 2003). Thus, WM encompasses both processing and storage of information. Importantly, a general consensus on WM is the complementary interaction between processing and storage; automatic processing gives more rooms for storage while controlled processing uses more spaces for storage (see Baddeley 2003 for an overview).

In cognitive science, there are many models of WM and there is considerable controversy on the exact nature of WM. One model looks at WM as the locus of controlled attention (Cowan, 2005; Cowan, Chen, & Route, 2004; Kane & Engle, 2003); Inhibition interprets WM as the ability to suppress irrelevant information (e.g., Hasher, Lustig, & Zachs, 2007; Gernsbacher & Faust, 1991, Gunter, Wagner, & Friederici, 2003); Activation models claim that WM plays a key role in keeping relevant information active (e.g., Miyake, Just, & Carpenter, 1994; Just & Carpenter, 1992); Another model describes WM as a task-switching ability (Hegarty, Shah, & Miyake, 2000). Importantly, the various models of WM are not mutually exclusive. Rather, they are complementary in terms of the trade-off between processing and storage of information.

The processing of a complex nominal involves the semantic integration of two nouns, in which the two nouns should be combined in a meaningful relationship. As described earlier, the semantic integration of the complex nominal is likely to involve the activations of various relational structures and an obligatory process of selecting a relational structure that gives an appropriate interpretation of the complex nominal. In this process, WM may play a role. Let us relate complex nominal processing to the various models of WM; one who is good at inhibiting irrelevant relational structures among many possible relations would be efficient in processing the complex nominal; one who has a better controlled attention would be faster in selecting a best relational structure and in suppressing irrelevant structures; one who are better at keeping relevant relational structure would be effective in processing the complex nominal. Therefore, it is worthwhile to examine whether high WM individuals may be faster at the semantic integration of complex nominals than their low WM counterparts. Figure 6 illustrates this process; the two solid lines represent the selection/maintenance of a relevant relation between *coffee* and *cup*, while dotted lines shows the inhibition of irrelevant relations.

Figure 6. An illustration of the potential relationship between WM capacity and complex nominal processing



An assumption I made is that the presence of computation in complex nominal processing allows us to examine the potential role of WM capacity in the processing. As discussed earlier, there are at least three models of complex nominal processing: (1) a full-listing model, (2) a full-parsing model, and (3) a dual model. A full-listing model does not predict any role of WM because the computation is not the part of the model. In contrast, a full-parsing account and a dual model predict that WM capacity may play a role in complex nominal processing because both models incorporate semantic computations into their models.

The final relevant point is that the effect of WM is generally observed with high-order cognitive activities. Put differently, the complexity of linguistic targets interacts with WM capacity and thus the effect of WM can be more prominent when individuals encounter complex items (Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle, 2005). Taking an example from language processing, the WM effect has been found in filler-gap dependencies where long-distance integration is required (e.g., Fiebach, Schlesewsky, and Friederici, 2001). King and Just (1991) found that WM capacity interacted with the complexity of linguistic targets. They compared the processing of subject relative clauses and object relative clauses; in general, object relatives are more complex than subject relatives so that object relatives requires more processing costs (see Just & Carpenter 1992 for a review). In a self-paced reading task, King and Just asked participants to remember one or two unrelated words while reading sentence; then, the participants were asked to judge the plausibility of the sentences. They found that the low span readers are significantly less accurate in comprehending object relatives than subject relatives, suggesting that WM plays a greater role in processing a processing costlier complex sentence such as object relatives than a sentence requiring less processing costs such as subject relatives. When relating the complexity requirement for observing the role WM capacity to complex nominal processing, there appears to be, to the best of my knowledge, no L1 empirical research on the relationship between WM capacity and complex nominal processing. The absence of L1 studies in this area is not surprising because complex nominal processing by native speakers is a speedy process that may not be observed in a normal environment.

However, L2 research could provide fruitful information in this area. A general consensus of L2 processing is that L2 learners have less efficient processing mechanisms than L1 speakers. Therefore, the delayed processing of complex nominal (i.e., slow semantic integrations in this study) would be related to L2 learners' WM capacity. In addition, the complexity requirement of WM allows us to test the effect of WM capacity with L2 learners whose L1 morphological structures differ (right-headedness vs. left-headedness in this study). For example, L2 learners whose L1 has left-headed structures may reveal more interference in processing L2 complex nominals which are right-headed than those who have right-headed compound structures in their L1. In this context, the effect of WM is likely to emerge in L2 learners whose L1 morphological structure differs from L2 equivalents.

2.4.1.2.2. Inhibitory Control Ability

Inhibitory control refers to mental processes that allow one to ignore or suppress irrelevant information when competition information is present. A representative measure of inhibitory control ability is the Stroop task where, for example, when a color word such as RED is visually presented in blue, one is asked to name the ink color but not the word written in. It is important to note that individuals vary in inhibitory control ability (Green, 1998). For example, when linguistic information competes, those who are good at inhibiting irrelevant linguistic information may perform better than those who are not (e.g., Kane & Engle, 2003; Kiefer, Ahlegian, & Spitzer, 2005).

Aphasia research provides a clue to the relevance of inhibitory control ability in compound processing. Libben (1998) reanalyzed the impairment in the comprehension of compounds by an aphasic patient, RH as a case of inhibition failure. When asked to choose which one does not belong from the list of TULIP, CARNATION, ROSE, and OAK, the patient RH chose CARNATION rather than the correct answer OAK. When asked the reason, she indicated that she chose it because CARNATION is a brand name for evaporated milk. Libben claimed that RH was unable to inhibit or ignore the activation of the subordinate (evaporated milk) meaning, even when CARNATION was presented with highly semantically related words such as TUILP and ROSE. That is, according to Libben, all the meanings for CARNATION were activated, due to the failure of RH's inhibitory control ability. Another example reported in Libben (1998) is that, when RS asked what *dumbbell* means, her response was "stupid weights…Arnold". Libben (1998) interpreted her response as the meaning activations of both constituents and the whole compound; the word *stupid* seems to be produced in conjunction with a constituent *dumb* while such words as weights and Arnold (Arnold Schwarzenegger) appear to be made through the meaning activations of the whole word (i.e., a type of exercise weight). This, in turn, suggested that the interpretation and production of complex nominals can be gained by inhibiting irrelevant competing information, particularly during the process of semantic integration.

An expectation for inhibitory control ability in complex nominal processing is that the inhibitory control ability may function similar to the WM capacity because both cognitive abilities are a type of executive functioning that controls and manages cognitive processes (e.g., Green, 1998; Norman & Shallice, 1986). As discussed earlier, compositional processes are a part of processing complex nominals particularly in the sense that two nouns in a complex nominal must find a relational structure that leads to a meaningful relationship between the two nouns. For example, the meaning relationship of *coffee cup* is FOR (i.e., a cup for coffee) but not is IN, BE, CAUSE or MADE OF. All relational structures such as FOR, IN, and BE could be activated in recognizing a complex nominal because, in theory, each constituent can have innumerable combinations. For example, *coffee* could be combined with diverse nouns.

Table 5. The top 20 high-frequency complex nominals with coffee as a modifier

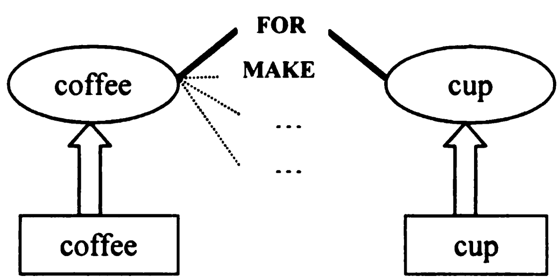
Rank	Modifier	Head	Frequency	Rank	Modifier	Head	Frequency
1	COFFEE	TABLE	1631	11	COFFEE	MACHINE	113
2	COFFEE	SHOP	1169	12	COFFEE	BAR	99
3	COFFEE	CUP	599	13	COFFEE	GROUNDS	99
4	COFFEE	BEANS	223	14	COFFEE	MAKER	99
5	COFFEE	POT	223	15	COFFEE	GRINDER	65
6	COFFEE	MUG	217	16	COFFEE	PLANTATIONS	59
7	COFFEE	CUPS	195	17	COFFEE	FARMERS	53
8	COFFEE	HOUSE	161	18	COFFEE	CANS	49
9	COFFEE	BREAK	123	19	COFFEE	FILTER	49
10	COFFEE	CAKE	117	20	COFFEE	ROOM	49

Table 5 illustrates the diverse combinations when *coffee* is used as a modifier in a complex nominal; the items in Table 5 is the most frequent top 20 items in the corpus of contemporary American English (Davies, 2009; see Task 1 for the detailed description of the corpus).

Given that all the possible relational structures are activated, the recognition of complex nominals requires the inhibitions of irrelevant relational structures among many possible relations. In this regard, one's cognitive ability to inhibit irrelevant information is likely to be related to how one processes complex nominals, when the use of computational routes is assumed to be used in complex nominal processing.

Let me describe the relevance of inhibition to the process of combing two constituents into a single representation or the process of relational selection in complex nominal processing, from the perspective of the CARIN (Gagné & Shoben, 1997, 2002) theory. As mentioned earlier, the CARIN emphasized that the availability of relations increases the interpretability of complex nominals. In both unambiguous and ambiguous complex nominals, for example, the CARIN model suggests that complex nominal processing involves competition among the possible relations. Yet, an alternative using an inhibition mechanism should also work. It may not be sufficient enough to explain the use of relations in complex nominal processing in terms of the availability of as many as possible relations and competitions among relations. It is highly plausible that higher availability of a relation will increase the range of selection and thus result in reduced processing time. However, in order to end up with a single interpretation, an individual should ignore or inhibit the irrelevant relation between modifiers and heads. Then, it is plausible that an individual who is good at inhibiting irrelevant relations associated with complex nominals would show better performance than a counterpart who has low inhibitory control ability. Figure 7 illustrates the relation selection process in terms of the CARIN theory; the dotted lines represent the inhibition of irrelevant relational structures in processing *coffee cup* while the two solid lines show the selections of an appropriate relational structure.

Figure 7. The potential role of inhibitory control ability on complex nominal processing with the framework of CARAN



As Figure 7 illustrates, the irrelevant activated relational information should be eliminated during semantic composition. Therefore, examining the processing of complex nominals may provide a good linguistic venue for determining the role of inhibitory control in second language acquisition.

Importantly, given the "invisibility" of the process in a normal circumstance (Gagne & Spalding, 2006b), I may not find that native speakers show the effect of inhibitory control ability on the recognition of complex nominals. In this regard, interlanguage data could provide another piece of evidence of the relevance of inhibitory control ability to the recognition of complex nominals, as suggested by the aforementioned aphasia studies.

2.4.2. An item variable: Frequency

Examining the frequency effect of complex nominal processing allows us to evaluate the three models of complex nominal processing discussed in 2.2.1.: (1) full-listing accounts, (2) full-parsing accounts, and (3) dual-routes accounts. A direct and widely accepted method to test the presence of retrieval routes is to examine the frequency of the whole words because empirical supports for full-listing models are grounded on frequency of the whole compounds (see Bybee, 1995). The basic idea of examining the frequency effect is that the more frequently complex nominals are used, the more likely they are to become lexicalized or to be stored as a whole. Therefore, looking at the role of frequency could be a good testing basis for the use of retrieval routes in the interpretation processes of complex nominals.

At the same time, in the L1 literature, the validity of computational routes in complex nominal processing has often been tested by examining the manipulated constituent frequency while keeping invariant the frequency of whole complex nominals (Andrews, Miller, & Rayner, 2004; Hyönä & Pollatsek, 1998; Juhasz, Starr, Inhoff, & Placke, 2003; Lima & Pollatesk, 1983; Shoolman & Andrews, 2003; Taft, 1979; Taft & Foster, 1976). Overall, empirical evidence revealed a facilitative effect of high-frequency constituents on the recognition of complex nominals, although there are mixed results for whether either the first or the second constituent or both has a greater effect. For example, *farmhouse* is easier to recognize than *graveyard* because both *farm* and *house* are high-frequency words whereas *grave* and *yard* are low-frequency words (Juhasz, Starr, Inhoff, & Placke, 2003).

Note that L1 research in support of full-parsing models or dual-route models has focused more on the frequency of each constituent (e.g., *coffee* and *cup*) in a familiar or novel complex nominal not only because the frequency effect of the whole familiar complex nominal (i.e., *coffee cup*) is always expected but also because, understandably, the frequency of novel complex nominals cannot be obtained. Thus, it may be less interesting or may not even be falsifiable that the frequency effect of the whole complex nominal emerges in native speakers. In contrast, interlanguage data allow us to examine the frequency effect of familiar complex nominals (i.e., coffee cup) because L2 learners would be less likely to store a familiar complex as a whole. Thus, it is a falsifiable hypothesis that there is a frequency effect of the whole complex nominal in non-native speakers.

Another difference between NS and NNS is that, in the case of NS, the effect of the whole-word frequency does not necessarily mean the presence of retrieval routes (see Gagne and Spalding, 2006b). The effect of the whole-word frequency in native speakers may be due to faster processing or efficient computations of complex nominals, indicating that the whole-word frequency effect could be inconclusive for the presence of retrieval routes. In contrast, the whole-word frequency effect by NNS could be a piece of supporting evidence for the retrieval routes, given that NNS may have less efficient processing systems in comparison to NS.

In general, with respect to the three models of compound processing, the examination of the frequency of whole complex nominals leads to three expectations. A full-listing account predicts a strong association of the frequencies of complex nominals and participants' performance. A full-parsing account expects no strong association while a dual-account predicts a moderate correlation.

2.5. General objectives

This dissertation investigates the regularity and the systematic patterns of second language acquisition of complex nominals, and explores the source of individual variation in second language acquisition. There are three major objectives in this dissertation as listed below. Specific hypotheses of each objective will be put forward in task 1, 2, and 3.

Objective 1. *Difference between NS and NNS in terms of dual functions*

Do both NS and NNS groups use retrieval and computational routes in recognizing complex nominals?

Objective 2. *L1 influence on L2 complex nominal processing*

Does L1 morphological knowledge (i.e., headedness) affect the processing of L2 complex nominals?

Objective 3. *The effect of cognitive abilities on the recognition of complex nominals*

Are L1 speakers and L2 learners with higher cognitive abilities (such as better inhibitory control ability and higher working memory capacity) more efficient in processing complex nominals that those with lower capacity?

CHAPTER THREE – RESEARCH DESIGN AND METHODOLOGY

3.1. Overview of the study

There were three computer-based tasks in this study: (1) a lexical sense decision task, (2) a working memory test, and (3) an inhibition test. Participants took part in all three tasks and did the three tasks in the order of (1) a lexical sense decision task, (2) a working memory test, and (3) an inhibition test. The first task was designed to examine whether native speakers and non-native speakers use either computational routes or retrieval routes or both when they comprehend complex nominals. For this, I created an interference design for complex nominal processing, which has not been tested in either the L1 or the L2 literature. Specifically, four experimental conditions were created in terms of the number of meanings of each constituent in a complex nominal (i.e., single-single such as *coffee cup*, single-multiple such as *violin bow*, multiple-single such as *well water*, and multiple-multiple such as *lead mine*). With an assumption that semantic integrations are involved in recognizing complex nominals, the second and the third task examined the role of cognitive capacity, which may be related to the performance of L2 learners. The second task was intended to investigate whether working memory (WM) capacity is related to the interpretations of complex nominals. The third task was aimed to examine the effect of inhibitory control ability on the recognition of complex nominals.

3.2. Task 1: Complex nominal processing in an interference paradigm

The goal of Task 1 was two-fold. First, I investigated the dual functions of the second language lexicon through the recognition of complex nominals. Specifically, Task

1 tested whether some complex nominals involve either semantic computations or retrieval mechanisms from long-term memory or both. Secondly, I examined whether the recognition of L2 complex nominals is influenced by the headedness of compound structure in the first language.

For this, as explained in Chapter 2, the linguistic target was familiar and semantically transparent complex nominals such as coffee cup. The term "familiar" is operationalized as the existence of compounds in the COCA (Corpus of Contemporary American English, Davies, 2009) corpus, a large English corpus containing more than 400 million spoken and written data. The reason I determined to use "familiar" complex nominals stems from empirical findings of L1 dual-route models suggesting that familiar compounds are accessed via whole-word access while novel compounds are interpreted via computational routes (e.g., Baayen, Dijkstra, & Schreuder, 1997). The dual route models suggest that L2 learners are highly likely to use computational routes in processing "novel" compounds, given that L1 speakers rely on the computational mechanism when they process novel compounds. A more empirically interesting question is whether L2 learners are able to use retrieval routes in processing "familiar" complex nominals because L2 learners may not store as many whole-word representations of complex nominals as NSs do. Put differently, in order to compensate for the shortage, L2 learners may rely more on computational routes.

Using the familiar and semantically transparent complex nominals, I propose a new interference paradigm for the recognition of complex nominals in conjunction with a robust psycholinguistic finding of multiple meaning activations. Specifically, I integrate the two processes of semantic integration of complex nominals (i.e., the meaning activations of individual constituents and the combinatorial processes of establishing meaningful relationships between the individual constituents) with meaning activations of words. This experimental paradigm, to the best of my knowledge, has not been explored in either the L1 or the L2 literature.

A word can have many meanings. For example, an English homonym or homograph *bank* has multiple entries in a dictionary (e.g., *bank* of a river versus *bank* where you deposit money). Importantly, much psycholinguistic research has illustrated that all the meanings of a word seem to be initially activated when people encounter the word containing multiple meanings, typically through priming studies both with decontextualized items (e.g., de Groot & Keijzer, 2000; Jared & Kroll, 2001; Marian, Spivey, & Hirsch, 2003) and with contextualized items (Schwartz & Kroll, 2006; Swinney, 1979). Frenck-Mestre and Prince (1997) found that L2 learners also showed multiple activations of meanings when processing L2 homonyms, with an assumption that L2 learners know all the meanings.

We know that complex nominals consist of two constituents (i.e., a modifier and a head). Table 6 illustrates four logically possible combinations, depending on whether or not either a modifier (the first constituent in English) or a head (the second constituent in English) or both has multiple meanings: (1) SS: single meaning – single meaning (e.g., coffee cup), (2) SM: single meaning – multiple meanings (e.g., violin bow), (3) MS: multiple meanings – single meaning (e.g., well water), and (4) MM: multiple meanings – multiple meanings (e.g., lead mine). I operationalize a word having multiple meanings as a word containing at least two entries in a dictionary.

Table 6. The four experimental conditions in Task 1

Condition	Modifier	Head	Example
SS	single-meaning	single-meaning	*Orange juice*
SM	single-meaning	multiple-meanings	*Violin bow*
MS	multiple-meanings	multiple-meanings	*Well water*
MM	multiple-meanings	multiple-meanings	*Lead mine*

Assuming computational routes are utilized in interpreting a complex nominal, the four combinations provide us a good venue to examine the computational routes, which may be a function of the L2 lexicon. In particular, when assuming that the two processes of semantic integration are obligatory for complex nominal processing, the four conditions imply differences in processing costs during the processing of complex nominals. First, the four conditions differ with respect to the meaning activations of individual constituents. The SS (single-single) condition implies the activations of single meanings of each constituent whereas the MM (multiple-multiple) condition entails the activations of multiple meanings of each constituent. SM (single-multiple) involves the activation of a single meaning of the first constituent and the activation of multiple meanings of the second constituent. In the case of the MS (multiple-single) condition, there would be the activations of multiple meanings of a modifier and the activation of a single meaning of a head.

Secondly, we know that the interpretations of complex nominals are not a simple union of two meanings of each constituent. Semantic integration processes of complex nominals involve the combinations of the meanings of each constituent into the whole meaning of a complex nominal. In other words, one should look for an interpretable relationship between two nouns. Also, we know that a word could be used in various semantic relationships. For example, *cup* is not just for *coffee cup*, but there are numerous contexts in which *cup* is used (e.g., paper cup, gold cup, etc). Within the contexts of the four experimental conditions, a constituent having multiple meanings provides more possible relationships between two nouns than a constituent having a single meaning. The activations of multiple meanings in the SM, MS, and MM conditions imply the increase in possible relationships between two nouns during the recognition of a complex nominal. With respect to processing cost, processing of the MM condition would be costlier than processing of the SM and MS conditions, which involve more processing costs than processing of the SS condition. Below are graphical representations of the four experimental conditions regarding the activations of meanings and relational structures.

Figure 8. The processing of a complex nominal in the SS condition

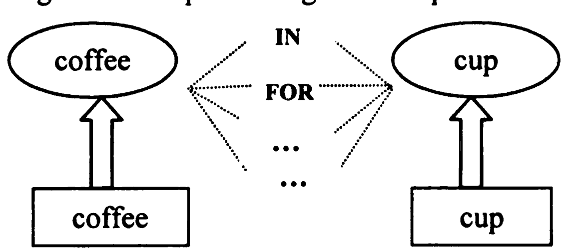


Figure 9. The processing of a complex nominal in the SM condition

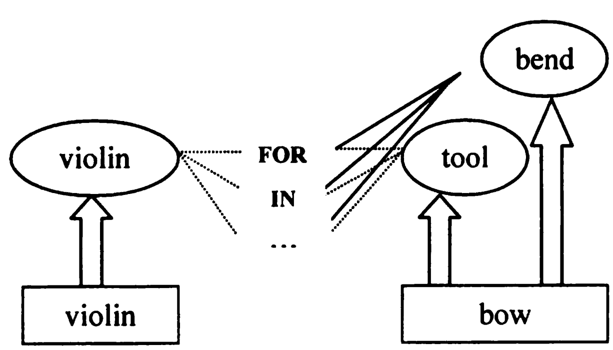


Figure 10. The processing of a complex nominal in the MS condition

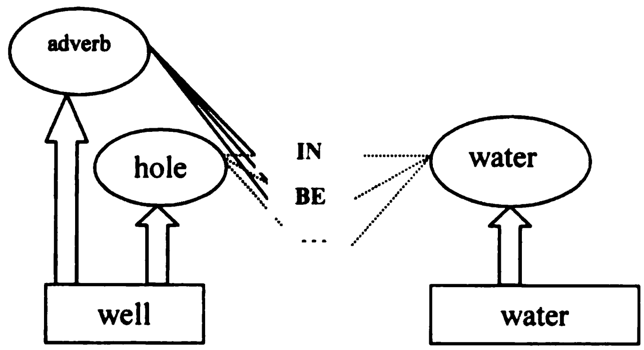


Figure 11. The processing of a complex nominal in the MM condition

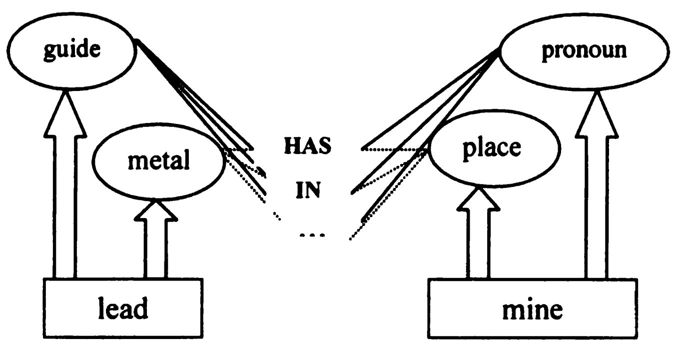


Figure 8, 9, 10, and 11 represent not only the meaning activations of each constituent in a complex nominal but also the processes of relation selection among the activated meanings. The rectangles show each constituent in a complex nominal, the ellipticals illustrate the activated meanings, and arrows demonstrate the meaning activations. The solid and dotted lines show the relation selection process and the capitalized bold words such as IN and MAKE mean the possible activations of relation structures among the activated meanings. As seen in the four Figures, the more the meanings of each constituent are activated, the more relation selections are available. To illustrate, Levi (1979) proposed that modifiers and heads in English compounds can be characterized as

12 meaning relationships. Let us assume that all of the 12 relations are activated in interpreting a complex nominal. Then, each constituent could have 12 relationships in semantic integration processes of complex nominals. For example, the interpretations of items in the SS condition could be selected via 12 x 12 relational possibilities, given that the items in the SS condition have a single meaning for both a modifier and a head. In the case of the MM condition, the interpretations of items may be 12 x 12 x 12 x 12 when assuming each activated meaning participates in establishing the relation between two nouns. In the same vein, the items in the SM and MS conditions would involve 12 x 12 x 12 activations of relational structure.

In the above processes, an assumption that I made is that all the possible relations are activated. However, it is an empirical question whether all the relations are activated in processing complex nominals. Some nouns, for example, tend to be used in a "typical" relation that might be indicated by its frequency. Particularly, the activations of relational structures could be guided by frequency. Examining the COCA corpus, a noun *juice* tends to be frequently used for MAKE 2 (e.g., orange juice 'juice made of orange') according to Levi (1978)'s taxonomy. Table 7 contains the top 10 uses of *juice* as a head in a complex nominal.

Nonetheless, my rationale for the four experimental conditions is that multiple meaning activations increase the numbers of relational structures. Put differently, probability would be a good term to describe the possibility of activations of relational structures. Complex nominals containing a multiple meaning word are more probable to get involved in the more complex selection processes of relational structures. Indeed, it may not be possible to define how many relational structures are activated in processing a complex nominal, as indicated by linguists' divergence on the number of relations between two nouns in a complex nominal (e.g., Gleitman & Gleitman, 1970; Kay & Zimmer, 1976; Levi, 1978).

Table 7. The most frequent uses of juice as a head noun

Items	The whole-word frequency	Items	The whole-word frequency
Lemon juice	3006	Grape juice	245
Orange juice	1970	Cranberry juice	213
Lime juice	1202	Tomato juice	174
Apple juice	409	Pineapple juice	125
Fruit juice	265	Grapefruit juice	106

The other assumption I made is that the computation is a part of complex nominal processing. The activations of relational structures are not expected if retrieval routes are fully responsible for recognizing complex nominals. With the assumption of the presence of computational routes in complex nominal processing, the differences in the meaning activations of each constituent and the activations of relation structures entail differences in processing costs across the four experimental conditions. Given the aforementioned numerical approximations of each condition, the SS condition involves the lowest processing costs, the MM condition would have the highest processing costs, and the SM and MS conditions would be in the middle.

Furthermore, in Chapter 2, we saw that the headedness of complex nominals differs across languages, which may affect L2 processing of complex nominals. For example, if L1 morphological knowledge plays a role in recognizing L2 complex nominals, the LH group may show more interference than the RH group in processing English complex nominals because the complex nominal structure of the LH group is different from that of English whereas the complex nominal structure of the RH group is identical to that of English. With respect to the four conditions, I predict that the behavioral differences between LH and RH groups will be greater as the processing costs increases. Yet, L2 proficiency needs to be taken into consideration. Particularly, when both the LH and the RH groups have the high level of L2 proficiency, the effect of L1 headedness on processing L2 complex nominals may not emerge in the sense that L2 learners become more independent of L1 as L2 proficiency increases (e.g., Frenck-Mestre & Prince, 1997; Kroll & Curley, 1988).

Taking all the consideration together, the following four research questions emerge.

The research questions of Task 1

RQ 1. *Difference between NSs and NNSs*

Do NSs show significantly better performance in all four conditions than the two NNS groups of high L2 proficiency?

Hypothesis 1:

The NS group performs better than the NNS groups, given that the NS group has an efficient processing ability as well as having more stored information.

I expect that the greatest difference between the NS group and the two NNS groups will be in the MM condition, which involves the greatest processing costs. However, in the SS condition where processing costs are low, I expect that the NS and NNS groups will not differ significantly.

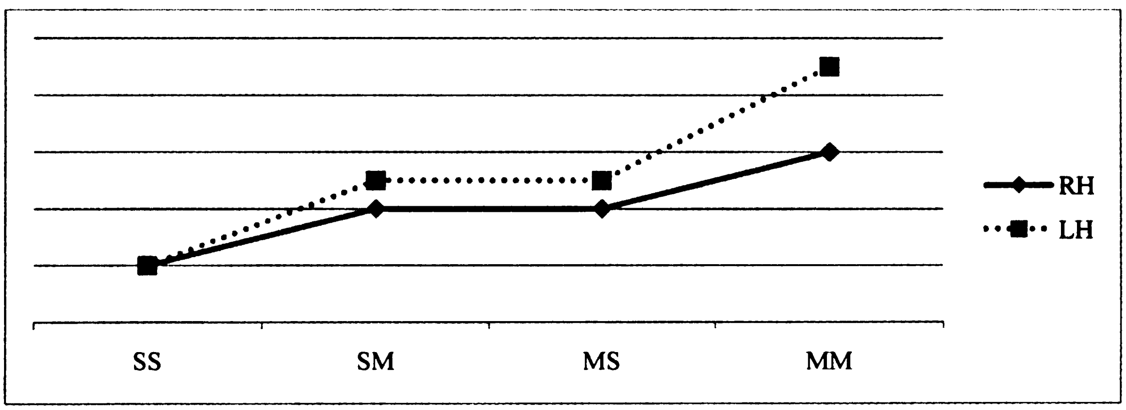
RQ 2. *L1 influence of morphological knowledge in processing L2 complex nominals*

Does the headedness of the L1 compound structure affect the processing of L2 complex nominals?

Hypothesis 2:

The difference in the headedness of the L1 compound structure affects L2 processing of complex nominals.

Figure 12. A prediction for the difference between the RH and the LH group in terms of reaction times



A general expectation is that, if L1 headedness plays a role in recognizing L2 complex nominals, the LH group may show more interference than the RH group in processing English complex nominals. More specifically, I expect that the difference between the two groups would be greatest in the MM condition which requires the greatest computational costs whereas the difference would be smallest in the SS condition where computational costs would be small. This prediction is illustrated in Figure 12.

Contrary to Hypothesis 2, Hypothesis 3 takes L2 proficiency into account. That is, the effect of L1 headedness on processing L2 complex nominals is not salient when two NNS groups having different headedness in their L1 morphology are highly proficient learners of the L2.

Hypothesis 3:

When comparing two NNS groups of high, comparable proficiency, the L1 effect, operationalized by the headedness of the L1, will be not significant between the two groups.

RQ3. *Uniform interference in the NS group versus graded interference in the NNS groups*

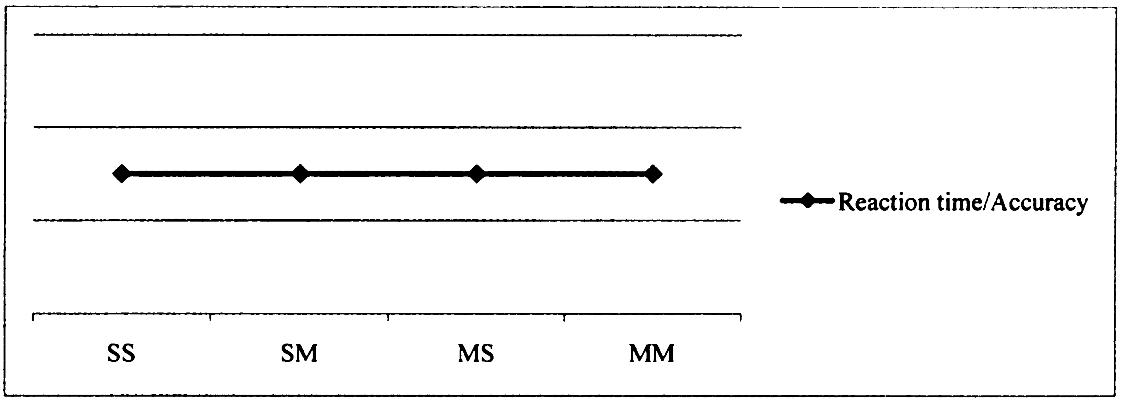
Do the NS group and the NNS groups differ in recognizing complex nominals in the four experimental conditions?

I predict that the NS and NNS groups will behave differently in the four conditions, particularly when the test items in the four conditions are familiar complex nominals. Familiarity is operationalized as existence in a large English corpus. This study uses complex nominals which actually occur in English, which enables us to make an interesting prediction as to different behavioral patterns between the NS and NNS groups.

Hypothesis 4 (NS):

Since the stimuli of this study are familiar complex nominals (which are found in a large English corpus), the NS group may rely more on the retrieval mechanism (or compute complex nominals efficiently). Thus, I expect that the NS group may not show a substantial difference in reaction times and accuracy across the four conditions (i.e., MM =MS = SM =SS).

Figure 13. A prediction for the NS group: Uniform interferences



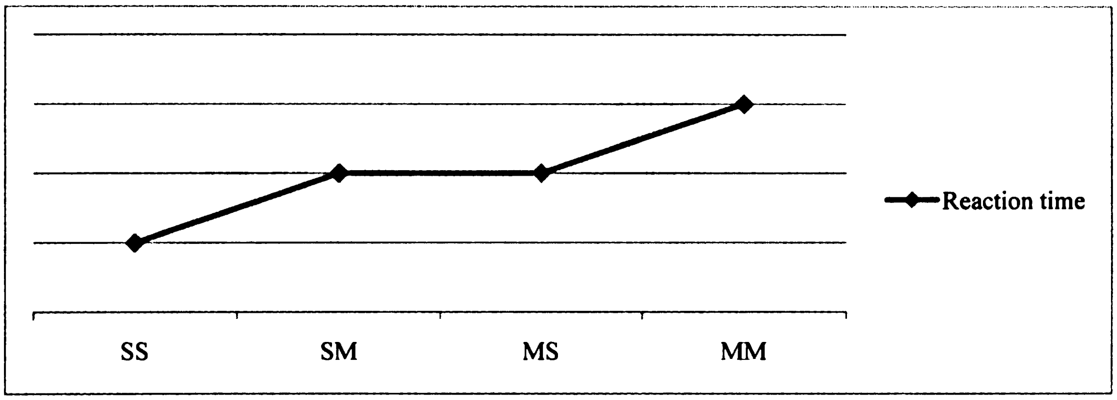
Although it is a bit controversial, it is generally accepted in the L1 literature that familiar complex nominals are recognized via retrieval routes whereas unfamiliar counterparts are interpreted via computational routes (e.g., Baayen, Dijkstra, & Schreuder, 1997; Bertram, Schreuder, & Baayen, 2000; Caramazza, Laudanna, & Romani, 1988; Pinker & Ullman, 2002). Given that familiar words are highly likely to be stored in the L1 lexicon and/or to be computed efficiently, a NS group may not show processing differences across the four conditions. In other words, a NS group would reveal a uniform interference across the four conditions which contain familiar complex nominals. Figure 13 demonstrates a hypothetical case of uniform processing costs by a NS group in the four experimental conditions.

Hypothesis 5 (NNS):

Since the stimuli of this study may function as *novel* complex nominals, the NNS groups may depend more on a computational route to interpret complex nominals. Thus, I expect that the NNS group may show a substantial behavioral difference among the four conditions. Particularly, given the manipulated difference of the four conditions in terms of meaning and relation activations, I expect that reliance on the computational route will yield the graded interference in accordance with the processing costs of each condition: the greatest interference in the MM condition, intermediate interference in the MS and the SM conditions, and the smallest inference in the SS condition (i.e., MM > MS, SM > SS).

With an assumption that the recognition of complex nominals involves computational processes, a NNS group may show graded processing difficulties in accordance with the number of meanings of an individual word embedded either in modifiers or in heads. In contrast to a NS group, a NNS group would demonstrate a different amount of processing costs in recognizing the familiar complex nominals of the four conditions. Specifically, I expect that unambiguous-unambiguous items involve the smallest processing costs among the four conditions while ambiguous-ambiguous items are associated with the greatest processing costs. Also, complex nominals containing an ambiguous item (i.e., MS or SM) would involve higher processing costs than unambiguous-unambiguous items, but may be related to less processing costs than ambiguous-ambiguous items. Figure 14 shows this hypothetical case of differences in processing costs.

Figure 14. A prediction for a NNS group: Graded interfere



RQ 4. *Comparing NSs and NNSs in terms of whole-word representations*

Do the frequencies of complex nominals as a whole play a significant role in recognizing complex nominals for both NS and NNS groups?

A canonical way to address the whole-word representations of a phrase is to examine the relationship between the frequencies of the whole phrases and the various measures related to the phrases such as response times. In this regard, the frequency of the whole complex nominals was examined to test the possibility of holistic representations of the complex nominals.

Hypothesis 6:

Given the robust effect of frequency in many L1 psycholinguistic studies as well as the familiarity of the stimuli in this study, a frequency effect will emerge for the NS group, particularly when the NS group processes complex nominals with high frequencies in a corpus. However, L2 learners are expected to show weaker or no frequency effects on recognizing L2 complex nominals because NNS groups may have a relatively smaller number of stored complex nominals.

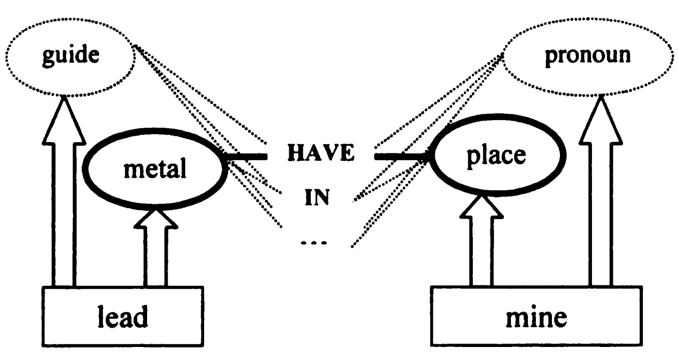
3.3. Task 2: Complex nominal processing and working memory capacity

Task 2 examines the potential role of a cognitive variable, working memory (WM) capacity, on L2 complex nominal processing. Specifically, Task 2 looks at the question of whether L2 learners with higher WM capacity are more efficient in processing a second language than their counterparts with lower WM capacity, when comparing the processing ability of NNS groups with comparable proficiency.

We have seen that the semantic integration of complex nominals involves many competitions, which are caused by (1) the meaning activations of each constituent and (2) a semantic integration process to combine two constituents in a meaningful relationship. Working memory (WM) capacity may play a role in this semantic integration process. As discussed in Chapter 2, there are many WM models including WM capacity as either inhibitory control/controlled attention or WM capacity as activation, yet these models are not mutually exclusive. Speaking of the meaning activations of each constituent, the interpretation of *lead mine* requires the suppression of irrelevant meanings of each constituent such as "guide" and "pronoun" or the controlled attention to relevant meanings such as "metal" and "place." Similarly, the integrations of two nouns require the suppression of irrelevant relational structures such as IN and CAUSE or the maintenance of a relevant relational structure such as HAVE. Considering the two possible roles of WM on the recognition of complex nominals, therefore, an individual having high WM capacity may be more efficient in interpreting *lead mine* than an individual with low WM capacity.

Figure 15 illustrates the functions of the WM capacity in the recognition of a MM (multiple meanings – multiple meanings) complex nominal such as *lead mine*. In Figure 18, the two solid ellipticals illustrate the maintenance of relevant meanings whereas the two dotted counterparts show the suppression of irrelevant meanings during the interpretive process of *lead mine*. Also, the two solid lines delineate the selection process of an appropriate relation of *lead mine* while the other dotted lines demonstrate the inhibition of irrelevant relations.

Figure 15. An illustration of the potential functions of the WM capacity in the recognition of a MM complex nominal



However, I do not expect that WM capacity exerts a role in processing all the complex nominals. Rather, the effect of WM would emerge with cognitively demanding tasks. An important assumption is that semantic integrations are a part of processing complex nominals; the effect of WM capacity is less likely to be found if the processing of complex nominals relies on retrieval routes, which is cognitively less demanding. That is, WM capacity, as described in Chapter 2, tends to be observed when an individual does cognitively demanding tasks. Within the current context, processing of MM complex nominals such as *lead mine* would be more cognitively demanding or involve greater processing costs than that of SS complex nominals such as *coffee cup*. Thus, the effects of WM are less likely to appear with SS complex nominals that require less processing costs than with MM equivalents.

The WM requirements for cognitively demanding tasks are related to the potential differences between NS and NNS groups in response times and accuracy. In the L1 literature, the role of WM capacity on complex nominal processing is rarely investigated. There might be two possible reasons in relation to the dual functions of the lexicon. First, if complex nominals are dependent upon a simple retrieval system, it is difficult to find a WM effect, which is more likely to be found in higher cognitive processes. Alternatively, although native speakers derive the meanings of complex nominals by computational routes (but not by a retrieval mechanism), the highly efficient morphological processing of native speakers does not allow us to observe the WM effect in natural circumstances. In other words, processing familiar complex nominals may not be cognitively demanding for the NS group.

In contrast, NNS groups lack two advantages that native speakers may possess because NNSs may have (1) a reduced number of stored complex nominals or (2) an inefficient or less automatized processing system. The disadvantage of non-native speakers may make the processing of complex nominals a cognitively demanding task, which, in turn, allows us to observe the effect of WM. An expectation is that cognitive ability is likely to compensate for higher processing loads of NNSs.

Furthermore, a different effect of WM would be expected between the two NNS groups, which have different headedness in their L1. One might expect that processing English complex nominals (right-headed structure) would be more cognitively demanding for the LH group than the RH group because the RH group has to switch the order of modifiers and heads in processing English complex nominals if their L1 morphological structure plays a role. Indeed, one WM model sees WM as a task-switching ability (Hegarty, Shah, & Miyake, 2000). Therefore, it may be the case that the effect of WM capacity on the recognition of complex nominals may be greater in the LH group than in RH group.

In sum, I expect that a WM effect on L2 complex nominal processing will be compounded with L1 background and the complexity of the test items. The two NNS groups in this dissertation have comparably high L2 proficiency; yet, the two groups differed with respect to the headedness of the compound structure in their L1s. The WM effect would be greater in the LH group whose L1 compound structure invokes more interference in processing L2 complex nominals than the RH group. As discussed in 2.4.1.2.1., the greater effect of WM emerged with the more complex items. Thus, I expect to find the effect of WM only in the MM condition, but not in the SS condition. Taking the above considerations into account, the following research question will be examined in Task 2.

The research question of Task 2

RQ. The effect of WM capacity on complex nominal processing.

Are L1 speakers and L2 learners with higher WM capacity more efficient in processing complex nominals than those with lower capacity?

Hypothesis:

There might be no substantial effect of WM on complex nominal processing, due to the NS group's efficiency in morphological processing. In contrast, I expect the effect of WM capacity on L2 complex nominal processing. Particularly, given that the complexity of the target is related to WM capacity, I expect that the LH group will show a significant WM effect on L2 complex nominal processing in the condition involving the highest processing costs (i.e., the MM condition).

To recapitulate, WM capacity is likely to be observed in relation to the dual functions. The reliance on the retrieval mechanism or the use of faster computations would result in no effect of the WM capacity in recognizing complex nominals, as illustrated in Figure 16. Semantic computations may be related to the WM effect only when the computations involve high processing costs. With respect to the reaction times of the participants, WM capacity is expected to be inversely related to the semantic integration of the NNS groups because those who have the higher WM capacity would be faster in responding to complex nominals than those who have lower WM capacity. In contrast, the accuracy scores may be positively related to the WM capacity, given that high WM individuals are efficient in processing information and have more storage of information. The idea is shown in Figure 17.

Figure 16. A prediction of the WM effect in case of retrievals or efficient computations

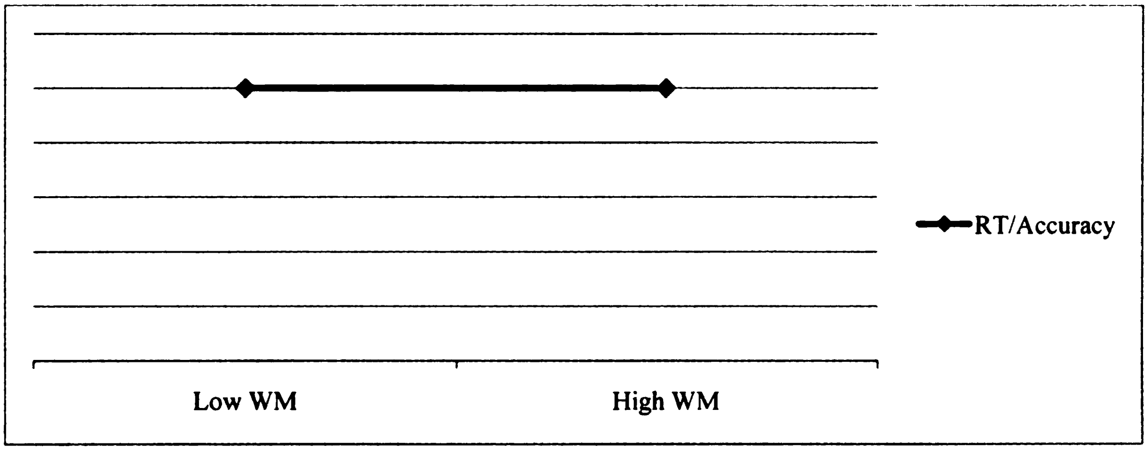
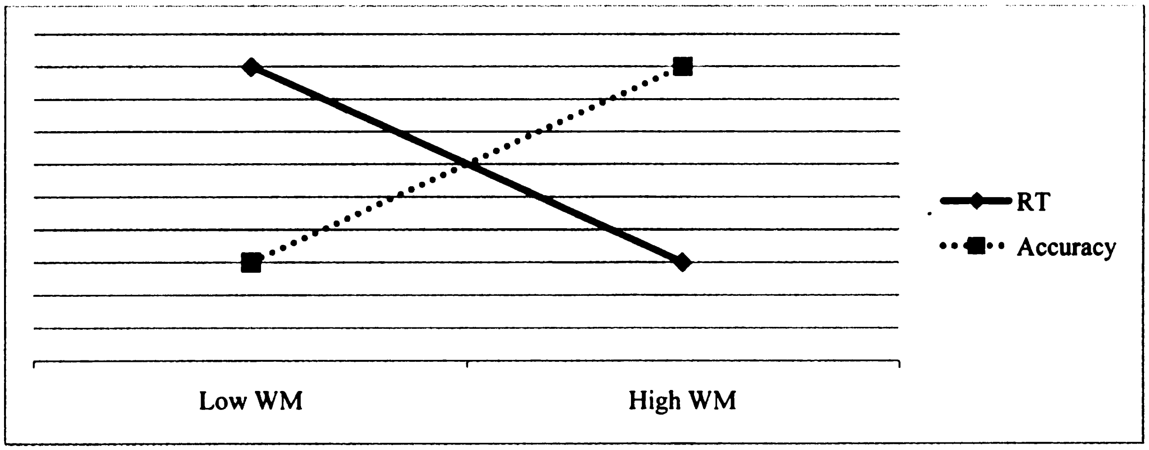


Figure 17. A prediction of the WM effect in case of the delayed computations



3.4. Task 3: Complex nominal processing and inhibitory control ability

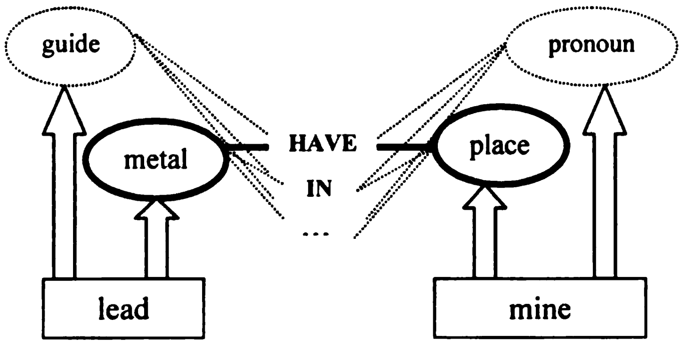
Inhibitory control ability refers to resistance to interference or the ability to suppress or inhibit irrelevant information. The Stroop task (Stroop, 1935) is known as the representative measure of inhibitory control ability (MacLeod, 1991). In the Stroop test, participants see color words (e.g., RED, BLUE, and GREEN), in which color could be either matched (e.g., RED in red) or unmatched (e.g., RED in blue). The task is to name the color of the font but not the name of the word; when seeing a word RED written in BLUE, for example, participants have to name RED. In the Stroop task, participants are in essence asked to inhibit irrelevant information (the color of the words) between two pieces of competing information that are automatically accessed (i.e., the orthography of the words and the color of the words). Importantly, individuals vary in this inhibitory control ability.

Inhibitory control ability appears highly related to the performance in the recognition of complex nominals. A piece of supporting evidence, as noted in 2.4. comes from aphasia studies which show that aphasic patients failed to inhibit irrelevant information in comprehending and producing complex nominals. Such examples as carnation and dumbbell reported in (Libben, 1998) illustrate that an aphasic patient did not inhibit irrelevant meanings of compounds while using both the meanings of the whole word and the meaning of the constituents.

A general prediction of this study is that inhibitory control ability functions similarly to working memory capacity, given that inhibitory control ability is a member of executive functioning (Anderson & Green, 2001; Green, 1998; Norman & Shallice, 1986) and a type of WM is based on inhibition (e.g., Hasher, Lustig, & Zachs, 2007;

Gernsbacher & Faust, 1991, Gunter, Wagner, & Friederici, 2003). Also, previous research found the interaction between working memory capacity and Stroop interference, in terms of goal maintenance and inhibition of competing information (Chiappe & Chiappe, 2007; Kane & Engle, 2003; Long & Prat, 2002). Thus, I expect that WM and Stroop effects would provide a converging piece of evidence; those who may have better inhibitory control ability would be more efficient in recognizing complex nominals.

Figure 18. An illustration of the potential functions of inhibitory control ability in the recognition of a MM complex nominal



Particularly, the semantic integration of complex nominals is likely to be related to inhibitory control ability in the sense that the integration processes invoke competitions. As described earlier, two competition resources are available in recognizing complex nominals: (1) the meaning activations of each constituent and (2) a semantic integration process to establish a meaningful relation between two nouns. The interpretation of *lead mine*, for example, requires the suppression of irrelevant meanings of each constituent such as "guide" and "pronoun" among the activated information, as illustrated in Figure 18. Also, the integrations of two nouns require the suppression of irrelevant relational structures such as IN and CAUSE. Therefore, an individual having high inhibitory control ability may be more efficient in interpreting *lead mine* than an individual with low inhibitory control ability.

Some related predictions are borne out regarding the effect of inhibitory control ability on complex nominal processing. With respect to the dual functions of the lexicon, the effect of inhibitory control ability on the recognition of complex nominals could be observed when the processing is in a more controlled fashion but not in an automatic manner. It is not surprising there is no L1 literature that looks at the role of inhibitory control processes on complex nominal processing. Retrieval routes or efficient computations would lead to difficulty in observing the functions of inhibitory control ability. Thus, I predict that inhibitory effects could be found not in a NS group but in a NNS group, given that a NNS group is generally assumed to have less efficient processing systems in comparison to a NS group. Secondly, the effect of inhibitory control ability would be more salient when processing loads are costly. In the current study, for example, I expect to find the effect of inhibitory control ability on the MM condition, but not in the SS condition because the MM condition would trigger the greatest interference. Thirdly, the effect of inhibitory control ability may be related to L1 morphological knowledge, given that L1 knowledge may interfere in L2 processing. In this study, for example, the LH group that has different compound structures from English would show more interference in processing complex nominals than the RH group. Put differently, the processing loads of complex nominals would be more costly for the LH group than the RH group. Finally, L2 inhibitory control ability is related to L2 proficiency. A general expectation is that lower proficiency L2 learners do not show L2 interference. That is, proficient L2 learners are likely to have more interference with an

L2 task than L2 learners having lower L2 proficiency. For example, Preston and Lambert (1969) found that level of proficiency in a second language influences color-naming interference. Zied et al. (2004) found that unbalanced bilinguals revealed declines in inhibitory mechanisms in their non-dominant language whereas balanced bilinguals did not show comparable declines, suggesting an important function of language proficiency to inhibitory control. A recent study by Gass and Lee (in press) did not find a significant L2 Stroop effect with low and intermediate levels of L2 Spanish, leading to a call to look at higher proficiency learners. Therefore, this study used learners with higher L2 proficiency, expecting that the Stroop effect would emerge in complex nominal processing (see Discussion section for the validity of the L2 inhibition in this study). Overall, the expectation in this study is that high proficiency L2 learners who have high L2 inhibitory ability process complex nominals more efficiently than those who have low L2 inhibitory control.

The research question of Task 3

RQ. *The effect of inhibitory control ability on complex nominal processing.*

Are L1 speakers and L2 learners with higher inhibitory control capacity more efficient in processing complex nominals than those with lower capacity?

Hypothesis:

As for NSs, the familiarity and high frequency of the stimuli would not induce the effect of inhibitory control abilities on complex nominal processing. Although the Stroop effect would be minimal for the NS group, I expect to find that inhibitory control ability plays a role in L2 complex nominal processing. I expect that the effect will be greater in a condition involving the highest processing costs (i.e., the MM condition) and in the LH group whose L1's compound structures differ from the target language.

To recapitulate, inhibitory control ability is expected to function similar to WM capacity, with reference to the dual functions. No effect of the inhibitory control ability is predicted when either the retrieval mechanism is mostly used or computations are efficient in recognizing complex nominals, as illustrated in Figure 19. In contrast, the effect of inhibitory control ability is expected when the computations involve high processing loads or are less efficient. Figure 20 shows that, with an assumption of the presence of semantic computations in complex nominal processing, those who have greater interference (i.e., lower inhibitory control ability) may be slower and less accurate in recognizing complex nominals than those who have smaller interference (i.e. higher inhibitory control ability).

Figure 19. A prediction of the inhibitory control ability in case of retrievals or efficient computations

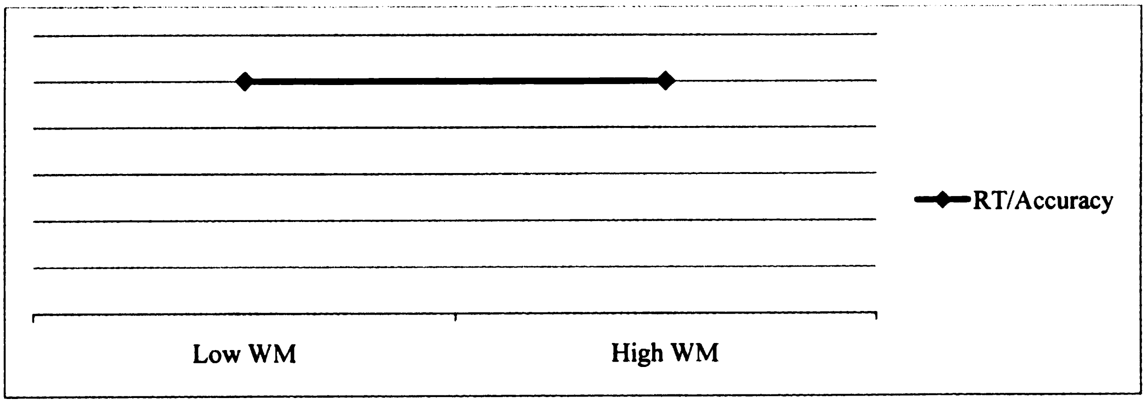
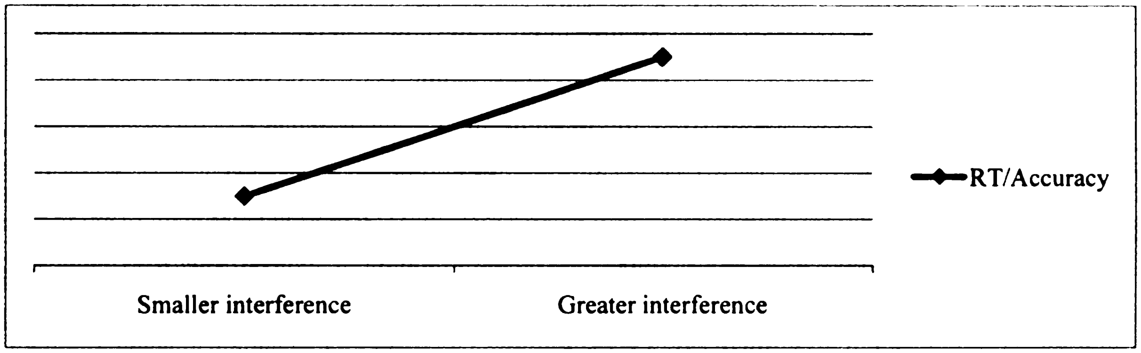


Figure 20. A prediction of the inhibitory control ability in case of the delayed computations



3.5. Participants

Participants in this study were 76 undergraduate and graduate students at Michigan State University. There were 20 native speakers (NSs) of English and 56 non-native speakers of English. The non-native speakers of English were divided into two groups depending on the compound structure of their first language. The first non-native speaker group (hereafter RH group) consisted of 17 Korean learners of English and 10 Chinese learners of English. Both Korean and Chinese have right-headed compound structure (i.e., the order of modifier-head) just as English does. The second non-native speaker group (hereafter LH group) included 19 Thai speakers of English and 8 Spanish speakers of English[10]. These languages have left-headed compound structure (i.e., the order of head-modifier)[11]. All students received 20 US dollars for their participation. The

[10] The initial sampling of the LH group included a French speaker of English and a Vietnamese speaker of English. Although French and Vietnamese also have left-headed compound structure, one sample from each language led me to the uncertainty in generalizing their patterns of the performance. I decided not to include the two participants in the data analysis.

number of men and women and the average age of all participants are provided in Table 8. The age of the participants was not significantly different, $F(2, 71) = 2.09, p = .13$.

Table 8. Gender and age information of participants

	NS (n= 20)	RH (n= 27)	LH (n= 27)
Gender			
Male	7	5	5
Female	13	22	22
Average Age			
	25.45	29.33	28.63

The target population of L2 learners in this study was high proficient learners of English due to a concern that lower proficiency L2 learners would be less likely to show the dual functions in the lexicon or they may not know the meanings of individual words. All the non-native speakers participated in a proficiency test in order to ensure the comparability of English proficiency. The Michigan State University English Language Test (MSUELT) was used for the independent measure of English proficiency. The MSUELT is designed to measure the English proficiency of non-native speakers. The

[11] Spanish and Thai have left-headedness in common. However, there is a potential concern because, strictly speaking, Spanish and Thai are somewhat different in terms of compound formation. As described earlier, in Spanish, it is more productive to insert a preposition between two nouns in a compound, although there are some Spanish compounds that do not have a preposition between two nouns. In contrast, Thai does not require the insertion of a preposition between two nouns. In this study, I decided to merge both Spanish and Thai speakers of English into the LH group because there were no statistical differences in comparing a group that contains both Thai and Spanish with a group that includes Thai alone (yet, see the conclusion section in this study for a future research agenda).

functions of the MSUELT test are to place students in a level of classes at the English Language Center of Michigan State University and to determine students' level of English in order to gain admission to regular university classes. One version of the MSUELT test consists of listening, reading, vocabulary, and grammar sections. In this study, the L2 participants took the vocabulary section and the grammar section[12]. The vocabulary section consisted of 25 test items and was presented in a multiple choice format. The grammar section was made up of 40 multiple choice questions. In both sections, there was a sentence with a blank and the participants were asked to choose the word or the phrase that best fits into the blank from four choices. The participants had 15 minutes to complete the vocabulary section and 20 minutes to answer the grammar section. The results of the proficiency tests are provided in Table 9.

Table 9. The summary of the L2 proficiency tests

	RH (n = 27)	LH (n = 27)
Vocabulary	.87 (.09)	.84 (1.00)
Grammar	.86 (.47)	.85 (.75)

Note. The numbers in the parentheses indicate standard deviations.

For the ease of comparison, the raw scores were converted into percentages by dividing raw scores of the two tests with the maximum scores in corresponding each test. Overall, the two groups scored above 80 percent on each test. The inferential statistics revealed that the RH and LH groups did not differ significantly in vocabulary scores, $t(52) = .40$, p

[12] Due to the copyright issue, the two tests used in this study could not be provided.

= .53 or grammar scores, $t(52) = 1.98$, $p = .17$. Therefore, the proficiency levels of the two groups were comparable.

3.6. Method – Task 1

3.6.1. Materials

All the stimuli in Task 1 are based on naturally occurring complex nominals taken from the COCA (Corpus of Contemporary American English) corpus, so as to minimize the familiarity and plausibility issue of stimuli. Four types of complex nominals were included in relation to the number of meanings of either the modifier or head: MM, MS, SM, and SS. The number of meanings of either the modifier or head was determined with reference to the on-line Wordsmyth dictionary. If a single word (e.g., *bank*) had two entries in the dictionary, the word was categorized as multiple. If a single word (e.g., *juice*) had one entry in the dictionary, the word was counted as single.

With the meaning criteria of single words, the complex nominals were randomly selected from a larger set of familiar compounds found in the COCA corpus (Corpus of Contemporary American English, Davies, 2009). The corpus is the first large and diverse corpus of American English and consists of more than 400 million words including the five balanced genres of spoken, fiction, magazines, newspapers, and academic journals.

Each of the four conditions has 24 complex nominals. Appendix A includes a full set of experimental items. Also, 96 fillers having insensible interpretations (Appendix B) were also constructed to make the number of sensible and insensible items equal. Both the frequency and the number of syllables of complex nominals were matched across the four conditions. The frequency of the whole complex nominals were based on the COCA corpus. In order to minimize the influence of outliers, the logarithmic transformations were used for the frequency. Table 10 summarizes the statistics of each condition.

Table 10. The frequency and the number of syllables of complex nominals in Task 1

Condition	Frequency (The whole words)	Syllables (The whole words)
SS (n= 24)	3.08 (1.32)	2.78 (.65)
SM (n= 24)	2.92 (1.41)	2.79 (.66)
MS (n= 24)	2.86 (1.72)	2.71 (.81)
MM (n= 24)	2.59 (1.71)	2.33 (.56)

The test items of the four conditions did not significantly differ in terms of number of syllables, F (3, 92) = 2.51, p = .064, or frequency, F (3, 92) = .41, p = .75. Four native speakers of English judged the acceptability of the test items on a six-point scale (1: Not acceptable, 6: Acceptable). In the offline test, complex nominals were judged highly acceptable, M = 5.4, SD = .7, and the fillers were unacceptable, M = 1.3, SD = .5.

3.6.2. Procedure

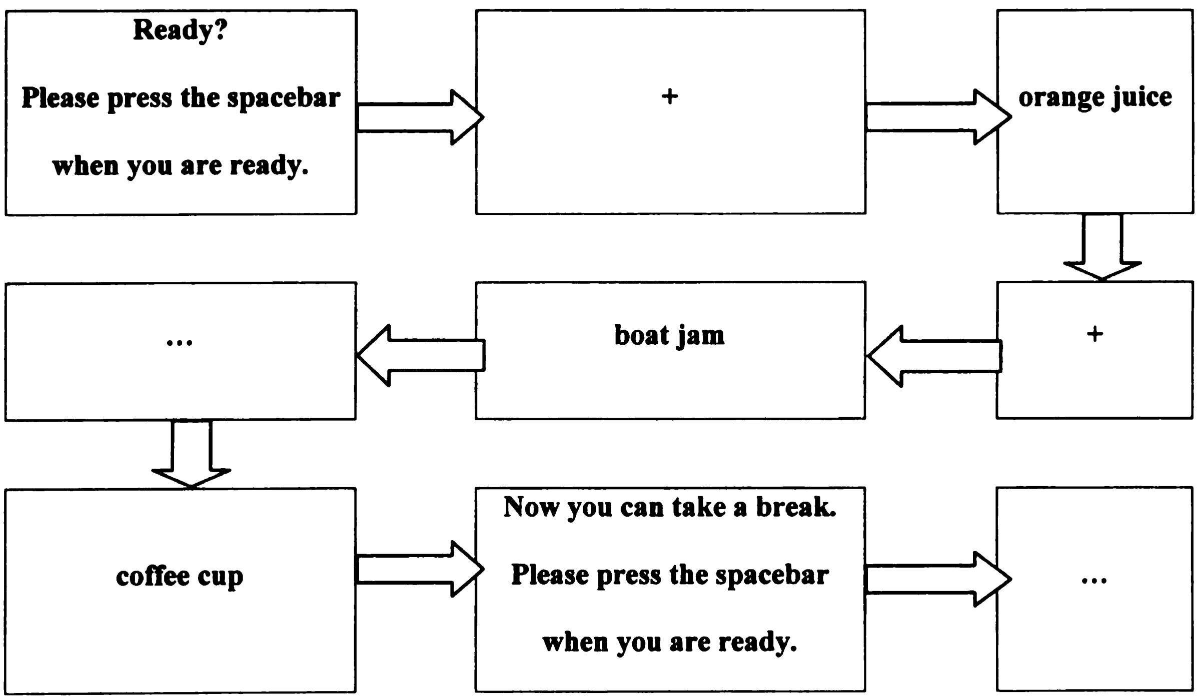
Participants took part in a computer-based session that lasted approximately 30 minutes. Before beginning the actual computer session, participants filled out a short biographical questionnaire about age, gender, native language, English language background, and self-evaluations of English proficiency in listening, reading, grammar, and vocabulary. Appendix C illustrates the instruction of Task 1 that was given to the participants.

The task in Task 1 was a lexical sense decision task (Gagné, 2001, 2002; Gagné & Spalding, 2004; Gagné, Spalding, & Ji, 2005). Participants were asked to judge whether a complex nominal had a sensible interpretation by pressing a button labeled *yes* or a button labeled *no*.

The test items were presented in isolation, although it is equally interesting to examine how complex nominals are interpreted in contexts (see Conclusion for suggestions for future research). Both semantic representations of each constituent and contextual information contribute to interpretations of complex nominals. Discourse context can influence the interpretation of a combined concept (Gagné & Murphy, 1996; Gerrig & Bortfeld, 1999; Gerrig & Murphy, 1992). At the same time, context is not a necessary condition for interpreting novel compounds (Coolen, van Jaarsveld, and Schreuder, 1991). That is, a novel compound can be interpreted on the basis of the meanings or semantic representations of each constituent. This dissertation focuses on the processing of complex nominals in isolation. As noted in Coolen, van Jaarsveld, and Schreuder (1991), the examination of compounds in isolation allows us to understand how the representations of each constituent contribute to the interpretations of complex nominals.

The task was constructed using E-Prime software (Psychological Software Tools, Pittsburgh, PA). The task consisted of a practice session and an actual experimental session. The practice trial included 5 sensible and 5 non-sensible complex nominals. To begin, participants saw a "Ready" and "Please press the spacebar when you are ready." Immediately after participants pressed the spacebar, a fixation point "+" appeared on the computer screen and stayed on the screen for 1000 milliseconds. Next, a complex nominal appeared on the computer screen and remained on the screen until participants pressed a button labeled *yes* or a button labeled *no* on the keyboard for a judgment of the sensibility of complex nominals. The complex nominal remained for a maximum of 5000 milliseconds, which was determined by pilot tests with ten L2 learners who had comparable levels of English proficiency. The cycle started again with a fixation point. The actual experimental session had the same procedure as the practice trials. The experimental session contained 96 sensible (as in Appendix A) and 96 non-sensible (as in Appendix B) complex nominals. In order to lessen participants' fatigue, participants saw the pause sign "*Now you can take a break. Please press the spacebar when you are ready.*" after 24 items were presented. Thus, the participants saw 8 blocks of complex nominals (made up of 96 plausible and 96 implausible items). The 8 blocks were randomized across the participants and the items in each of 8 blocks were presented in a random fashion. Figure 21 demonstrates the procedure of the lexical sense decision task.

Figure 21. The procedure of the lexical sense decision task



3.7. Method –Task 2

3.7.1. Materials and procedures

Students participated in a computer-based WM task that lasted about 15 minutes. A version of the operation span test (Hitch, Towse, & Hutton, 2001; Turner & Engles, 1989; Unsworth, Heitz, Schrock, & Engle, 2005) was designed to measure L1 working memory capacity, regardless of the participants' L1 backgrounds. The operation span task was intended to increase the practicality and comparability of measuring the construct of WM. In second language research, it is more common to use WM tasks based on language such as reading or listening span tasks. Recent SLA studies indicated the difficulties of using an L2 working memory task (e.g., Gass & Lee, in press; Sagarra, 2008). This caution of using an L2 WM task is related to practicality issues in a second language learning setting (but not in a foreign language learning setting). This study, for example, included a NS group of English speakers and L2 learners of four different L1 backgrounds, which would require 5 different language-based WM tasks. Although it is not impossible to make 5 different language-based tasks, another issue is whether the language-based WM tasks using 5 different languages are comparable in measuring WM capacity because it is not simply assumed that the same formats using different languages can measure the same underlying construct of WM. In order to overcome the issues of practicality and comparability, this study used an operation span, which is not only common in cognitive psychology (e.g., Hitch, *et. al.*, 2001; Kane & Engle, 2003; Kane, *et. al.*, 2001; Turner & Engles, 1989; Unsworth *et. al.*, 2005) but also is reported to measure the same underlying construct of WM when testing latent variable modeling (e.g., Conway et al., 2005).

In operation span tasks numbers are used for recalls, instead of words. It is common to use words as recalls in the WM tests (Conway et al., 2005). L2 words could be adopted as recalls. However, the measure of WM memory might be compounded with L2 proficiency when recalls are L2 words because L2 vocabulary knowledge is an aspect of L2 proficiency. Alternatively, L1 words could be used as recalls, instead of numbers. Again, it is not practical to use L1 words in the context of a second language learning environment. In this study where the participants were from five different L1s, for example, it is possible to have five different language versions of the recalls such as English, Chinese, Korean, Spanish, and Thai. Furthermore, the translation equivalents of a language do not necessarily result in a measure of the same underlying constructs in the various languages. For example, the Korean translation of the English word *snow* is *nwun*, which has two meanings in Korean ("snow" and "eye"). Therefore, it was more feasible to use numbers as recalls.

In general, the WM task of this study is similar to a version of reading span tasks (e.g., Daneman & Carpenter, 1980), in which sentences are presented as interfering stimuli and the recall items are either the last word of each sentence or a series of words presented independently after each sentence. In this study, however, sentences in a reading span task were replaced by mathematical equations in the operation tasks. Another notable characteristic of this version of operation span is that it uses numbers (but not words) as the recall stimuli. In order to increase the costs of processing and storage, this study used mathematical equations using four digits (e.g., $(2X3) + 2 = 8$) as interference and two digit numbers as recalls.

A series of pilot tests was administered to determine the methodological details of the operation span task that was used in the main study[13]. I decided to present the WM test via computer so that I could control the processing time of interference and the storage time of recall numbers. The first pilot test was intended to measure the timeline of presenting interferences (i.e., mathematical equations) and presenting recalls. Four participants (two NSs and two NNSs) saw four blocks of WM tests consisting of four equations and four recalls. The three blocks differed in terms of how long each equation stayed, ranging from 4000 ms to 5000 ms, to 6000ms. According to the four participants, the block presented with 4000 ms-interval was highly challenging while the blocks presented with 5000 ms or with 6000 ms intervals were manageable. In order to increase individuals' variability, I decided to use 5000 ms as the maximum time of presenting each mathematical equation. Secondly, the presentation of recalls was also tested. Another group of five students (two NSs and three NNSs) saw three blocks of WM tests made up of four mathematical operations and four recalls. The operations were presented in 5000 ms and the presentation of recalls varied ranging from 1000 ms to 2000 ms to 3000 ms. In the case of the 1000 ms-intervals, the participants could recall approximately 40% of the recalls, suggesting that the task was too challenging. The participants could remember above 90% of the recalls when the recalls stayed for 3000 ms while about 75% of the recalls were remembered with 2000 ms-interval. In order to decrease the rehearsal time of the recalls, I decided to present the recalls for 2000 ms. Using the above timelines,

[13] Since pilot studies are based on a small number of participants, I did not run inferential statistics. The rigor of this test remains as future research.

the second part of the pilot test was administered. The purpose of the pilot test was to determine the maximum number of recalls. The results of a group of 10 NNS students revealed that the main variations of the recall scores were found in 4 and 5 mathematical equations, about 78% and 58%, respectively. In a block made up of 6 operations, the chance of the recalls dropped to less than 30%. Therefore, I determined to use blocks containing 5 recalls as the maximum recalls.

Table 11. A sample of the working memory test

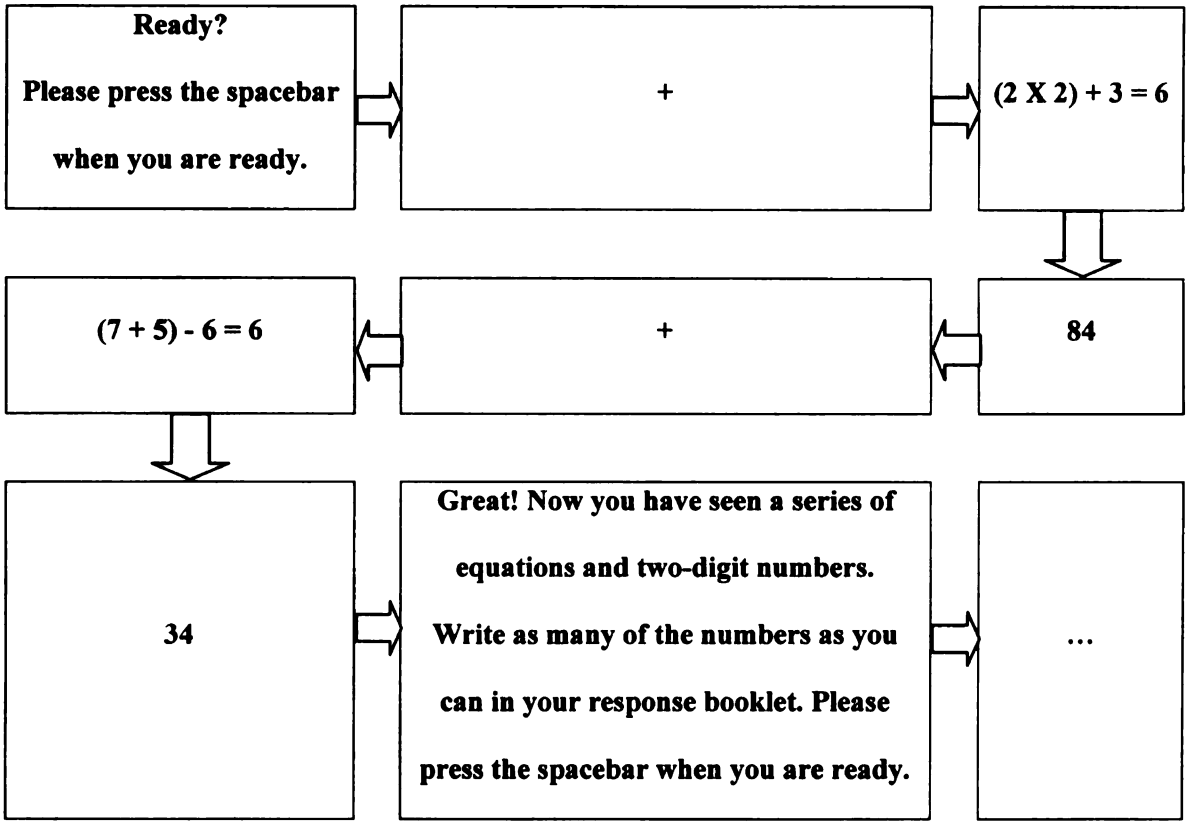
Equations	Recalls
(2 X 2) + 3 = 6	84
(7 + 5) - 6 = 6	39

Based on the pilot tests, the following method was used in the main test. The WM task consisted of two parts. The first part of the task involved a judgment of correctness of a series of mathematical equations in order to ensure that the equations were being processed and not just stored. Participants read a series of 2, 3, 4, and 5 simple mathematical equations (using addition, subtraction, multiplication, and division). The participants were asked to answer whether each solution was correct by clicking corresponding buttons. The second part was to remember numbers. Immediately after solving each equation, participants saw two digit numbers, which they were asked to remember. At the end of a block of equations, they were asked to recall the two-digit numbers they saw after each equation. Identical two-digit numbers (e.g., 22 or 33) were not used for recalls. A sample of a block containing two mathematical equations and recalls are shown in Table 11. The full list of the operation span can be found in Appendix D.

The WM task began with a fixation cross (+), which remained on the screen for 1000 milliseconds. Next, an equation of the set appeared on the computer screen and remained on the screen until participants pressed a button labeled *yes* or a button labeled *no* to make a judgment on the correctness of the equation. The operation remained for a maximum of 5000 milliseconds. Immediately after the participants pushed the button indicating the correctness or incorrectness of the operation, a two-digit number appeared and remained on the screen for 2000 milliseconds. The cycle started again with a fixation point. After all the operations and letters of a set had been presented, a screen appeared which instructed participants to write the letters that they had seen on a piece of paper. The procedure of the WM test is illustrated in Figure 22.

The task was created using E-Prime software (Psychological Software Tools, Pittsburgh, PA). Each participant saw two practice blocks, each of which consisted of two levels. The actual test consisted of 6 blocks, 2 at each level: 2 through 5. The maximum number of recall numbers was 5 as determined by a pilot test with 6 students. The six blocks of operations were totally randomized, so that the blocks of operations were presented differently across the participants.

Figure 22. A sample of a block containing two equations and two recalls in the WM test



3.7.2. Scoring Procedures

A version of partial-credit load scoring (Conway et al., 2005) was used. Regardless of the order of the recalled numbers, the scoring consisted of giving credit for each correct number in a set. In scoring, a single digit of each of the two-digit numbers was credited. For example, when a recall was 23 and a participant recalled it as 24, one point was credited. If students recalled the two-digit number correctly regardless of the order of the recalled numbers, they received two points for the recall. For instance, those who recalled 39 as either 39 or 93 got two points for the recall.

The total number of points for participants was 56 (2 blocks of 2 operations with 2 digit recall number = 8; 2 blocks of 3 operations with a 2 digit recall number = 12; 2

blocks of 4 operations with a 2 digit recall number = 16; 2 blocks of 5 operations with a 2 digit recall number = 20). I also gave a zero for each item for which a participant judged an incorrect equation (e.g., 1 + 2 = 4) as correct or vice versa.

3.8. Method – Task 3

3.8.1. Materials

The Stroop test is intended to measure how successfully a participant inhibits certain irrelevant information when conflicting information is presented. In cognitive psychology, Stroop tests (Stroop, 1935) have been reported as the "golden" measure of inhibitory control (MacLeod, 1991, 1992). In the Stroop test, participants see words and determine in what color the word is written. Some of the words will be congruent with color (the word "red" written in red); some will be neutral (e.g., a symbol @ written in red); and some will be incongruent (the word "blue" written in red). This task usually yields longer reaction times for the incongruent condition (Stroop, 1935). These longer reaction times are assumed to be measuring linguistic interference.

A modified English version of the Stroop test, used in Gass and Lee (in press), was used to measure L1/L2 inhibitory control. The test measures the L2 inhibitory control of L2 learners of English and the L1 inhibitory control of native speakers of English.

In the Stroop test, participants see a series of color words (e.g., RED) and determine in what color the word is written, by pressing keys on the keyboard which were taped with red, green, or blue. Some of the words are congruent with color (the word "red" written in red); some will be neutral (a symbol @ written in red); and some will be incongruent (the word "blue" written in red).

The test items consist of 60 congruent items (i.e., colors and words are matched) and 60 incongruent item (i.e., colors and words are not matched). There were 20 congruent and incongruent trials for each color.

3.8.2. Procedures and scoring procedures

The task began with a fixation point on the screen, which stayed on the screen for 1000 milliseconds. Then, a color word followed and the participants were to push a button to indicate the color that the word was written in. The word remained on the screen until the button was pushed. When there was no response, the word stayed on the screen for 4000 milliseconds. A fixation point appeared again, immediately after the button was pushed.

There were three phases of the Stroop test: (1) a practice session using actual words, (2) a Stroop test using actual words, and (3) a baseline session using @ symbols. Participants saw the baseline session after the Stroop with the actual words. Across each participant, the practice session was presented in a fixed format, whereas the Stroop test and the baseline session were randomly presented.

The practice session consisted of six examples using actual color words, which contained three congruent and three incongruent trials. In the actual Stroop test, participants saw both 60 congruent items (i.e., colors and words are matched) and 60 incongruent items (i.e., colors and words are not matched). There were 20 congruent and incongruent trials for each color. Finally, as a baseline, participants saw 30 @ symbols (10 in red, 10 in blue, and 10 in green).

The Stroop test was scored by subtracting the mean reaction time of the neutral trials from the mean reaction time of the incongruent trials (Kane & Engle, 2003; MacLeod, 1991). Individual data points exceeding two standard deviations above/below the means were eliminated from the data analysis.

CHAPTER FOUR –RESULTS

There were three computer-based tasks in this study: (1) a lexical sense decision task, (2) a working memory test, and (3) an inhibition test. The first task was designed to examine whether native speakers and non-native speakers use either computational routes or retrieval routes or both when they comprehend complex nominals. The second task was intended to investigate whether working memory (WM) capacity is related to the interpretations of complex nominals. The third task was aimed to examine the effect of inhibitory control ability on the recognition of complex nominals.

4.1. Task 1

Both the mean response times and the accuracy scores of the three groups in the four experimental conditions are used to address research questions. The response times and the accuracy scores were analyzed separately[14]. Both by-subject (F_1) and by-item (F_2)

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[14] There were no violations of statistical assumption in both the mean response times and the accuracy scores of the three groups. First, the univariate normality of each of four dependent variables among the three groups was examined via skewness, kurtois, Shapiro-Wilk's test, normal Q-Q plots, and detrended Q-Q plots. The multiple indications of the univariate normality suggest that every dependent variable meets the normality assumption. The bivariate normality, one of the assumptions of multivariate normality was checked through a scatter plot, in which every plot appears close to elliptical shapes. Thus, in general, the dependent variables seem not to violate the univariate and multivariate assumption. Second, the equality of univariate variance and multivariate covariance was examined. The univariate homogeneity assumption was checked through Levene's test, in which there was no violation of equal variance in each of four dependent variables ($p > .05$). MANOVA assume that for each group the covariance matrix is

analyses were conducted[15]. Individual data points exceeding above/below two standard deviations were eliminated from data analysis[16]. The descriptive statistics of the mean response times the four conditions is given in Table 12 and Figure 23. Table 13 and Figure 24 show the accuracy scores of the three groups in the four experimental conditions.

Table 12. The response times in the four experimental conditions

	Conditions			
	SS	SM	MS	MM
NS (n = 20)	948.01	937.20	946.68	1002.38
	(115.34)	(132.16)	(156.34)	(167.39)
RH (n = 27)	1572.71	1754.66	1666.27	1876.87
	(351.14)	(366.63)	(319.39)	(431.48)
LH (n= 27)	1566.24	1771.39	1735.51	1994.87
	(342.29)	(604.01)	(522.94)	(694.84)

Note. The numbers in the parentheses are standard deviation.

similar, and Box' M test suggests the equality of covariance matrix is met (p= .23). Finally, since each task was answered by a different participant, their data are considered to be independent.

15 In psycholinguistics literature, by-subject (F1) and by-item (F2) analyses in psycholinguistics had been used as standard quantitative methods since an influential work by Clark (1973). The rationale for the use of F1 and F2 analyses was that both human participants and linguistic materials should be modeled as random variables. Yet, the use of F1 and F2 analyses has not remained unchallenged (see Baayen, Davidson, & Bates, 2008; Raaijmakers, Schrijnemakers, & Gremmen, 1999 for the recent developments of quantitative analyses of psycholinguistic data).

16 Researchers vary in handling outliers. One uses 3sd as the cutting point of outliers and the other uses 2.5 sd as the outer bounds of outliers. In this study, I followed a common practice of handling outliers (2 sd) in second language psycholinguistic research such as Beck (1998), Gass (2001), and Bley-Vroman and Masterson (1989).

Figure 23. The mean response times of the three groups in the four conditions

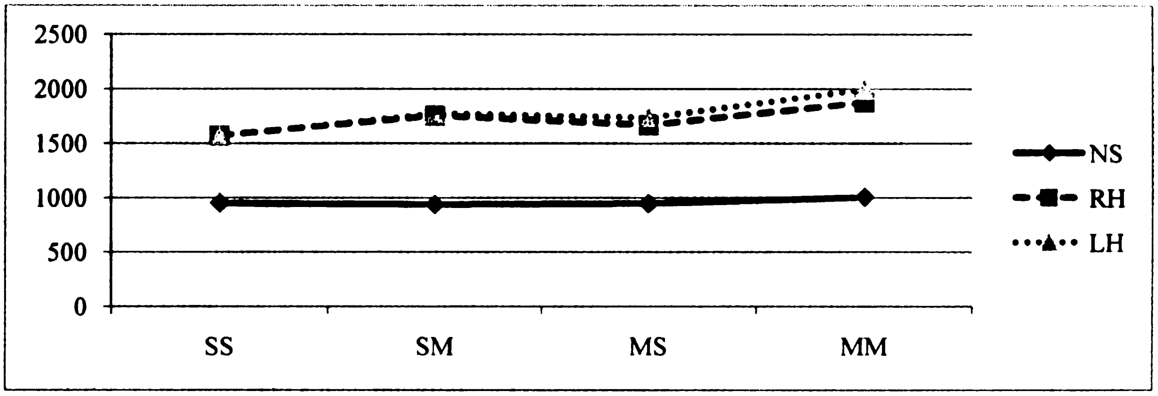
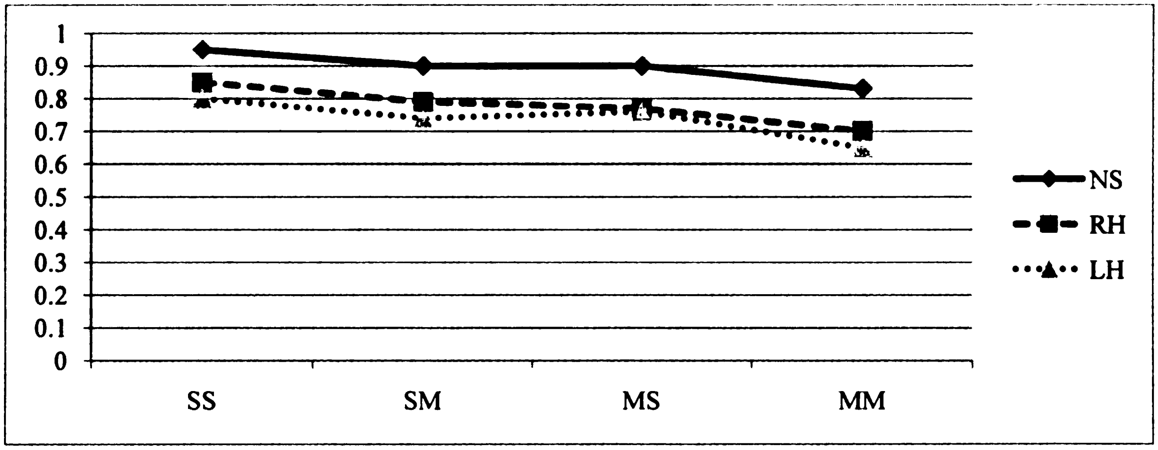


Table 13. The accuracy scores in the four conditions

	Conditions			
	SS	SM	MS	MM
NS (n = 20)	.95 (.06)	.90 (.09)	.90 (.09)	.83 (.12)
RH (n = 27)	.85 (.12)	.79 (.17)	.77 (.17)	.70 (.17)
LH (n= 27)	.80 (.17)	.74 (.18)	.76 (.17)	.65 (.23)

Note. The numbers in the parentheses are standard deviation.

Figure 24. The accuracy scores in the four conditions



4.1.1. Research question 1: The difference between the NS and the NNS groups

The first research question addressed the difference between the NS group and the two NNS groups in interpreting complex nominals. Specifically, I questioned whether the NS group is significantly faster and is more accurate in comprehending items in all the four conditions than the two NNS groups. A multivariate analysis of variance (MANOVA) was performed with a Group variable (three-levels: NS, RH, and LH) as an independent variable as well as the response times and the accuracy scores in the four conditions as dependent variables. Reaction times and accuracy scores were analyzed separately.

Evidence of Difference between NS and NNS. The MANOVA analysis of the response times revealed that the main effect across the four conditions was significant, Wilks' Lambda = .44, F (8, 136) = 8.51, p = .0001, η^2= .33. The four separate univariate analyses of variance were conducted to locate the source of the significant difference in a multivariate space. The results showed that there were significant differences across all the four conditions in both by-subject and by-item analyses, F_{1_MM} (2, 71) = 25.56, p = .0001, η^2 = .42; F_{2_MM} (2, 46) = 78.70, p = .0001, η^2 = .77; F_{1_MS} (2, 71) = 29.09, p = .0001, η^2= .45; F_{2_MS} (2, 46) = 63.49, p = .0001, η^2 = .73; F_{1_SM} (2, 71) = 26.55, p = .0001, η^2= .43; F_{2_SM} (2, 46) = 106.30, p = .0001, η^2 = .82; F_{1_SS} (2, 71) = 30.68, p = .0001, η^2= .46; F_{2_SS} (2, 46) = 101.05, p = .0001, η^2= .82. Post-hoc comparisons of response times were carried out using Bonfermoni adjustment. As seen in Table 14, the NS group was significantly faster in judging the meanings of complex nominals than the two NNS groups across all the four conditions.

The MANOVA analysis of the accuracy scores also revealed that the main effect across the four conditions was significant, Wilks' Lambda = .74, F (8, 136) = 2.77, p = .007, η^2= .14. The univariate results of accuracy scores showed that there were significant effects across the four conditions in both by-subject and by-item analysis,

$F_{1\_MM}(2, 71) = 6.43, p = .003, \eta^2 = .15; F_{2\_MM}(2, 46) = 8.64, p = .001, \eta^2 = .27; F_{1\_MS}(2, 71) = 5.56, p = .006, \eta^2 = .14; F_{2\_MS}(2, 46) = 8.95, p = .001, \eta^2 = .28; F_{1\_SM}(2, 71) = 5.97, p = .004, \eta^2 = .14; F_{2\_SM}(2, 46) = 14.16, p = .0001, \eta^2 = .38; F_{1\_SS}(2, 71) = 6.43, p = .003, \eta^2 = .15; F_{2\_SS}(2, 46) = 7.39, p = .24$. Post-hoc pairwise comparisons using Bonferrnoi correction were performed, as seen in Table 15.

Table 14. Bonferroni Post-hoc comparisons of response times

Condition		Group	
		NS	RH
MM	RH	874.49**	
	LH	992.49**	117.99
MS	RH	719.59**	
	LH	789.82**	70.23
SM	RH	817.46**	
	LH	834.19**	16.72
SS	RH	624.70**	
	LH	618.24**	6.46

**. $p < .01$. *Note*. The numbers indicate the mean differences between two groups

Table 15. Bonferroni Post-hoc comparisons of accuracy scores

Condition		Group	
		NS	RH
MM	RH	.13 (p = .055)	
	LH	.19* (p = .002)	.06 (p = .66)
MS	RH	.126* (p = .017)	
	LH	.14* (p = .009)	.01 (p = 1.0)
SM	RH	.11* (p = .07)	
	LH	.16* (p = .003)	.05 (p = .71)
SS	RH	.09 (p = .054)	
	LH	.13 (p = .002)	.04 (p = .67)

*. $p < .05$. *Note*. The numbers indicate the mean differences between two groups

The post-hoc comparisons of accuracy scores indicated that the NS group interpreted complex nominals significantly more accurately across all conditions than the RH and LH groups, although the differences between NS and RH were marginal in MM and SS conditions.

4.1.2. Research question 2: The difference between the LH and the RH groups

The second research question asks whether there is the influence of L1 morphological knowledge on processing complex nominals. Of particular interest is whether the headedness of the first language affects processing L2 morphology, even for advanced learners of a second language. Potential differences between the LH and RH groups were examined using two separate mixed ANOVAs, one for response times and the other for accuracy scores. Within-subject factors were the measures of each group (i.e., response times and accuracy in the four conditions) and a between-subject factor was a group variable with two-levels (i.e., RH and LH).

No evidence of L1 influence: RH versus LH. The results of response times showed that the within-subject effect was significant, $F_1(3, 156) = 11.58, p = .0001, \eta^2 = .40$; F_2 $(3, 92) = 7.49, p = .007, \eta^2 = .08$. However, there were no significant between-subject effect, F_1 $(1, 52) = .23, p = .63$; F_2 $(1, 92) = .61, p = .44$. The interaction between within and between-subject factors was not significant, F_1 $(3, 156) = .39, p = .76$; F_2 $(3, 92)$ $= .90, p = .45$. Therefore, RH and LH groups did not differ significantly in terms of response times.

The results of accuracy scores were similar to those of response times. The within-subject difference was significant, $F_1(3, 156) = 11.74, p = .0001, \eta^2 = .43$; F_2 (3,

92) = 3.33, p = .023, η^2 = .10, yet there was no between-subject difference, F_1 (1, 52) = 1.49, p = .23; F_2 (1, 92) = 1.01, p = .31 as well as no interaction, F_1(3, 156) = .36, p = .79; F_2 (3, 92) = .27, p = .27 .

In general, the results of both response times and accuracy scores demonstrated that there was no significant difference between the RH and LH groups, suggesting that, at least with the participants of the current study, L1 morphological knowledge did not play a role in recognizing L2 complex nominals[17].

4.1.3. Research question 3: Within-group differences

The third research question concerns whether the NS group and the NNS groups differ in recognizing complex nominals in the four experimental conditions. Two different hypotheses have been proposed. The NS group is not expected to show a substantial behavioral difference across the four conditions (i.e., MM =MS = SM =SS), considering the high probability of reliance on retrieval routes or efficient morphological computations. In contrast, the NNS groups are expected to produce the graded interference in accordance with the processing costs of each condition. Specifically, the NNS groups are predicted to reveal the greatest interference in the MM condition, the

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[17] When the reaction times across the four conditions collapse into a measure (i.e., the combined average of the four conditions), the RH group (M =1717.63, SD = 302.87) was faster than the LH group (M= 1767.25, SD = 438.77), descriptively. The accuracy scores were similar to the reaction times; the RH group (M =.78, SD = .11) judged the test items a bit more correctly than the LH group (M = .74, SD =.14). However, inferential statistics showed that the two groups did not differ significantly in both the reaction times (t(52) = .48, p = .63) and in the accuracy scores (t(52) = 1.22, p = .23).

intermediate interference in the MS and the SM conditions, and the smallest inference in the SS condition (i.e., MM > MS, SM > SS).

Two separate within-subject design were used to test the two hypotheses in the first research question. Dependent variables were reaction times and accuracy scores of the NS group and the NNS group (combining RH and LH groups) in the four conditions, which were run separately.

Mixed evidence of uniform interference in NS group. Results of response times revealed that the NS group did not differ significantly in responding to all the four conditions, F_{1_NS} (3, 57) = 1.83, p = .15; F_{2_NS} (3, 96) = 2.18, p = .10. In terms of accuracy, the by-subject analysis of accuracy revealed NSs to show a significant main effect, F_{1_NS} (3, 57) = 8.53, p = .0001, η^2= .31, and the by-item analysis indicated marginal differences, F_{2_NS} (3, 92) = 2.51, p = .06. A follow-up Bonferroni test was performed to examine the locus of the significant difference, as seen in Table 16.

Table 16. Post-hoc comparisons of accuracy scores of the NS group

	MM	MS	SM
MS	.067* (p = .038)		
SM	.072* (p = .022)	.01	
SS	.113* (p = .005)	.05	.04

*. $p < .05$.

Table 16 shows clearly that the NS group made more mistakes in interpreting the items in the MM condition.

Evidence of the graded interference in the NNS group. The results of response times indicate that both the RH and LH groups did differ significantly in responding to all the four conditions, $F_{1\_RH}(3, 78) = 7.60, p = .0001, \eta^2 = .23; F_{2\_RH}(3, 92) = 6.82, p = .0001, \eta^2 = .18; F_{1\_LH}(3, 78) = 5.37, p = .002, \eta^2 = .17; F_{2\_LH}(3, 92) = 11.89, p = .0001, \eta^2 = .28$. The follow-up pairwise comparisons revealed that, in the MM and SS conditions, the 304.17 mean difference of the RH group ($p = .0001$) and the 428.63 mean difference of the LH group ($p = .017$) were significant. Thus, the locus of significant differences in the two NNS groups was the MM and SS conditions, which corresponded to the highest and the lowest processing costs, respectively.

Similarly, the accuracy analyses revealed that there were significant main effects on each of the two NNS groups, $F_{1\_RH}(3, 78) = 5.43, p = .002, \eta^2 = .17; F_{2\_RH}(3, 92) = 2.74, p = .048, \eta^2 = .08; F_{1\_LH}(3, 78) = 6.62, p = .0001, \eta^2 = .20; F_{2\_LH}(3, 92) = 3.25, p = .025, \eta^2 = .10$. A follow-up Bonferroni test was reported in Table 17.

Table 17. Post-hoc comparisons of accuracy scores of RH and LH group

Group		Condition		
		MM	MS	SM
RH	MS	.07		
	SM	.02	.02	
	SS	.15* ($p = .035$)	.08	.06
LH	MS	.12* ($p = .02$)		
	SM	.10	.02	
	SS	.16* ($p = .001$)	.05	.07

*. $p < .05$.

In terms of accuracy scores, the RH group interpreted the items in the MM condition less accurately than the SS condition; the LH group made more mistakes in judging the MM condition than the MS and SS conditions.

4.1.4. Research question 4: Comparing the NS and the NNS groups with respect to holistic representations of complex nominals

The fourth research question is whether the NS group and the NNS groups store some of the complex nominals as a whole. In order to address this question, I look at the relationship between the frequency of the whole complex nomninals and the performance of NS group and NNS groups. This method is common in inferring the holistic representations of multi words such as formulaic sequences (e.g., Jiang & Nekrasova, 2007).

A series of correlation analyses was carried out with (1) frequency measures and (2) the measures of performances of the three groups in terms of reaction times. First, I create new measures of the whole word frequency based on the COCA corpus (Corpus Of Contemporary American English). Specifically, regardless of the 4 experimental conditions (SS, SM, MS, and MM), 96 test items were merged and divided into three conditions (High, Mid, Low) according to the frequency of the whole complex nominals. An assumption of full-listing models (in favor of the holistic representations of complex nominals) is that the semantic integrations are not the part of the mental representation. Note that I assume that semantic computation would lead to the graded interference across the four experimental conditions. With the context of this study, the holistic representations of complex nominals imply that the manipulated processing costs in the four experimental conditions are not an important consideration. Rather, full-listing models predict that the frequency of the complex nominals is the key to the performances of the NS and the NNS groups. These three variables are used for the measures of the frequency. Table 18 shows the descriptive statistics of the frequencies of the three conditions.

Table 18. The descriptive statistics of the 96 test items according to the frequency of the whole words

	Frequency	
Hi (n = 32)	Mid (n = 32)	Low (n =32)
4.51 (.10)	3.00 (.39)	1.10 (.15)

Note. The numbers in the parentheses are standard deviation.

Inferential statistics of the frequency measures revealed that there is a significant difference among the three conditions, $F(2, 93) = 237.88$, $p = .0001$. A post-hoc comparison with Bonferroni correction shows that all the three conditions differ significantly; Hi vs. Mid, $M = 1.51$, $SD = .16$, $p = .0001$; Hi vs. Low, $M = 3.43$, $SD = .16$, $p = .0001$; Mid vs. Low, $M = 1.91$, $SD = .16$, $p = .0001$.

Overall, I predict that the reaction times of the participants are inversely related to the frequency of the whole complex nominals (see Monsell, 1991 for the overview of frequency effect). That is, the higher frequency words are expected to lead to faster reaction times. Yet, I predicted that the frequency effect would emerge only with the NS group, but not with the two NNS groups, given that the NS group is likely to have more stored complex nominals as a whole.

A series of separate correlation analyses were conducted for each group. The reaction times of each group are examined in relation to the three frequency measures.

Evidence of the frequency effect of complex nominals for the NS group. The results of the correlation analyses are presented in Table 19. In general, the NS group behaved in a predicted fashion. With respect to the directionality of the correlations, the frequencies of the whole complex nominals are inversely correlated with the reaction times of the NS group. In terms of the magnitudes, the high frequency complex nominals showed the strongest correlation with the reaction times of the NS group, r (30) = -.38, p = .03., the mid-frequency words revealed the marginal correlation, r(30) = -.34, p = .059, and there is a weak relationship between the low-frequency words and the reaction times of the NS group, r (30) = -25, p = .16. In case of the NS group, therefore, some of the high frequency complex nominals are likely to be stored as a whole.

Table 19. The correlations between the frequency and the reaction times in the NS group

The frequency of the whole complex nominals	The reaction times of the NS group (n = 20)
Hi (n= 32)	r = -.38, p = .03
Mid (n= 32)	r = -.34, p = .06
Low (n= 32)	r = -.25 p = .16

Some evidence of the frequency effect of complex nominals for the RH group. Table 20 shows the results of the correlation analyses of the RH group. The directionality of the high- and the mid-frequency words are in a predicted way. However, the low-frequency words are positively correlated with the reaction times of the RH group, r (30) = .20, which is not predicted by full-listing accounts. The positive correlation between the low-frequency words and the reaction times of the RH group suggest that the RH group may not store the low-frequency words as a whole but rather is likely to interpret the low-frequency complex nominals via computations. In terms of the magnitudes, the marginal correlations were found in high-frequency words, r(30) = -.34, p = .055, and in the mid-frequency words, r(30) = -.32, p = .072. Therefore, although it is not highly strong, the RH group may store some of the complex nominals as a whole.

Table 20. The correlations between the frequency and the reaction times in the RH group

The frequency of the whole complex nominals	The reaction times of the RH group (n = 27)
Hi (n= 32)	r = -.34, p = .06
Mid (n= 32)	r = -.32, p = .07
Low (n= 32)	r = .20 p = .27

Weak evidence of the frequency effect of complex nominals for the LH group. The results of the LH group, in general, replicate the performances of the RH group; however, the strength of associations in the LH group was much weaker than in the RH group. Table 21 shows the results of the correlation analyses of the LH group.

Table 21. The correlations between the frequency and the reaction times in the LH group

The frequency of the whole complex nominals	The reaction times of the LH group (n = 27)
Hi (n= 32)	r = -.19, p = .31
Mid (n= 32)	r = -.16, p = .39
Low (n= 32)	r = .11 p = .56

As in the case with the RH group, the LH group behaves in responding to the high- and the mid- frequency words in a predicted way. That is, the LH group responded faster to the complex nominals with higher frequency. However, the reaction times of the RH group was positively proportional to the low-frequency words, $r(30) = .11$. Similar to the RH group, the fact that low-frequency words and the reaction times of the LH group are positively correlated suggest that the low-frequency words may be not stored as a whole in the memory of the LH group. In terms of the magnitudes, there was no strong correlations in high-frequency words, $r(30) = -.19$, $p = .31$, and in the mid-frequency words, $r(30) = -.16$, $p = .39$. Given the weak correlations even for the high-frequency complex nominals, the LH group is likely to recognize the complex nominals in this study through computational routes but not retrieval routes.

To recapitulate, Table 22 summarizes the research questions that were addressed in Task 1 and the corresponding findings for each research question.

Table 22. A summary of research questions and the corresponding findings in Task 1

Research questions	Findings	Summary
RQ1. *Difference between NSs and NNSs* Do NSs show significantly better performance in all four conditions than the two NNS groups of high L2 proficiency?	Yes	The NS group performed better than the NNS groups in all experimental conditions.
RQ 2. *L1 influence of morphological knowledge in processing L2 complex nominals* Does the headedness of the L1 compound structure affect the processing of L2 complex nominals?	Partially yes	The LH group was descriptively slower than the RH group in responding to complex nominals in English; however, the L1 effect, operationalized by the headedness of the L1, was not significant between the two groups, presumably due to high, comparable proficiency of the two NNS groups.
RQ3. *Uniform interference in the NS group versus graded interference in the NNS groups* Do the NS group and the NNS groups differ in recognizing complex nominals in the four experimental conditions?	Yes	The NS group did not show a substantial difference in reaction times and accuracy across the four conditions (i.e., MM =MS = SM =SS). In contrast, the NNS groups did show the graded interference in accordance with the processing costs of each condition (i.e., MM > MS, SM > SS).
RQ 4. *Comparing NSs and NNSs in terms of whole-word representations* Do the frequencies of complex nominals as a whole play a significant role in recognizing complex nominals for both NS and NNS groups?	Yes for the NS group; partially yes for the NNS groups	The NS group showed a strong frequency effect. In contrast, the NNS groups revealed a weak frequency effect for the high-frequency complex nominals; however, the low-frequency words are positively correlated with the reaction times of the two NNS groups, which was not predicted by full-listing models.

4.2. Task 2

Task 2 examines the potential role of working memory (WM) capacity on L2 complex nominal processing. Of particular interest in Task 2 is to examine the question of whether L2 learners with higher WM capacity are more efficient in processing a second language than their counterparts with lower WM capacity, when comparing the processing ability of NNS groups with comparable proficiency.

The descriptive statistics for WM are provided in Table 23. The maximum score of the WM test was 56. No significant difference was found among the three groups, $F(2, 71) = .78, p = .46$.

Table 23. A summary of working memory scores

Group		
NS (n= 20)	RH (n= 27)	LH (n= 27)
43.10 (9.43)	46.30 (6.44)	44.37 (10.39)

Note. The numbers in parentheses refer to the standard deviations.

A series of bivariate regression analyses were conducted with the WM scores of each group as a predictor variable; criterion variables were the response times and the accuracy scores of MM and SS conditions on the lexical sense decision task of each group, which were measured in Task 1.

4.2.1. NS group

No evidence of the effect of WM capacity on response times in the *MM condition.* The response times of the NS group in the MM condition was a criterion variable and the WM scores of the NS groups was a predictor variable. Results showed that the WM scores of the NS group cannot explain a significant variance in their response times in the MM condition, $F(1, 18) = .03, p = .87$.

No evidence of the effect of WM capacity on accuracy in the *MM condition.* The accuracy scores of the NS group in the MM condition was a criterion variable in this regression model. Results revealed that the accuracy scores of the NS group in the MM condition cannot be explained by the WM scores of the NS group, $F(1, 18) = .13, p = .73$.

No evidence of the effect of WM capacity on response times in the *SS condition.* A dependent variable was the response times of the NS group in the SS condition. The regression analysis indicated that the WM scores was not a good predictor of the response times of the NS group, $F(1, 18) = .08, p = .78$.

No evidence of the effect of WM capacity on accuracy in the *SS condition.* The accuracy scores of the NS group in the SS condition was a criterion variable in this analysis. Results demonstrated that the accuracy scores of the NS group in the SS condition cannot be predicted by the inhibition scores of the NS group, $F(1, 18) = .69, p = .42$.

Summary of NS group. As predicted, the performances of the NS group could not be explained in terms of WM capacity.

4.2.2. RH group

No evidence of the effect of WM capacity on response times in the *MM condition.* The response times of the RH group in the MM condition was a criterion variable and the WM scores of the RH group was a predictor variable. Results showed that the working scores of RH group did not have an explanatory value for variance in the response times of the RH group in the MM condition, $F(1, 25) = .04, p = .85$.

No evidence of the effect of WM capacity on accuracy in the *MM condition.* The accuracy scores of the RH group in the MM condition was a criterion variable. Results revealed that the accuracy scores of the RH group in the MM condition was not explained significantly by the inhibition scores of the RH group, $F(1, 25) = .48, p = .49$.

No evidence of the effect of WM capacity on response times in the *SS condition.* A dependent variable was the response times of the RH group in the SS condition. The regression analysis showed that the WM scores of the RH group was not a good predictor of the response times of the RH group, $F(1, 25) = .01, p = .91$.

No evidence of the effect of WM capacity on accuracy in the *SS condition.* The accuracy scores of the RH group in the SS condition was a criterion variable in this analysis. Results revealed that the inhibition scores of the RH group did not explain a significant proportion of the accuracy scores of the RH group in the SS condition, $F(1, 25) = .01, p = .93$.

Summary of RH group. The WM scores of the RH group was not a good predictor of the performances of the RH group.

4.2.3. LH group

Evidence of the effect of WM capacity on response times in the *MM condition.* A regression analysis was run using the response times of the LH group in the MM condition. The response times of the LH group in MM condition were a criterion variable and the WM scores of the LH group were a predictor variable. Results showed that the

WM scores of the LH group can explain a significant proportion of variance in the response times of the LH group in the MM condition, $\beta = -.41$, $t(25) = -2.27$, $p = .03$, $R^2 = .17$. There was an inverse relationship between the WM scores and the response times of the LH group, as in $\beta = -.41$; those who have high scores of WM tend to respond faster to the stimuli in the MM condition.

Evidence of the effect of WM capacity on accuracy scores in the *MM condition.* A regression analysis was run using the accuracy scores of the LH group in the MM condition. The accuracy scores of the LH group in the MM condition were a criterion variable and the WM scores of the LH group were a predictor variable. Results showed that the WM scores of the LH group can explain a significant proportion of variance in the accuracy scores of LH group in the MM condition, $\beta = -.41$, $t(25) = -2.21$, $p = .04$, $R^2 = .16$. The negative value of the beta indicates an inverse relationship between WM scores and accuracy scores. This implies that the higher WM scores are, the more accurately the LH group responded.

No evidence of the effect of WM capacity on response times in the *SS condition.* The dependent variable was the response times of the LH group in the SS condition. The regression analysis showed that the WM scores of the LH group was not a good predictor of the response times of the LH group, $F(1, 25) = .24$, $p = .63$.

No evidence of the effect of WM capacity on accuracy in the *SS condition.* The accuracy scores of the LH group in the SS condition was a criterion variable in this analysis. Results revealed that the WM scores of the LH group did not explain a significant proportion of their accuracy scores in the SS condition, $F(1, 25) = .23$, $p = .64$.

Summary of LH group. The WM scores of LH group can explain a significant proportion of the LH group in both their response times and accuracy scores in the MM condition. In contrast, the WM scores of LH group were not a good indicator of their response times and accuracy scores in the SS condition.

In summary, Table 24 shows the research question of Task 2 and its corresponding findings.

Table 24. A summary of research questions and the corresponding findings in Task 2

Research questions	Findings	Summary
The effect of WM capacity on complex nominal processing. Are L1 speakers and L2 learners with higher WM capacity more efficient in processing complex nominals than those with lower capacity?	Yes for the LH group	The NS group and the RH group did not show any substantial effect of WM capacity on complex nominal processing. In contrast, the LH group did reveal the effect of WM capacity on L2 complex nominal processing, particularly when they processed the items in the MM condition involving the highest processing costs.

4.3. Task 3

The descriptive statistics for inhibition scores are provided in Table 25. Descriptively, the NS group showed greater interference than the RH group and the LH group[18].

[18] An ANOVA revealed that the inhibition scores of the three groups did not differ significantly, $F(2, 71) = 1.14, p = .33$.

Table 25. A summary of inhibition scores

Group		
NS (n= 20)	RH (n= 27)	LH (n= 27)
161.24 (.96)	113.55 (.96)	121.47 (.97)

Note. The numbers in the parentheses refer to the accuracy scores (Max = 1, Min = 0).

Note that the inhibition scores are based on the reaction times of the participants. Thus, the higher inhibition scores correspond to the lower inhibitory control ability because the higher scores mean the greater interferences. For example, those who have 100 inhibition scores were better/faster in inhibition or underwent less interference than those who have 200 corresponding scores.

A series of a bivariate regression analysis was conducted to answer the research question. The predictor variable was inhibition scores and the criterion variables were both response times and accuracy scores of MM and SS conditions from the lexical sense decision task, which were measured in Task 1.

4.3.1. NS group

No evidence of the effect of inhibitory control ability in response times in MM condition. The response times of the NS group in the MM condition was a criterion variable and the inhibition scores of the NS group was a predictor variable. Results showed that the inhibition scores of the NS group cannot explain a significant variance in the response times of the NS group in the MM condition, $F(1, 18) = .003, p = .96$.

No evidence of the effect of inhibitory control ability in accuracy in MM condition. The accuracy scores of the NS group in the MM condition was a criterion variable in this regression model. Results revealed that the accuracy scores of the NS group in the MM condition cannot be explained by the inhibition scores of the NS group, $F(1, 18) = .10, p = .75$.

No evidence of the effect of inhibitory control ability in response times in SS condition. A dependent variable was the response times of the NS group in the SS condition. The regression analysis indicated that the inhibitory scores was not a good predictor of the response times of NS group, $F(1, 18) = 3.00, p = .10$.

No evidence of the effect of inhibitory control ability in accuracy in the SS condition. The accuracy scores of the NS group in the SS condition was a criterion variable in this analysis. Results demonstrated that the accuracy scores of the NS group in the SS condition cannot be predicted by the inhibition scores of the NS group, $F(1, 18) = .90, p = .36$.

Summary of NS group. As predicted, the performances of NS group could not be explained in terms of inhibitory control ability.

4.3.2. RH group

Some evidence of the effect of inhibitory control ability in response times in MM condition. In this regression model, the response times of the RH group in the MM condition was a criterion variable and the inhibition scores of the RH group was a predictor variable. Results showed that, although marginal, the inhibition scores of the RH group can explain some proportion of variance in the response times of the NS group in the MM condition, $\beta = .34$, $t(25) = 1.80, p = .084$, $R^2 = .11$. Also, the positive directionality as in $\beta = .34$ is in a predicted direction because the inhibition measures of this study correspond to the interference (i.e., high scores = higher interference in inhibiting irrelevant information).

No evidence of the effect of inhibitory control ability in accuracy in the MM condition. The accuracy scores of the RH group in the MM condition was a criterion variable. Results revealed that the accuracy scores of the RH group in the MM condition was not explained significantly by the inhibition scores of the RH group, $F(1, 25) = 2.24$, $p = .15$.

No evidence of the effect of inhibitory control ability in response times in the SS condition. A dependent variable was the response times of the RH group in the SS condition. The regression analysis showed that the inhibitory scores of the RH group was not a good predictor of the response times of the RH group, $F(1, 25) = 1.34$, $p = .26$.

No evidence of the effect of inhibitory control ability in accuracy in the SS condition. The accuracy scores of the RH group in the SS condition was a criterion variable in this analysis. Results revealed that the inhibition scores of the RH group did not explain a significant proportion of the accuracy scores of the RH group in the SS condition, $F(1, 25) = 1.39$, $p = .25$.

Summary of the *RH group.* The response times of the RH group in the MM condition can be explained to some extent in terms of inhibitory control ability of the RH group. In other conditions, the inhibition scores were not a good indicator of predicting the performances of the RH group.

4.3.3. LH group

Evidence of the effect of inhibitory control ability in response times in the MM condition. A regression analysis was run using the response times of the LH group in the

MM condition as a criterion variable and the inhibition scores of LH groups as a predictor variable. Results showed that the inhibition scores of the LH group can explain a significant proportion of variance in the response times of the LH group in the MM condition, $\beta = .47$, $t(25) = 2.57$, $p = .02$, $R^2 = .21$.

No evidence of the effect of inhibitory control ability in accuracy in the MM condition. The accuracy scores of the LH group in the MM condition was a criterion variable. Results revealed that the accuracy scores of the LH group in the MM condition was not explained significantly by the inhibition scores of the LH group, $F(1, 25) = 2.31$, $p = .14$.

No evidence of the effect of inhibitory control ability in response times in the *SS condition.* A dependent variable was the response times of the LH group in the SS condition. The regression analysis showed that the inhibitory scores of the LH group was not a good predictor of the response times of the LH group, $F(1, 25) = .01$, $p = .93$.

No evidence of the effect of inhibitory control ability in accuracy in the *SS condition.* The accuracy scores of the LH group in the SS condition was a criterion variable in this analysis. Results revealed that the inhibition scores of the LH group did not explain a significant proportion of the accuracy scores of the LH group in the SS condition, $F(1, 25) = 2.01$, $p = .17$.

Summary of LH group. Inhibitory control ability can explain a significant proportion of the response times of the LH group in the MM condition. As in the case of the RH group, the inhibition scores of the LH group were not a good indicator of the response times of the LH group in the SS condition and their accuracy scores in the MM and SS conditions.

In summary, Table 26 demonstrates the research question and the major findings of Task 3.

Table 26. A summary of research questions and the corresponding findings in Task 3

Research questions	Findings	Summary
RQ. *The effect of inhibitory control ability on complex nominal processing.* Are L1 speakers and L2 learners with higher inhibitory control capacity more efficient in processing complex nominals than those with lower capacity?	Yes for the NNS groups	The NS group did not show any substantial effect of inhibitory control ability on complex nominal processing. In contrast, the two NNS groups showed the effect of inhibitory control ability on L2 complex nominal processing, particularly when they processed the items in the MM condition involving the highest processing costs. Furthermore, the effect of inhibitory control ability was stronger in the LH group than in the RH group.

CHAPTER FIVE - DISCUSSION

4.1. The second language mental lexicon

Task 1 was intended to see how L2 learners represent and retrieve complex nominals, a type of morphologically complex word, with reference to native speakers. Of focal interest is an examination of the dual functions of the language faculty, that is, storage and computation, in the second language mental lexicon.

Task 1 set out with four research questions. In order to examine the dual functions of the second language lexicon, I proposed a new interference paradigm; specifically, I manipulated the lexical ambiguity of each constituent in complex nominals (i.e., single meaning-single meaning (SS) such as *orange juice*, single meaning-multiple meanings (SM) such as *violin bow*, multiple meanings-single meaning (MS) such as *well water*, and multiple meanings-multiple meanings (MM) such as *lead mine*).

In essence, the four conditions would differ in terms of processing costs when there are delayed computations; the items in the SS condition would have the smallest processing costs while those in the MM condition would have the greatest cost in terms of processing. The processing costs of the items in both SM and MS conditions would be in the middle of the SS and the MM conditions. L1 dual-route models suggest that novel compounds are interpreted via computational routes while familiar compounds are recognized through retrieval routes (e.g., Baayen, Dijkstra, & Schreuder, 1997; Bertram, Schreuder, & Baayen, 2000; Caramazza, Laudanna, & Romani, 1988; Pinker & Ullman, 2002). Looking at the four experimental conditions from the perspective of the distinction between novel and familiar compounds, the four experimental conditions establish a continuum from lexicalized to novel complex nominals. Words in the MM condition are likely to function as novel compounds, the SS condition is comprised of lexicalized compounds, and the SM and MS conditions are positioned along the continuum between the SS and MM conditions. Therefore, I expected that, if complex nominals involve delayed computations, the frequency-matched and syllable-matched stimuli in the four conditions would result in a graded interference of their response times and accuracy scores. Assuming that each constituent plays a role in the interpretation of complex nominals, I expected that interference would be greatest when both constituents have multiple meanings, whereas the processing costs would be minimal when each constituent has a single meaning. Thus, I predicted that participants would respond slowly and inaccurately in the MM (multiple meanings-multiple meanings) condition (i.e., the highest in processing costs), as compared to the SS (single meaning-single meaning) condition (i.e., the lowest in processing costs).

With respect to potential behavioral differences between NS and NNS groups, I expected that the predictions related to the four conditions would emerge only among non-native speakers. Recall that the stimuli used in Task 1 are "familiar" complex nominals, which can be found in a large English corpus. That is, native speakers could either store the familiar nominals or compute them very efficiently or automatically, given that, as Gagné and Spalding (2004) state, high-frequency words are more likely to be stored in a long-term memory (availability) or are easy to process (familiarity). In other words, high frequency complex nominals may not simply mean the holistic representations (i.e., availability); rather, the high frequency could mean "familiarity" in the sense that compounds that are encountered very frequently could enjoy easier computations. In contrast, insofar as NNS groups are concerned, it is not obvious that the stimuli of Task 1 are lexicalized even among the NNS groups with high L2 proficiency, because high frequency in a large corpus does not necessarily guarantee the lexicalization of complex nominals in the L2 lexicon. Assuming that both retrieval and computation mechanisms are part of the L2 lexicon, a failure to retrieve the meaning of a whole complex nominal necessitates the use of computational routes. Yet, given that L2 learners are generally less efficient in processing the L2, the NNS groups would yield delayed computations, which would be reflected in the graded interference among the four experimental conditions.

Differences between NS and NNS. The first research question focused on the difference between the NS and NNS groups in terms of their behavioral patterns. The first research question asked whether the NS group differs significantly from the two NNS groups, the RH (right-headed) and LH (left-headed) groups. Regarding response times, as predicted, the result revealed that the NS group responded significantly faster in all four conditions than the two NNS groups. There are two possible interpretations for this finding: (1) a storage difference and (2) a processing difference. First, the difference between the NS group and the two NNS groups may be because the NS group stored or lexicalized each of the stimuli in Task 1 as a whole unit. In contrast, the NNS groups may have experienced more interference due to semantic computation in the same way that NSs likely compute a novel complex nominal when encountering it. Alternatively, a difference in processing efficiency could explain the performance discrepancy between the NS and NNS groups. That is, the NS group was able to compute the stimuli very efficiently, whereas L2 processing of complex nominals is relatively slower. The results of accuracy scores, in general, replicated the findings of the differences in response times, although there were some marginal differences between the NS and RH groups.

Overall, the significant difference between the NS and NNS groups seems to suggest that the two NNS groups relied more on computational processes in order to recognize the meanings of complex nominals.

No difference between RH and LH groups. The second research question is concerned with L1 influence on morphological processing. Particularly, I questioned whether the compound structure of L1s (particularly, the headedness) affects the processing of L2 complex nominals.

Complex nominals in English have the order of modifier-head (i.e., orange juice). L2 learners belonging to the RH group have the identical complex nominal order in their native language as in English. Thus, I expected less interference would be involved in the construction of meaning of complex nominals. In contrast, the LH group has to switch the order of complex nominals from head-modifier (L1 structure) to modifier-head (English) to derive the appropriate meaning for them, assuming that the LH group experience interference due to the compound structure of their L1. Thus, I expected that, if the L1 plays a role in processing L2 complex nominals, the LH group, including Spanish and Thai learners, would experience more interference than the RH group, including Chinese and Korean learners, when processing English complex nominals, which are right-headed.

However, the findings revealed that there was no significant difference between RH and LH groups in terms of both reaction times and accuracy scores in all four conditions[19]. This finding, in turn, suggests that the L1 compound structure did not play an important role in recognizing L2 complex nominals. A possible interpretation for the lack of difference between RH and LH groups is related to the two groups' comparable L2 proficiency. Note that the L2 sample populations both have high L2 proficiency. Given that L2 learners become more independent of the L1 as L2 proficiency increases (e.g., Frenck-Mestre & Prince, 1997; Kroll & Curley, 1988), the effect of L1 compound headedness was minimal with the sample of this study. Alternatively, I would expect to find greater evidence of L1 influence with learners of lower L2 proficiency.

The mixed results of uniform and graded interferences in the NS group. The third research question examined whether the NS group shows different amounts of interference in processing the stimuli in the four conditions. In general, two competing hypotheses have emerged in relation to the dual functions of the lexicon. First, if the NS group relies on a simple retrieval or employs an efficient computational mechanism, there would not be graded interferences among the four conditions. A second possibility is based on computational routes in recognizing complex nominal in which NSs would show graded interference among the conditions.

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[19] When Spanish learners are excluded from the LH group, the overall results were the same, indicating that the Thai and Spanish speakers in this study behaved comparably. For example, when a MANOVA was run with reaction times of the LH group and the Thai group only, there was no significant difference (Wilk's Lamdba = .96, $F(4, 41) = .38$, $p = .82$). A corresponding analysis of accuracy scores (i.e., the RH group vs. the Thai group) did not reveal any significant difference (Wilk's Lamdba = .93, $F(4, 41) = .77$, $p = .55$). However, since the number of the Spanish participants was small (i.e., less than 10), the differences between Thai and Spanish learners in terms of processing L2 complex nominals are temporarily tabled and invite a future investigation.

The response time data and the accuracy score data provided two conflicting pieces of information. The reaction time data indicated that the NS group showed no significant differences in interference or lexical competition among the conditions because the response times of the NS group are statistically comparable. A possible interpretation is that the NS group simply retrieved the familiar complex nominals that were used in Task 1, which would suggest holistic representations of complex nominals. Yet, it should also be noted that, although statistically not significant, the NS showed the greatest interference in their response times in the MM condition ($M_{\_MM} = 1002.38$), compared to the other three conditions ($M_{\_MS} = 946.68$; $M_{\_SM} = 937.20$; $M_{\_SS} = 948.01$). When the differences between the response times in the MM condition and those in the other conditions were estimated by effect sizes (Cohen's d) based the pooled standard deviation corrected for the correlation, the practical significance was large in the contrast between MM and SM conditions ($d = .61$). Also the effect sizes was moderate in the contrast between MM and SS ($d = .47$) and in the contrast between MM and MS conditions ($d = .48$). The results of descriptive statistics and the effect sizes seem to suggest that NS use computational routes, yet the efficient computational parser of the NS group reduced the competition between each constituent in the four conditions.

In the accuracy data, the NS group responded more inaccurately to the stimuli in the MM condition than those in the remaining three conditions. It is plausible to say that the stimuli in the SM, MS, and SS conditions may be stored as single lexical items. In the MM condition, however, the accuracy results indicate lexical competitions between modifier nouns and head nouns. A simple retrieval mechanism failed to explain the performance of the NS group in MM condition. That is, if the stimuli in the MM condition such as *lead mine* are represented as individual items, it seems difficult to provide a rationale for the significant inaccuracy found in the MM condition. Rather, NS are highly likely to rely on semantic computations (i.e., integrating the meanings of modifiers and heads) in interpreting the familiar complex nominals in the MM condition.

In order to explain the results of the NS group, it seems necessary to accommodate the dual functions of the language faculty (i.e., computation and storage) or full-parsing accounts. No difference in the response times among the four conditions suggested holistic representations of familiar complex nominals; at the same time, the difference in accuracy scores provided evidence of both holistic (SM, MS, and SS conditions) and discrete representations (MM condition) of complex nominals. Alternatively, the comparable performance of the NS group may stem from efficient morphological processing, which is in support of a full-parsing account.

The graded interference of the NNS groups. The fourth research question asks whether NNS groups show competition effects in processing complex nominals. I expected that, since the familiar complex nominals in Task 1 could function as *novel* items for non-native speakers, NNS groups would show competition effects across the four conditions. More specifically, if computational processes are involved in the recognition process, graded interferences are expected from the SS condition to the SM and the MS conditions, and from there to the MM condition because the processing costs will increase in relation to the number of ambiguous constituents.

The descriptive statistics for both reaction times and accuracy scores suggested that graded interference emerged in both RH and LH groups, which is consistent with our prediction based on the difference in processing cost. That is, both RH and LH groups showed the greatest interference in the MM condition, the smallest interference in the SS condition, and intermediate interference in the MS and SM conditions (i.e., MM > SM, MS > SS). Inferential statistics revealed that the difference between the MM and SS conditions is significant, but other comparisons did not differ significantly. This finding does suggest a graded interference across the four conditions.

A full-listing account is unable to explain the graded interference because uniform interference should be found with the established meanings of complex nominals. In contrast, both full-parsing and dual-route accounts seem to explain the findings appropriately. A full-parsing account could claim that the difference in the processing loads of the four conditions led to the graded interference among the four conditions. The NNS groups' difficulty in judging the combinations in the MM condition imply that NNS employed semantic computations to construct an interpretation and that the computation loadings or interferences in computation are differentiable in terms of the ambiguity of each constituent in the combination. The finding of differentiated competition suggests that NNSs constructed the interpretation of a complex nominal rather than retrieved the meaning of the familiar combination. From a dual-route account, there was a competition between retrieval and computational routes. The retrieval route won for the SS condition where the processing cost was lowest. The computational route played a major role for the recognition of complex nominals, resulting in the slow-down in reaction times and the inaccurate responses. The responses in the SM and MS conditions seem to show a middle ground of the dual processes.

An assumption I made for the four experimental conditions is that L2 learners actually know all the meanings of each multi-meaning word[20]. This is based on previous research that has found that L2 learners do activate multiple meanings when processing L2 homonyms (Frenck-Mestre & Prince, 1997). A point can be used to verify whether the L2 participants of this study who had high level of L2 proficiency were able to activate the multiple meanings of a constituent. The idea of the graded interference is based on competitions that may be caused by both the meaning activations of each constituent and the activations of relational structure. If the semantic integration of complex nominals does not involve competition, there should be similar uniform interference to the case of the NS group. Given that a resource of competition is the meaning activations of each constituent in a complex nominal, the graded interference displayed by the NNS groups indicate multiple meaning activations of each constituent when a constituent has multiple meanings.

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[20] An issue with regard to the stimuli is whether the homonyms in the complex nominals could have diverse syntactic categories. In this study, I included items that contain the use of nouns either in the first meaning or in the second meaning or both. For example, the word *bear* could have a verb reading in their first meaning or have a noun reading in their second meaning. A related issue is that there are two types of homonyms in terms of meaning dominance; balanced homonyms have two relatively equally frequent meanings whereas polarized homonyms have a primary meaning which is much more frequent than the next roost common meaning (e.g., Twilley, Dixon, Taylor, & Clark, 1994). The fine-grained classifications of homonyms with respect to meaning dominances remain as a future research.

Another implication of the graded interference in the NNS groups is that each constituent is actively engaged in constructing the meaning of complex nominals. If one of the constituents (i.e., either modifier or head) plays a more dominant role in interpreting complex nominals, I would expect not only a comparable interference either between MM and SM or between MM and MS, but also different magnitudes for the MS and SM condition. The greater interference in the MM condition than in both SM and MS conditions found in this study favors an account of interactive roles of each constituent in the interpretive processes of complex nominals. As discussed in Chapter 2, there are two competing theories of establishing semantic relations between two constituents in a complex nominal in L1 psycholinguistics literature: a schema-based theory (Murphy, 1988, 1990; Wisniewski, 1996) versus CARIN (competition among relations in nominals) theory (Gagné & Shoben, 1997, 2002). In general, the schema-based theory claims that the modifier (the first noun in English complex nominals) serves as a filler for a slot in the head noun (the second noun) and thus the head noun plays a key role in establishing semantic relations of complex nominals; in contrast, the CRAIN theory emphasizes the role of the modifier (i.e., the first noun) in complex nominal processing, arguing that the modifiers trigger/activate the competition of possible semantic relations with the heads (the second noun). Interestingly, the findings of this study based on an interference paradigm provide counter-evidence for both the schema-based theory and the CRAIN theory. In both theories, the responses to the MM conditions should be comparable to those to the MS and the SM conditions because either the head or the modifier plays a key function in constructing a meaningful relationship between the two nouns in a complex nominal. The greatest interference in the MM condition suggests that the construction of a meaning relationship between the constituents should be viewed as an interactive process, which is not entirely determined by either the head or the modifier.

In general, the findings suggest that the two NNS groups did use compositional routes. This, in turn, provides a challenge to storage-based accounts of L2 vocabulary acquisition, which is dominant in second language lexicon research. Importantly, the findings implicated the expansion of L2 vocabulary research to encompass both storage and computational routes.

The Frequency effect. Frequency is often considered as evidence for the holistic representations of multi-words such as formulaic sequences (e.g., Jiang & Nekrasova, 2007). Thus, the examination of the frequency effect is a way to examine whether both NSs and NNSs rely more on the retrieval route. The fourth research question addressed this issue. A general expectation regarding the dual functions in the lexicon is that the lexicalized items are directly retrieved from the lexicon whereas unlexicalized complex nominals are derived by semantic computations of two constituents. The frequency effect was expected for the NS group, given that the stimuli in this study are based on "familiar" complex nominals that may be lexicalized in native speakers' minds. At the same time, I expected that the frequency effect may be moderate among the NS group because even NSs might interpret some proportion of the familiar combinations through semantic computation.

I examined the reaction times of the three groups to see if they are predictable based on the frequency of the whole complex nominals. As predicted, the frequency effect of complex nominals emerged only in the NS group, but not in the two NNS groups. The response times of the NS group were predictable with the frequency of complex nominals, which replicates the robust findings of the frequency effects, in general. Not surprisingly, the NS group demonstrated a strong negative correlation between their reaction times and the highly frequent complex nominals as a whole. The finding suggests that the NS group is likely to represent the high-frequency complex nominals as single lexical items. However, it should be noted that the effect size (estimated by the r-squared) was moderate even in the strongest correlation between the high-frequency complex nominals and the reaction times of the NS group, $r = -.38$, $r^2 = .14$, given that the r^2 of 0.14 means that 14% of the variance of the frequency measures is shared with the reaction times of the NS group. In other words, there are many proportions that the holistic representations do not cover. Thus, the NS group's behavior can be characterized better in terms of the dual routes (i.e., storage and computation) of complex nominal processing.

In the case of the NNS groups, there were mixed results in terms of the associations between the frequency of complex nominals and the RTs of the NNS groups[21]. Two noticeable patterns were identified in terms of the directionality of correlations. First, both the RH and the LH groups showed negative correlations between the frequency of the whole complex nominals when the complex nominals are either high- or mid frequency. The inverse relationship corresponded to the patterns of the NS group, which seems to suggest that the NNS groups stored small portions of complex

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[21] It may not fair to say that NNSs have the same degree of exposure to complex nominals. This study follows a conventional method that the frequency is estimated through a corpus that is based on L1 data. A rigorous investigation of frequency effects for NNSs remains as a future research.

nominals holistically. Secondly, the two NNS groups revealed a positive correlation between the low-frequency complex nominals and their reaction times. The positive correlations suggest that, in contrast to the NS group, the NNS groups may not store the low-frequency words as a whole but rather interpret the low-frequency complex nominals via computations.

Overall, the convergence and divergence of the NS and the NNS groups in Task 1 suggests that the dual functions of language faculty (i.e., storage and computation) play a key role in the comprehension of complex nominals. There was converging evidence that both NS and NNS groups not only retrieve the established meanings of complex nominals but also construct the meanings of complex nominals. At the same time, there was diverging evidence between the NS group and NNS groups. NS seem to retrieve the meaning of familiar items from Task 1 from their memory, evidenced by comparable RTs in the four conditions; however, the NS group's reliance on the retrieval mechanism was a small proportion (14%), which was estimated by the relationship to frequency, suggesting that the efficient morphological parsing of the NS group minimized the graded interference.

In contrast, the NNS groups tended to rely greatly on the computation route to establish the meanings of complex nominals, as suggested by the highest interference in the MM condition; yet, I also found minimal evidence that the NNS groups utilized the retrieval route to interpret complex nominals, as indicated by the predicted inverse relationship between reaction times and the frequency of the high- and mid-frequency complex nominals. Therefore, both the NS and NNS data revealed a continuum of dual mechanisms (i.e., retrieval route and computational route) in interpreting complex nominals.

4.2. The role of cognitive ability on comprehending complex nominals

Tasks 2 and 3 are concerned with whether cognitive abilities play a role in the recognition of complex nominals. The semantic integrations were observed to involve the resolution of competing information, which is caused by the meaning activation of each constituent in a complex nominal and the activation of relational structures. Given that the semantic integrations are the part of the architecture of the L1 and L2 lexicon, I questioned whether those with better cognitive ability may have an advantage in resolving competitions associated with the recognition of complex nominals over those with lower cognitive ability. The question was examined in relation to the processing loads of the test items and the influence of L1 morphological knowledge.

Working memory capacity. Working memory (WM) capacity involves the cognitive processes required to perform mental operations on chunks of information and the temporary storage of those chunks (Baddeley & Hitch, 1974; Cowan, 2005; Hasher, Lustig, & Zacks, 2007; Kane & Engle, 2003). I reasoned that, if the recognition of complex nominals involves a computational process, then working memory capacity may be related to the comprehension processes. That is, it is possible that high WM individuals may be faster at combining complex nominals than their low WM counterparts.

The effect of WM is salient when processing loads are costly or when tasks are cognitively complex. Thus, I expected that the WM effect on the recognition of complex nominals would emerge when not only processing cost is high, but when language background also plays a role. My first expectation was that computational costs would be minimal in the NS group, intermediate in the RH group, and the greatest in the LH group. The possible difference in processing cost allows us to predict different effects of WM among the three groups. It is not likely to find a WM effect in the NS group because their interference would be minimal. However, I expected that the effect of WM would be found in at least the LH group, given the possibility of L1 interference and great processing costs. As for the RH group, it was predicted that WM capacity would play a moderate role in processing complex nominals. Secondly, I did not expect that the effect of WM would be observed in all the conditions. WM capacity generally states that those who have higher WM capacity could be faster in a higher cognitive process than those who have lower WM capacity. In our four conditions, the MM condition involves the highest interference whereas the SS condition involves the lowest interference. Therefore, I expect that the WM effect may be found only in the MM condition but not in the SS condition.

The results confirmed that the WM capacity of the LH group played a significant role in predicting both reaction times and accuracy scores only in the high interference condition. That is, the participants in the LH group who have higher WM scores took less time and were more accurate in interpreting complex nominals whose constituents are homonyms than those who have lower WM scores. However, the effect was neither found in the single meaning-single meaning condition, nor among the NS and RH groups, as expected.

An implication for the findings of the WM effect on the LH group in the MM condition is that the LH group made the stronger reliance on computational routes than the RH group. The difference between the LH and the RH group was not substantial in Task 1. Note that, as expected, the NS group did not show a significant effect of WM capacity. This, in turn, suggests that the recognition of complex nominals may not be sufficiently difficult for the NS presumably because the NS individuals could use more simple retrieval mechanisms or compute complex nominals with high efficiency. As with the NS group, the RH group did not reveal a substantial effect of WM capacity on recognizing the complex nominals. The behavioral pattern of the RH group appears to indicate that the recognition task invoked less processing costs for the RH group than for the LH group. Therefore, the WM effect is compounded with L1 background in the sense that the recognitions of complex nominals invoked greater computational loads to the LH group than the RH group.

A notable finding of this study is that the role of WM capacity was observed even with complex nominals. It is plausible that, at least in the domain of L1 processing, morphological processing would involve less processing costs or efficient computations. Thus, the relationship between WM capacity and L1 morphological processing may be a less interesting question, given that the WM effects were generally observed in complex cognitive tasks such as sentence processing (e.g., Daneman & Carpenter, 1980; Harrington & Sawyer, 1992; Juffs, 2004; Waters & Caplan, 1996). Thus, this L2 study provides an important piece of information regarding the relationship between WM capacity and morphological processing, information that is not available through an examination of L1 data alone.

Inhibitory control ability. Complex nominal processing involves the inhibition of irrelevant information, as supported by aphasia studies. Particularly, in Task 3, the role of inhibitory control ability was examined in relation to (1) the effect of processing cost manipulated by the number of meanings of each constituent and (2) the consequence of language background. The results indicated that these two factors (i.e., processing cost and language background) jointly affect the recognition of complex nominals.

In general, inhibitory control ability was expected to play comparable function to working memory capacity, considering that the similarity between inhibitory control ability and the WM capacity such as goal maintenance and inhibition of competing information (Chiappe & Chiappe, 2007; Kane & Engle, 2003; Long & Prat, 2002). Thus, I expected that WM and inhibitory control ability effects would reveal a converging piece of evidence; those who may have better inhibitory control ability would be more efficient in recognizing complex nominals.

The findings revealed that the LH group showed a significant effect of inhibitory control ability on comprehending complex nominals whereas the RH group was associated with a marginal effect of inhibitory control ability. That is, in the LH group, the individuals with higher inhibitory control ability significantly outperformed those with lower corresponding ability when inhibiting irrelevant information in comprehending complex nominals. As expected, the NS group did not show the effect of inhibitory control ability on the recognition of complex nominals. The findings suggest that the cost of processing and L1 background jointly affect the recognition of complex nominals.

Despite the different magnitudes of the effect, the LH group and RH groups demonstrated that inhibitory control processes are involved in complex nominal processing. This finding converges with those of aphasia studies (e.g., Badecker, 2001; Libben, 1998). Therefore, interlanguage data add an important piece of information to understand the mechanism of complex nominal processing in the same way as the previous aphasia study did.

A methodological issue is that the measure of inhibitory control in this study is based on a second language for the NNS groups. In case of L2 Stroop test, the level of L2 proficiency is at an issue because research suggests that L2 inhibitory control ability is compounded with level of L2 proficiency (Brauer, 1998; Goldfarb & Tzelgov, 2007; La Heij, de Bruyn, Elens, Hartsuiker, & Helaha, 1990; Preston & Lambert, 1969; Zied, et al., 2004). Simply put, it is easy for L2 learners of low L2 proficiency to inhibit information because they can ignore the language information in the Stroop task. For example, one who does not know Korean shows no interference in doing a version of the Stroop test where the stimuli are presented in Korean. Thus, an expectation for the L2 Stroop test is that the effect of L2 inhibitory control ability would be observable with learners of high L2 proficiency. In this regard, one may ask whether the L2 inhibition scores in this study is a measure of L2 learners' ability to suppress irrelevant information. Or one may question whether the NNS participants in this study have "sufficient" levels of L2 proficiency that lead to an appropriate measure of L2 inhibitory control ability. One way to look at this issue is to examine the interaction between inhibitory control ability and working memory capacity. The relationship between them is expected to be inversely correlated; that is, those who have higher WM capacity would show less interference or greater inhibition in processing information. A recent study by Gass and Lee (in press) found the predicted inverse relationships between L1 working memory scores and L2 inhibition scores in both the first year and the third year Spanish groups. In terms of the magnitudes, the correlations were not significant (r (41) = -.28) for the first year Spanish group but was significant for the third year Spanish group (r (65) = -.24). Compared to Gass and Lee (in press), the NNS participants were higher levels of L2 proficiency, although the differences in the target languages do not allow us to directly compare Gass and Lee (in press) and this study. In case of this study, when combining both the LH and the RH group into a NNS group, there was a strong correlation between the L2 inhibition scores and the WM scores measured by an operation span, $r(52) = -.34$, $p = .01$. Note that not only the directionality is in the expected negative way, but also the magnitude of the correlation coefficient is stronger. Thus, it seems reasonable that the L2 inhibition scores in this study did measure L2 learners' inhibitory control ability.

CHAPTER SIX - CONCLUSION

The general goals of this dissertation were: (1) to investigate whether the dual functions such as computational routes and retrieval routes can be demonstrated in both the L1 and L2 lexicon structures, through the performance of NSs and NNSs in recognizing complex nominals in English, (2) to examine whether the headedness of L1 complex nominal structures influences the acquisition of L2 complex nominals, and (3) to explore whether L2 learners with better cognitive abilities such as inhibitory control and working memory may have an advantage in the processing of complex nominals. In order to address these issues, three tasks were carried out with one NS group of English and two NNS groups whose L1 compound structures differ in terms of headedness.

With respect to the dual functions in the lexicon, this study investigated an interesting theoretical question of whether a complex nominal such as *coffee cup* is represented either holistically (i.e., coffee-cup) or discretely (i.e., coffee and cup) or in a dual fashion (coffee-cup, coffee, and cup). In this regard, complex nominals could be a window to the understanding of how lexical information is organized. Based on the previous L1 research of complex nominals, this study examined both NS and NNS groups, with respect to (1) full-listing models in favor of holistic representations, (2) full-parsing models in support of discrete representations, and (3) dual-route models accommodating both full-listing and full-parsing models. The findings of L1 and L2 speakers in this study support both full-parsing and dual-route models; the NS group appeared to have a balanced use of retrieval and computational routes whereas, while exhibiting moderate evidence for the use of retrieval routes, the NNS groups seemed to rely more on computational routes.

A theoretical implication for second language lexicon research is that both computation and retrieval are equally important to our understanding of the architecture of the second language lexicon. The findings of the current study indicated that L2 learners may store individual words but have fewer complex nominals stored as a whole. Despite this unbalanced display of dual functions in the second language lexicon, importantly, L2 learners were able to recognize complex nominals correctly, as evidenced by the accuracy scores of this study. The correct recognitions of L2 learners indicate the use of computational routes or semantic integrations/computations in interpreting complex nominals. However, L2 learners are less efficient in integrating the two constituents than NSs, showing greater processing loads in the multiple meanings – multiple meanings condition of complex nominals. Therefore, this study provides a strong piece of empirical evidence that computation is the structure of the second language lexicon. At the same time, this study provides strong support for storage-based L2 lexicon research. A clear disadvantage for L2 learners is that they possess a smaller number of stored complex nominals. In order to compensate for this disadvantage, L2 learners have to rely more on computational routes. Thus, it is important to study how L2 learners can increase the amount of stored information in their second language lexicon and to examine whether L2 learners benefit from the use of retrieval routes.

Another implication for L2 lexicon research is that L1 morphological knowledge affects the structure of the second language lexicon. At the level of descriptive statistics, the left-headed NNS group showed slower processing of English complex nominals than the right-headed NNS group, presumably due to the difference in the headedness of L1 and L2 complex nominals. Yet, it is also notable that, when comparing L2 learners of comparably high L2 proficiency, the difference between the LH and the RH was not significant at the level of inferential statistics, suggesting that, as L2 proficiency increases, the influence of L1 headedness may lessen.

Furthermore, the L1 morphological structures of L2 learners were associated with the effect of cognitive variables on the recognition of complex nominals. The effects were observed in conjunction with the processing loads of the test items and L1 backgrounds. Although the behavioral differences in the LH and the RH groups were not significant, individuals with high cognitive abilities in the LH group have greater benefits in processing English complex nominals than those in the RH group. An implication of this finding is that the LH group yield greater interferences in processing L2 complex nominals which are right-headed, indicating an L1 influence on L2 morphological knowledge.

The current study leaves open several areas for future investigation. The first research area is related to L1 influence. Particularly, we should consider the more fine-grained classifications of L1 morphological structures in investigating the influence of L1 morphological structure on processing L2 complex nominals. For example, this study collapses Spanish and Thai into one group because the two languages are left-headed in terms of L1 morphological structures of complex nominals. Despite this commonality between the two languages, as described earlier, the two languages somewhat differ in terms of structures of complex nominals. Specifically, in Spanish it is more productive to insert a preposition between two constituents in a complex nominal whereas in Thai, complex nominals are made up without a preposition. More importantly, in the case of Spanish, a preposition can have semantic functions to clarify the relationship between two nouns. In Spanish, although the preposition *de* is widely used to link two constituents in a complex nominal, a preposition such as *para* can also be used to express the intended use of the head noun such as *jarra para cerveza* 'beer mug' (Bradley & Mackenzie, 2004). The examples from Spanish show clearly that a preposition is not a simple syntactic link between two nouns, but has semantic functions to clarify the relation between two constituents. In contrast, in such languages as Thai and Vietnamese, linking prepositions are not used in the formation of complex nominals. Therefore, it is worthwhile to examine whether the second language acquisition of complex nominals differs depending on whether the L1 structure of complex nominal includes linking prepositions.

A related research domain is that noun-noun compounding is a highly productive system in some languages such as German whereas the compounding is relatively less common in other languages such as Spanish. It may be possible that German speakers have an advantage in learning compounds in other languages. In this regard, it would be interesting to examine whether the morphological productivity of the L1 affects the acquisition of L2 compounds.

The second future research area is to look at the role of L2 proficiency in recognizing L2 complex nominals. This study only examined L2 learners who have high L2 proficiency. The findings of this study imply that L2 learners with low L2 proficiency may depend far more on computational mechanisms than those with high L2 proficiency.

Yet, this is an empirical question and it is also important to look at how exactly L2 learners who have low proficiency process L2 complex nominals.

The third domain of future research is to examine the difference in modality. This study is based on the recognition of L2 complex nominals. Obviously, production data broadens our understanding of how L2 learners acquire L2 complex nominals. For example, the marginal difference between the LH and the RH groups in this study may be magnified in a study of complex nominal production.

The fourth area for a future investigation is to examine the effect of context on the interpretations of complex nominals. As with the case of this study, it is important to see how complex nominals can be interpreted on the base of the meanings or semantic representations of each constituent. At the same time, it is also important to examine how L2 learners are influenced by contexts or discourse in interpreting complex nominals, as investigated in much L1 research (Gagne & Murphy, 1996; Gerrig & Bortfeld, 1999; Gerrig & Murphy, 1992).

This dissertation has theoretical value for the broader domain of language science. The contrasting ideas of retrieval and computation in the lexicon are related to the theoretical division between symbolist/generative and connectionist accounts in language science. Overall, a generative account supports the idea of computations whereas a connectionist favors the idea of retrieval within the lexicon. However, this dissertation illustrates that both retrieval and computation are not mutually exclusive; rather, both notions are integral in providing an appropriate account of the architecture of both the L1 and L2 lexicon. The results of this study suggest that both L1 and L2 lexicons may be structured to maximize both retrieval mechanisms and the computational system. Beyond

SLA research, this dissertation filled a gap in the complex nominal research base, in which L2 findings were not reflected. The interlanguage data is particularly valuable because the behavioral patterns of L2 learners reflect the continuum between lexicalized and novel complex nominals. The dissertation demonstrated that L2 learners rely on the dual functions of the lexicon in interpreting complex nominals, which corresponded to the findings of much of previous L1 research, including L1 psycholinguistics (e.g., Gagné, 2001; Libben, 1998), L1 neuro-imaging studies (e.g., Fiorentino & Poeppel, 2007) and L1 aphasia studies (e.g., Badecker, 2001).

Furthermore, interlanguage data enable us to identify the role of cognitive variables on the interpretation of familiar complex nominals, which is difficult to observe in L1 studies. L1 studies have rarely tested the effect of cognitive variables on the recognition of complex nominals, partly because the efficient processing of NSs fails to demonstrate the effect under normal circumstances. Thus, most evidence for the role of cognitive variables on complex nominal processing is based on aphasia studies. The current study, based on L2 learners' performance in a normal environment, identified the effect of inhibitory control abilities and working memory capacity on recognizing complex nominals, due to the delayed processing mechanism of L2 learners. Therefore, this study provides an important piece of empirical evidence for understanding the relationship between complex nominal processing and cognitive abilities.

Also, this dissertation has theoretical relevance for theories of L2 acquisition. Within the domain of L2 vocabulary learning, this dissertation highlights the importance of the dual functions in the L2 lexicon. Despite the fact that many SLA researchers have pointed out that connectionist approaches (i.e., retrieval-preference) cannot explain the entire process of second language acquisition, this research clarifyies the necessity of both symbolist/generative (computation-preference) and connectionist accounts in a better understanding of SLA (Ellis, 2003; Gregg, 2003; Hulstijn, 2002; O'Grady, 2003; Sharwood Smith, 1994). The findings of this study showed that L2 learners were more dependent upon computational routes, suggesting a call for in-depth investigations of computations in L2 lexicon research. At the same time, this study added the finding that L2 learners are not efficient in using retrieval routes. Assuming that both computation and retrieval mechanisms are parts of the L2 lexicon, this dissertation also illustrates why the study of the storage of L2 multi-morphemic words (e.g., complex nominals and formulaic sequences) in the L2 lexicon matters.

This dissertation of the L2 lexicon provides an insight into the two key concepts -- storage and computation -- of understanding the language faculty (e.g., Nooteboom, Weerman, & Wijnen, 2002), which are also fundamental considerations in explaining L2 acquisition. In this regard, this study illustrates how L2 empirical research can contribute to both L1 and L2 theoretical literature through testing and validating theoretical constructs.

APPENDIX A

The sensible test items used in Task 1

	SS	SM	MS	MM
1	ankle bone	apple peel	arm chair	arch bridge
2	battle scar	army rank	bear claws	bank staff
3	beach towel	art fair	brush handle	bat box
4	blood cell	candy jar	cloth napkin	card pack
5	butter bread	coffee pot	corn soup	clock tower
6	career plan	diaper rash	desert sand	cow hide
7	church bells	dog tag	down coat	cricket sound
8	city museum	fish scales	ear plugs	egg noodles
9	clay brick	flower stem	fast day	fly trap
10	engine noise	glass pitcher	job depression	ground pipes
11	female teacher	grass root	key fact	jet plane
12	finger nail	hand drill	liver damage	lead mine
13	fog machine	laugh lines	mail route	light pole
14	fox fur	maximum fine	novel writer	mint gum
15	goat milk	moon rock	pen name	pet cat
16	mango juice	morning prayers	phone button	pine bark
17	melon seed	mountain soil	piano pedals	punch bowl
18	motor bike	navy fleet	pie pieces	race policy
19	mud bath	right angle	pool party	rear post
20	night gown	soccer fan	saw blade	rose bush
21	oil country	steel case	top quality	rubber band
22	patient profile	travel log	truck wheel	spray wax
23	pocket knife	violin bow	well water	tire size
24	tree branch	zebra stripes	wind gauge	yard stick

APPENDIX B

The non-sensible test items used in Task 1

1	boom bound	area dart	bargain bud	advance corner
2	cape strain	ash comment	beer sole	antique hang
3	capital grave	bang street	board buffet	approach cold
4	compound dove	calf doubt	care hatch	beat poster
5	cube wound	clip benefit	class bay	bend door
6	felt boil	count hood	clinic sack	carving fancy
7	fit fuse	cue trash	comb pile	century litter
8	fold palm	dam printer	contrast hail	close news
9	guy foil	lie missile	council trace	concern beam
10	hold chop	meal police	distance mill	credit claim
11	host lap	poker ivory	engine stole	depth soak
12	kid flush	pound anxiety	event rest	hammer drain
13	mark diet	rent chew	lecture low	holiday office
14	might flat	rung penalty	marine bass	kit bid
15	mole pick	scrub Mounds	medicine row	mess shade
16	port drove	seal surgery	menu die	opinion maple
17	shark pupil	slip tide	rabbit console	painting blast
18	stake second	sow layer	river firm	place smash
19	stunt junk	spell criminal	secret loaf	price pass
20	swallow present	tap visitor	shell counter	smell stain
21	tense pat	tear infant	student squash	spin treat
22	till refuse	temple scrap	suite bit	stamp wrong
23	vault blow	toast ink	tourist heel	tiger practice
24	will stable	toll beauty	window rifle	wheat star

APPENDIX C

The instruction in Task 1

INSTRUCTIONS
Welcome!!! In this experiment, you will be asked to judge whether a phrase made up of TWO words is acceptable in English. For example, you will see a phrase like "computer printer", which is OK in English. Also you will see a phrase like "water tape", which may not be Ok in English. Here is the procedure that you will see in this experiment. (1) You will see "+" sign, which shows that a two-word phrase will show up very soon. You don't need to press any button at this moment, but please be prepared for responding to a two-word phrase followed by "+". (2) When you see the phrase, please press either "Yes" or "No" button. (3) If you don't know either/both of the meaning(s) of the phrase, please press SPACEBAR. For example, when seeing "computer printer", please press the SPACEBAR only if you don't know the meaning(s) of either "computer" or "printer" or both. IMPORTANT: If you know the meanings of both words in a two-word phrase (i.e., "computer" and "printer" in "computer printer"), please press "Yes" or "NO", but do NOT press the spacebar. Ok, Let's begin with some practices!!! Press the SPACEBAR when you are ready to begin.

APPENDIX D

The working memory test

	Operations	Correct responses	Recalls
A block of 2			
	(2 X 2) + 3 = 6	No	84
	(6 - 5) + 1 = 2	Yes	49
A block of 2			
	(4 X 3) - 3 = 9	Yes	65
	(7 + 5) - 6 = 6	No	39
A block of 3			
	(2 X 2) + 5 = 8	No	46
	(1 X 3) X 2 = 6	Yes	73
	(9 - 7) X 2 = 4	Yes	23
A block of 3			
	(8 - 5) X 2 = 9	No	17
	(4 X 1) X 2 = 8	Yes	32
	(3 X 5) - 9 = 5	No	95
A block of 4			
	(8 - 6) X 3 = 4	No	78
	(9 - 2) - 5 = 3	No	64
	(9 - 8) + 1 = 2	Yes	37
	(7 - 5) + 1 = 3	Yes	19
A block of 4			
	(3 X 2) + 3 = 7	No	54
	(9 - 4) - 3 = 2	Yes	83
	(2 + 1) + 3 = 4	No	97
	(7 - 4) + 3 = 5	No	62
A block of 5			
	(3 + 2) + 5 = 9	No	68
	(2 + 1) + 2 = 5	Yes	25
	(2 + 1) X 2 = 3	No	74
	(6 + 2) - 5 = 2	No	13
	(3 X 3) - 4 = 5	Yes	92
A block of 5			
	(9 + 1) - 4 = 6	Yes	53
	(2 X 2) X 3 = 8	No	89
	(4 X 2) - 1 = 7	Yes	47
	(9 - 2) - 5 = 2	Yes	35
	(2 + 1) X 3 = 4	No	71

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