THE INFLUENCE OF GRAMMATICAL NUMBER ON THE COGNITION OF THAI-ENGLISH BILINGUALS

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THE INFLUENCE OF GRAMMATICAL NUMBER ON THE COGNITION OF THAI-ENGLISH BILINGUALS

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BY

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This study aimed to investigate the linguistic relativity hypothesis by examining the influence of grammatical number on cognition among monolinguals and bilinguals. The cognition of participants of 30 native Thai speakers, 30 native English speakers, and 90 Thai-English bilinguals, categorized into basic, intermediate, and advanced proficiency levels in English (30 participants per level) was compared. Lucy's approach was used to test participants' cognition. The cognitive tests included an attention test, a memory test using a photo hunt and a memory test using short-answer questions. Data were analyzed using ANOVA and Scheffe's test. The findings mostly supported the hypotheses. Native English speakers paid attention to and memorized object quantities better than Thai-English bilinguals across all proficiency levels and native Thai speakers in the attention and short-answer memory tests. However, the photo hunt test revealed no significant differences among English speakers, advanced Thai-English bilinguals, and intermediate Thai-English bilinguals. Additionally, there were no significant differences between basic Thai-English bilinguals and Thai speakers in all tests, although basic Thai-English bilinguals showed higher performance in attention to and recall of object quantities. For the bilingual group, higher English proficiency correlated with cognitive patterns more closely resembling those of native English speakers, particularly in the attention and short-answer memory tests. However, there were no significant differences between advanced Thai-English bilinguals and intermediate Thai-English bilinguals in the photo hunt memory test. Overall, the results suggest that grammatical number influences cognition in both monolinguals and bilinguals. These support the linguistic relativity hypothesis. Moreover, bilingualism influences bilinguals' cognitive processes at different levels based on language proficiency.

Keyword : linguistic relativity hypothesis, grammatical number, bilinguals, cognition

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INTRODUCTION

1.1 Rationale

The linguistic relativity hypothesis, initially proposed by Edward Sapir and Benjamin Lee Whorf, explores the relationship between language and cognition. Known as the "Whorfian Hypothesis" or "Sapir-Whorf Hypothesis," it suggests that grammar in a language influences its speakers' cognitive processes (Sapir, 1957; Whorf, 1956). In this context, cognition refers to a range of mental activities, including the acquisition, storage, manipulation, and retrieval of information through sensory experiences, thought, and reflection (Cognition, 2005; Dhakal & Bobrin, 2021).

Early studies on linguistic relativity hypothesis focused on how grammatical aspects within different languages might influence cognitive processes. However, these investigations often relied on observational methods with inconclusive results (Carroll, 1994, as cited in Birjandi and Sabah (2012); Reines and Prinz (2009)). A central challenge of these early studies was the difficulty in assessing the cognitive processes of speakers through grammatical analysis alone. Since both language and cognition are abstract, empirical research must carefully interpret the theoretical framework of linguistic relativity and employ effective methodologies to measure cognitive influences accurately (Athanasopoulos, 2006). Despite these challenges, linguistic relativity hypothesis remains a prominent framework for understanding how different grammatical aspects across languages may influence cognitive processes, as supported by both theoretical discourse and experimental studies (elaborated in Chapter 2).

Given that cognition cannot be directly observed, John Lucy proposed a systematic comparative paradigm for studying cognitive differences among speakers of distinct languages. (Lucy, 1992a) This framework treats grammatical aspects as independent variables and cognitive processes as dependent variables (Swoyer, 2011).

Lucy's framework stated that testing speakers' cognition must be comparative; it must present contrastive data on two or more languages. The languages at issue should have clear, strong differences, and they must be habitually used in everyday talk. Grammatical aspect under examination—such as number, tense, gender, or kinship terms—must be relevant to the speakers' lived experiences to meaningfully contribute to the analysis. For example, grammatical number relates to the number of entities. Grammatical tense relates to time. Verbal terms relate to the action of speakers. Kinship terms relate to relatives. Honorific terms relate to seniority, etc. Regarding cognition, Lucy claimed that cognitive pattern comparison should take an external non-linguistic reality, which is cognition. That cognition could be assessed through observable testable cognitive behavior that reflected cognitive processes—such as attention, short-term memory and categorization—could be empirically studied in speakers' daily lives. (Lucy, 1992a)

Inspired by Lucy's framework, many studies have tested the linguistic relativity hypothesis through various grammatical aspects, such as nominal grammatical categories (Charunrochana, 2000; Lucy, 1992b), grammatical number (Kirjavainen et al. (2020), grammatical gender (Charunrochana (1997), Thongnium and Prasithrathsint (2020)), number system (Gordon (2004)), time metaphor (Boroditsky (2001), Boroditsky et al. (2010)), semantic terms (Aemdit (2007), Nusartlert (2009), Chanyeam (2017)) honorific terms (e.g., Chandharath (2013)), spatial terms (e.g., Majid et al. (2004)). For instance, speakers of languages with grammatical gender, such as Spanish and German, tend to assign male or female characteristics to inanimate objects based on their language's gendered nouns (Boroditsky, 2003). Similarly, speakers of languages with obligatory grammatical number, like English, are generally better at paying attention to and recalling the number of objects compared to speakers of languages where grammatical number is optional, such as Thai, Japanese, and Yucatec Maya (Charunrochana, 2000; Kirjavainen et al., 2020; Lucy, 1992b).

These studies primarily focused on monolingual speakers, consistently showing that grammatical aspects influence cognition. These evidences support the linguistic relativity hypothesis by demonstrating that cognitive differences among monolinguals are influenced by the grammar of the language they speak.

While the majority of linguistic relativity research has focused on monolingual speakers, this approach may not fully capture the complexities of cognition in today's increasingly bilingual and multilingual world (Pavlenko, 2014). Globalization, which emerged in the early 20th century (James & Steger, 2014), has led to the widespread movement of people, businesses, and cultures across borders, fostering greater linguistic and cultural exchange (Fernando, 2020; Pavlenko, 2014; The Levin Institute, 2020). Consequently, languages are more frequently used between communities, resulting in the growing prevalence of bilingualism and multilingualism. Bilingualism, defined as the ability to communicate in two languages, is more common than multilingualism, which involves proficiency in more than two languages (Pavlenko, 2014). Recent estimates indicate that approximately 43% of the global population is bilingual, while 17% is multilingual (Gration, 2022; Ilanguages, 2018).

Given the increasing prevalence of bilingualism, it leads to some preliminary attempts to apply the concept of linguistic relativity to the field of bilingualism and cognition (e.g., Green (1998), Odlin (2005), Pavlenko (2005)). Especially if grammar in any languages affects monolinguals' certain cognitive processes, will acquiring a second language influence some of these cognitive processes? (Athanasopoulos, 2006) Knowing two languages representing two distinct ways of looking at the world may cause bilinguals to perceive the world differently than monolinguals and may assist them in seeing beyond what their native language represents (Bassetti & Cook, 2011).

Research on bilingualism and cognition has examined various grammatical aspects, such as grammatical tense (e.g., Aemdit (2013)), grammatical gender (e.g., Bassetti (2007); Thongnium (2017)), countability (e.g.,

Athanasopoulos (2006, 2007); Athanasopoulos and Kasai (2008); Cook et al. (2006); Mazuka and Friedman (2000), color terms (e.g., Athanasopoulos (2009), and counterfactual reasoning (e.g., Ruthirago (2011). These studies have yielded mixed results. Some suggest that bilinguals are influenced by the grammar of their second language regardless of proficiency level (e.g., Aemdit and Prasithrathsint (2016); Ruthirago (2011); Thongnium (2017)). Others propose that bilinguals develop cognitive processes resembling those of native speakers of both languages (e.g., Cook et al. (2006)), while some argue that bilingual cognition occupies a "third space," distinct from either language (e.g., Athanasopoulos (2006, 2007, 2009); Athanasopoulos and Kasai (2008); Bassetti (2007)). Additionally, several studies indicate that bilinguals' cognitive processes may be influenced by their proficiency in their second language at different levels (e.g., Aemdit and Prasithrathsint (2016); Athanasopoulos (2006, 2007); Athanasopoulos and Kasai (2008)).

Despite the growing research on bilingualism and cognition, the influence of grammatical number on bilingual cognition remains underexplored. Previous studies have shown that speakers of languages with obligatory grammatical number systems, like English, are more sensitive to numerical distinctions than speakers of languages where number is optional, such as Thai, Japanese, or Yucatec Maya (Charunrochana, 2000; Kirjavainen et al., 2020; Lucy, 1992b). However, the majority of this research has focused on monolingual speakers, leaving a significant gap in understanding how bilinguals process numerical distinctions across languages with contrasting grammatical systems.

This gap highlights the need for further investigation into how bilinguals navigate and integrate the cognitive effects of grammatical number across languages. Kibort and Corbett (2008) define grammatical number as "a grammatical category which encodes quantification over entities or events denoted by nouns or nominal elements." In languages, like English, grammatical number functions to enhance clarity and accuracy, which becomes particularly

evident with count nouns that require obligatory number marking. For example, countable nouns in English can be quantified with numerals, as in "an apple" or "two apples," with pluralization marked by adding "-s." In contrast, uncountable nouns require unitizers for quantification, as in "a glass of water" or "two glasses of water." However, in languages with optional grammatical number systems, such as Thai, plurality is often inferred from context without explicit markers. This flexible approach highlights grammatical number's varied role in structuring communication.

The difference in grammatical number aspect between English and Thai is particularly valuable to examine how these grammatical differences influence cognition, especially among Thai-English bilinguals. English employs strict rules for marking grammatical number, while Thai, which is optional, allows for plural inference based on context. This distinction serves as an ideal foundation for investigating how Thai-English bilinguals who know both languages process numerical distinctions. In Thailand, English is taught as a foreign language, with the teaching of grammatical number being a key focus (Ministry of Education, 2008; Office of Basic Education Commission, 2022). Thai learners of English are introduced to the concept of grammatical number, which is not obligatory in their native language. This makes Thai-English bilinguals an ideal population for studying how acquiring a second language with obligatory number marking influences cognitive processes. Specifically, it is interesting to explore whether exposure to English leads Thai-English bilinguals to become more sensitive to numerical distinctions, and how this sensitivity compares to that of monolingual Thai and English speakers.

According to grammatical number in Thai, countable nouns typically do not take grammatical number marking and can be used without explicitly indicating number, even when referring to multiple entities. This allows Thai speakers to refer to situations without specifying whether one or more entities are involved. For example, or "ʔép pân nìŋ phŏn" (one apple), or "ʔép pân sǎ:m phŏn" (three apples). These examples demonstrate that in Thai, countable nouns can refer to multiple objects without numerical or quantifier markers, maintaining grammatical correctness. Additionally, despite the lack of these markers, the sentence remains grammatically correct, such as "ʔép pân" (an/one apple or apples). In contrast, English requires obligatory grammatical number marking for countable nouns. English speakers must indicate whether they are referring to one or more entities by using plural suffixes (e.g., "-s"), articles (e.g., "a," "an," "the"), quantifiers (e.g., "some," "many," "several"), or numerals (e.g., 1, 2, 3). For example, "an/one apple or apples", or "three apples", or "many/some apples". Missing these markers, such as "*apple", results ungrammaticality

Additionally, the systems for count and mass nouns in English and Thai further illustrate fundamental differences. In English, count nouns (e.g., dog) allow pluralization and can be modified directly by numerals, whereas mass nouns (e.g., mud) are quantified using terms like (e.g., much) or unitizers (e.g., piles) (Athanasopoulos, 2007; Wisniewski et al., 2010). In contrast, Thai treats all nouns as grammatically mass-like and relies on classifiers to indicate quantity. Classifiers are selected based on attributes such as shape, size, or category. For example, "tuā" is used for animals like "mǣw" (cat), while "lăŋ" is used for houses (Shoichi & Ingkaphirom, 2005). When paired with a classifier, a noun shifts from generic to specific. For instance, "mǣw tuā lék" ("the small cat") specifies a particular entity, whereas "mǣw sĭ dām" ("black cats") remains generic without a classifier (Piriyawiboon, 2008).

These linguistic differences highlight the fact that Thai lacks mandatory grammatical number marking. Consequently, understanding the context of the conversation is essential for determining the precise meaning. These features highlight the Thai language's characteristic to refer to objects without explicitly specifying number, leading to ambiguity when referring the number of objects. In contrast, the grammatical number is obligatory in English, so English speakers have to be concerned about the number for using language grammatically. To understand these languages, Thai speakers learning English need to become familiar with plural markers, quantifiers, and articles to effectively communicate about numerical distinctions. On the other hand, English speakers learning Thai should pay attention to contextual cues to interpret numerical information accurately. Gaining an understanding of these linguistic systems can greatly improve mutual comprehension and support effective communication across different linguistic and cultural contexts.

Additionally, several research studies indicated that proficiency in a second language significantly influences cognitive processes in bilinguals, as evidences in various cognitive tasks. For example, research by Athanasopoulos (2006, 2007); Athanasopoulos and Kasai (2008) conducted the study in monolinguals and bilinguals by examining the relationship between countability in English and Japanese. Results demonstrated that advanced-level Japanese-English bilinguals exhibited cognitive behaviors closely resembling those of native speakers of their second language, while intermediate-level Japanese-English bilinguals displayed behaviors more aligned with native speakers of their first language. This finding suggests that bilingual's cognitive behaviors vary according to their proficiency in the second language. However, a question arises regarding the cognitive behaviors of basic-level bilinguals, as previous studies above focus primarily on intermediate and advanced proficiency levels. Specifically, how do basic-level bilinguals perform in cognitive tasks, and to what

extent, if any, does their limited proficiency in a second language influence their cognitive processes?

In a study by Aemdit and Prasithrathsint (2016), they addressed this gap by examining the relationship between grammatical tense in English and time perception among Thai-English bilinguals. This study uniquely categorized bilinguals into basic, intermediate, and advanced proficiency levels. The results showed that advanced bilinguals performed better on time memorization tasks compared to those with basic or intermediate proficiency, suggesting that greater mastery of the second language leads to more pronounced cognitive effects. However, this study did not include monolingual comparison groups, which limits the broader understanding of how bilinguals at basic, intermediate, and advanced proficiency levels perform in cognitive tasks relative to monolinguals, and how bilinguals' cognitive adaptation progresses across proficiency stages.

Therefore, this research underscores the importance of further investigating the linguistic relativity hypothesis, particularly in terms of how different grammatical number influences cognition in monolingual and bilingual speakers. It also raises the question of whether varying proficiency levels in a second language play a role in cognitive differences among bilinguals. Understanding how bilinguals navigate languages with different grammatical number systems is crucial for advancing knowledge of linguistic relativity and cognition. Knowing a second language with obligatory grammatical number distinctions, such as English, may enhance bilinguals' attention to and ability to recall the number of objects.

The significance of this research lies in its potential to enhance our understanding of how grammatical number influences cognition in both monolingual and bilingual contexts. The findings highlight the significant influence of grammar on cognitive processes, particularly in terms of attention and memory related to numerical awareness. English speakers demonstrated better attention and memory for numerical distinctions compared to Thai speakers, likely due to

the presence of grammatical structures like singular and plural forms in English. These insights suggest that language education policies in Thailand should not only focus on language proficiency but also consider how grammatical differences between languages influence cognition. By raising awareness of these cognitive effects, language education could enhance both language skills and broader cultural and cognitive understanding.

In conclusion, this dissertation aims to investigate the effect of grammatical number on the cognition of Thai-English bilinguals compared to monolingual Thai and English speakers, using Lucy (1992a)'s experimental design. By comparing cognitive behaviors across these groups, the study seeks to demonstrate the influence of grammatical number on speakers' cognition and explore how bilingualism affects cognitive processes. Two research questions involved were proposed as presented below.

1.2 Research questions

1. How does grammatical number marking in English influence performance in attention and memory tasks involving number across native Thai speakers, native English speakers, and Thai-English bilinguals?

2. How does bilingual proficiency in English influence performance in attention and memory tasks involving number in Thai-English bilinguals?

1.3 Objectives

1. Investigate how grammatical number marking influences performance in attention and memory tasks involving number across native Thai speakers, native English speakers, and Thai-English bilinguals.

2. Analyze the relationship between bilingual proficiency in English and performance on attention and memory tasks involving number in Thai-English bilinguals.

1.4 Theoretical framework

This study adopts the linguistic relativity hypothesis (Whorf, 1956) and the methodological framework proposed by Lucy (1992a) to examine the cognitive processes of both monolingual and bilingual speakers. Specifically, cognitive behaviors related to attention (Broadbent, 1958; Kahneman, 1973; Treisman, 1964) and memory (Friedenberg & Silverman, 2006) are utilized to assess participants' cognition.

1.5 Methodology

The methodology of this study started by defining the criteria for selecting participants. Data were then collected using standardized attention and memory tests, which were given to all participants. The data were analyzed using a quantitative approach to objectively measure cognitive performance. The details are briefly described below

1.5.1 Participants

The participants were categorized into two main groups: monolingual and bilingual.

1. Monolingual groups

- 30 English speakers (control group)
- 30 Thai speakers (control group)

2. Bilingual groups

- 30 Thai-English bilinguals who have English proficiency at the basic level
- 30 Thai-English bilinguals who have English proficiency at the intermediate level
- 30 Thai-English bilinguals who have English proficiency at the advanced level

1.5.2 Data collection

This study assessed participants' cognitive behaviors, focusing on attention and short-term memory, through cognitive tests. Participants were divided into two main groups: monolinguals and bilinguals, with a total of 150 participants. The monolingual groups included 30 English speakers and 30 Thai speakers, serving as control groups. The bilingual groups comprised 30 Thai-English bilinguals with basic English proficiency, 30 Thai-English bilinguals with intermediate English proficiency, and 30 Thai-English bilinguals with advanced English proficiency.

1.6 Hypotheses

1. Native monolingual English speakers, whose language has obligatory grammatical number marking, will perform better than native Thai speakers and Thai-English bilinguals in tasks requiring attention and memory of numerical distinctions.

2. Thai-English bilinguals with higher English proficiency will perform closer to native English speakers in tasks requiring attention and memory of numerical distinctions.

1.7 Definition of specific terms

1. Bilingualism

Bilingualism refers to “the use of two languages by individual speakers and groups of speakers”. (Pavlenko, 2014)

2. Grammatical number

A grammatical number is a grammatical category that conveys quantification over nouns or nominal components that describe entities or activities. (Kibort & Corbett, 2008)

3. Cognition

Cognition is “a mental action that involves obtaining knowledge and understanding through thought, experience, and senses. It includes high-level intellectual functions and processes such as attention, memory, knowledge, decision making, planning, reasoning, judgment, perception, comprehension, language, and visuospatial function, etc.” (Dhakal & Bobrin, 2021)

4. Attention

Attention is one of cognitive behaviors which is adopted to test participants’ cognition in this dissertation. It refers to “The mental activity that is shared across multiple sources of information. When we pay to attend to one source, that source will come to our consciousness and transcend to the stage of processing from the sensory store to the short-term memory.” (Friedenberg & Silverman, 2006)

5. Memory

Memory also is one of cognitive behaviors which is adopted to test participants’ cognition in this dissertation. It refers to “The mental process of remembering things for a long time. Memory can store our knowledge and past experiences, and then it also retrieves that knowledge and past experiences. It is what we retain and draw on our past experiences to use that information in the present.” (Friedenberg & Silverman, 2006; Kalat, 1991; Sternberg & Sternberg, 2012).

6. English proficiency level

The English proficiency level is the Council of Europe's standard for determining language competency for people all over the world. It is used to standardize a person's language ability. There are six distinct English proficiency levels: “A1 (Beginner), A2 (Elementary), B1 (Intermediate), B2 (Upper-intermediate), C1 (Advanced), and C2 (Upper advanced)” (Education First, 2022).

CHAPTER 2
LITERATURE REVIEW

This dissertation aimed to study the influence of grammatical number on monolinguals and bilinguals' cognition, necessitating a comprehensive review of relevant literature. The literature review is structured around five primary areas: bilingualism, language and cognition, nominal grammatical categories, cognitive behavior, and the Common European Framework of Reference for Languages (CEFR).

In the section on **bilingualism**, the definition of bilingualism was clarified, and related research within this field was examined. Studies related to bilingualism and language acquisition, as well as bilingualism and cognition, were reviewed. Additionally, research on bilingualism in other relevant domains was discussed to provide a holistic understanding of its multifaceted nature.

The **language and cognition** section described key concepts regarding the relationship between language and cognition. The linguistic relativity hypothesis, which posits that language influences cognitive processes, was explored through contributions from pioneering scholars and empirical studies that both support and challenge this hypothesis. Furthermore, the broader implications of language on cognition across various contexts were addressed.

The **nominal grammatical categories** between Thai and English, including grammatical number, countability, and classifiers, were clarified for understanding how Thai and English organize nouns and their relationships with elements like determiners and quantifiers.

In the section on **cognitive behavior**, the cognitive processes utilized in this dissertation—namely attention and memory—were defined and examined. For attention, distinctions between selective attention and divided attention were described, along with the theoretical frameworks supporting each type. Regarding memory, it was categorized into sensory memory, working memory (or

short-term memory), and long-term memory. Each type was defined, and primary methodologies for assessing memory functions were outlined.

The final section on the **Common European framework of reference for languages (CEFR)** discussed its role in standardizing language proficiency levels and its relevance to the study of bilingual cognition. The CEFR provides a structured approach to evaluating language skills. The detailed findings and analysis of these areas are below.

2.1 Bilingualism

This part consists of 1) the definition of bilingualism and 2) research about bilingualism. In the part of the definition of bilingualism, scholars' broad and narrow definitions of bilingualism were clarified, alongside the criticisms opposing these definitions. Additionally, the categorization of bilinguals into different types based on study purposes, as proposed by Pavlenko (2014), was discussed. In the part of research on bilingualism, research within the linguistic domain was examined, including studies on bilingualism and language acquisition, as well as bilingualism and cognition. Furthermore, research on bilingualism in other areas was addressed. Detailed discussions of these topics are provided below.

2.1.1 The definition of bilingualism

The phenomenon of bilingualism has become the focus among scholars, so considering the definition of bilingualism is a starting point. Intuitively, it is the knowledge of two languages, as opposed to monolingualism. However, defining a scientific description is quite difficult. Various definition has been proposed. (Bassetti & Cook, 2011) Bloomfield (1933) defined bilingualism as “the native-like control of two languages.” Haugen (1953) defined bilingual produces as “complete and meaningful utterances in other languages” Weinreich (1953) defined bilingualism as “the practice of alternately using two languages.” Unlike

Macnamara (1967), he defined “bilinguals as “persons who possess at least one of the language skills even to a minimal degree in their second language.” Hoffman (1991) summarized various definitions of bilinguals and categorized them into two levels of assumption. The first assumption is a maximal view. (e.g., Bloomfield (1933), Haugen (1953)) In this sense, the proficiency level in both languages of bilinguals must be at a high level. The second assumption is a minimal view. (e.g., Macnamara (1967)) In this sense, bilinguals mean people who know more than one language at whatever level.

Romaine (1989), cited in Bassetti and Cook (2011), said that “Both types of definition have a fatal flaw. Clearly, a reasonable account of bilingualism cannot be based on a theory which assumes monolingual competence as its frame of reference.” Bassetti and Cook (2011) interpreted terms of maximal and minimal definitions of bilingualism as follows.

The maximal definition of bilingualism assumes that bilinguals are monolinguals in one person. Their language competence in both languages is the same way as monolingual native speakers. However, it is pretty clear that bilinguals have different knowledge in both languages from monolinguals of the first and second languages (Cook, 2003) cited in Bassetti and Cook (2011). Bilinguals also possess uses of languages that no monolinguals do, such as code-switching, code-mixing, and translation, etc. It might not say that “A bilingual is not two monolinguals in one person.” (Grosjean, 1998) cited in Bassetti and Cook (2011) Bilingual competency cannot be measured using monolingual criteria for the majority of bilinguals. (Hoffman, 1991)

For the minimal definition, it seems to show that a smattering of knowledge of another language is sufficient to alter the way of thinking of monolinguals. Bassetti and Cook (2011) gave some examples from Yelland et al. (1993). For example, a group of Hebrew kindergarten children who learned English, took a few months to alter their concept of time flow or even a group of English kindergarten children, who learned Italian for an hour a week for a year,

developed a distinct concept of 'word.' Bassetti and Cook (2011) also show results from experimental studies supporting their idea. For example, learning a second language as an artificial language for a short time had an influence on their non-language cognitive tasks. (Boroditsky, 2001) Therefore, it may assume that any cognitive consequences of bilingualism do not only appear in maximal bilinguals who have acquired and used the second language for many years. Influences can reveal themselves after having language proficiency of a second language at a low level or using a second language after a few hours.

As mentioned above, Bassetti and Cook (2011) said that it might not be possible to establish a proper definition of bilingualism. Different groups of bilinguals require different definitions depending on different purposes of studying. Pavlenko (2014) also supported this idea and indicated that the downside of such broad definitions leads to questionable which appropriate criteria to distinguish different types of bilinguals. Therefore, Pavlenko came up with the idea to divide bilinguals into different types depending on different purposes of studying. The details are as follows.

First, the order of language acquisition; this term refers to the first language (L1), the second language (L2), the third language (L3), and others. The term of the first language (L1) may refer to a language learned from birth, regardless of language proficiency. The term of the second language (L2) or additional language (LX) may refer to a language acquired after the first language (L1) at the age of 1–3 years. The term of the target language (TL) refers to the second language that a person wants to learn.

Second, the age of acquisition; this term refers to the range of age in which speakers began learning the second language. It can be separated into three terms. The first term is simultaneous bilinguals referring to speakers who acquired more than one language since they were born. The second term is early or childhood bilinguals who acquired the second language prior to the age of 12.

The third term is late or adult bilinguals which refer to speakers who acquired the second language when they have turned 12.

Third, the age of arrival; this term refers to the speaker's age when arriving in the second language speaking country. It can be separated into two terms. The first term is early arrivals, which refers to speakers who arrived in the second language-speaking country as children before the age of 12. The second term is late arrivals refer to speakers who arrived in the second language speaking country as children until the age of 12.

Fourth, the context of language acquisition; this term refers to the environment where the second language was learned. It can be separated into three terms. The first term is a foreign language (FL) or instructed contexts are the foreign-language classroom. The second term is L2 or naturalistic contexts which refer to the environment where the language is spoken. The third term is the mixed context, which refers to acquiring the language in a setting where it is being taught as a first language.

Fifth, language proficiency; this term is used to refer to the speaker's overall level of achievement in languages. It can be separated into five terms. The first term is language proficiency which refers to achievement in overall levels of language. The second term is language dominance which refers to being more proficient in one language, making it easier to understand sentence structure (syntax) and finding the right words (lexical retrieval). The third term is balanced bilinguals that refer to bilinguals in different places who have somewhat similar skills in both languages. The fourth term is dominant bilinguals which refer to bilinguals that are more comfortable with one language than the other. The fifth term is language attrition which refers to a decreased level of language activation.

Sixth, modes of engagement with language, this term is used to the engagement of speakers. It can be separated into two terms. The first term is foreign learners or second language learners, referring to speakers who actively

study the second language. The second term is that foreign learners or second language users refer to speakers who use the L2 in everyday life.

In this study, bilingualism is defined as the ability to use and understand more than one language, with a specific emphasis on proficiency in a second language beyond the native tongue. This definition demonstrated the diversity in bilinguals for varying levels of second language proficiency, from basic to advanced, and the varying contexts in which bilinguals use their second language. Based on insights from prior studies (e.g., Boroditsky (2001); Yelland et al. (1993)), they indicated that even minimal exposure to or use of a second language influences speakers' cognition. This broadens the interesting perspective on bilingualism, moving beyond high proficiency of bilinguals and considering the influence of low proficiency or limited usage of them.

To address the complexity of defining bilingualism, this study aligns with Pavlenko (2014)'s recommendation of using several criteria to categorize bilinguals. By aligning the research objectives, this approach enables more precise classifications, enabling researchers to examine different types of bilinguals in targeted populations. For instance, bilinguals might be grouped based on age of acquisition, context of language use, or proficiency levels, ensuring that the definition aligns closely with the study's objectives.

Therefore, this study separated bilinguals into different groups based on their language proficiency in a second language. This approach not only knows different backgrounds of bilinguals but also ensures that their classification is both relevant and methodologically consistent with the study's research objectives.

2.1.2 Research on bilingualism

The study of bilingualism has been widespread since early research identified differences between bilinguals and monolinguals. A comprehensive literature review on bilingualism across various fields is presented below.

2.1.2.1 Bilingualism in linguistic areas

1) Bilingualism and language acquisition

Bilingualism and language acquisition have been central topics in linguistics, psychology, and education, exploring how individuals learn and use multiple languages. Research in this field sheds light on how bilinguals manage two language systems and the potential interactions between them. Several studies are presented below.

Paradis and Genesee (1996) studied the syntactic acquisition of bilingual children. The authors investigated the possibility of interference between the grammar of bilingual children who spoke French and English. These children were two to three years old. The study examined the acquisition of functional categories, specifically finiteness, agreement (INFL), and negation. The results indicated no evidence of transfer, acceleration, or delay in the grammatical development of bilingual children, thereby supporting the hypothesis that their grammar is acquired independently in each language.

Hartsuiker et al. (2004) studied whether syntactic information is separate or shared between languages in Spanish-English bilinguals. Participants were asked to describe cards to each other in a dialogue game. The result showed that, following a Spanish intransitive or active statement, Spanish-English bilinguals generated English passive sentences more frequently than Spanish passive sentences. The result can be implied that there was cross-linguistic syntactic priming between production and understanding in the interactive usage of two languages.

Fabiano-Smitha and Barlowb (2009) examined phonological acquisition in bilingual children, positing that interaction enhances phonological development. They aimed to investigate what constitutes the typical development of bilingual speech sound inventories. The study included three groups of participants: Spanish-English bilingual children, monolingual Spanish speakers, and monolingual English speakers. Results demonstrated that bilingual children developed two phonological inventories in the same period, whereas monolingual children maintained a single inventory. Additionally, both groups exhibited similar levels of phonological complexity. Despite the separation of phonological structures in bilingual children, the interaction between the two languages was at a low level.

Overall, the studies reviewed in this section investigate bilingual language acquisition at different language levels, including phonological and syntactic development. While Hartsuiker et al. (2004); Paradis and Genesee (1996) provide evidences for independent grammatical acquisition and cross-linguistic interaction respectively, Fabiano-Smitha and Barlowb (2009) highlight the simultaneous development of phonological inventories in bilingual children. These findings contribute significantly to the understanding of bilingual language acquisition; however, the necessity for larger sample sizes and more diverse participant demographics remains to enhance the robustness and generalizability of the results.

2) Bilingualism and cognition

The study of bilingualism expanded significantly following the emergence of the notion about language and cognition. Scholars began to investigate whether the grammar of language affects monolinguals' certain cognitive processes, will the acquisition of a second language influence some of these cognitive processes? (Athanasopoulos, 2006) Knowing two languages that represent two distinct ways of looking at the world may cause bilinguals to

perceive the world differently than monolinguals and may assist them in seeing beyond what their native language represents. (Bassetti & Cook, 2011)

Various aspects of grammar have been utilized to assess the cognition of bilinguals through non-linguistic tasks inspired by Lucy (1992a). These aspects include nominal grammatical categories such as grammatical number, countability, and classifiers; grammatical tense; grammatical gender; domain-specific terms; and counterfactual reasoning. Most studies indicate that proficiency in a second language influences bilingual cognition at different levels. Related studies are described as follows.

Countability has been used in studying bilingual cognition. The studies by Athanasopoulos (2006, 2007); Athanasopoulos and Kasai (2008); Cook et al. (2006); Mazuka and Friedman (2000), explore how differences in countability system in English and Japanese affect participants' cognitive processes. These studies share overlapping part in their methodologies and findings while also offering different perspectives on the role of language proficiency, cultural immersion, and linguistic background in affecting cognition.

Across these studies, the participants included English monolinguals, Japanese monolinguals, and Japanese-English bilinguals at varying levels of L2 proficiency. The bilingual groups were typically divided into intermediate and advanced proficiency levels based on standardized tests such as the Oxford Quick Placement Test (QPT) (Athanasopoulos, 2006, 2007; Athanasopoulos & Kasai, 2008) or the Nation test for English proficiency (Cook et al., 2006). These classifications allowed researchers to compare cognitive patterns across monolinguals and bilinguals at different levels of proficiency in a second language. Additionally, tasks like attention tasks (Athanasopoulos, 2006), and triad-matching categorization tasks (Athanasopoulos, 2007; Athanasopoulos & Kasai, 2008; Cook et al., 2006; Mazuka & Friedman, 2000) were consistently employed to assess participants' cognition.

In Japanese, all common nouns referring to inanimate entities are 'mass' nouns. Nouns in this language cannot take grammatical number marking. Their referents are perceived as non-individual entities with a distinct of material. Numerals cannot directly modify them. The external unitizers are used in order to be quantified. In English, there are mass nouns and count nouns. Mass nouns cannot take morphological plural marking. They also require unitizers in order to be quantified. Count nouns can take obligatory plural marking and the numeral. Their referents are perceived as individuated entities with distinct shapes and functions. Thus, it can be stated that English is the language with obligatory plural marking whereas Japanese is a classifier language that does not.

The triad-matching categorization task was widely used. Participants were shown an object and asked to choose between two alternatives—one resembling the original in shape and the other in material. This task aimed to reveal whether participants prioritized shape-based or material-based categorization, reflecting the cognitive influence of countability distinctions in their languages.

Although the studies shared core methodologies, their experimental procedures and participant contexts differed. Athanasopoulos (2006) employed an attention test where participants identified the most similar picture to an original from five alternatives, varying the language of instruction based on proficiency. Bilinguals received instructions in their dominant language, while monolinguals used their native language. The findings revealed that advanced bilinguals showed cognitive patterns aligned with English monolinguals, preferring shape-based categorization, whereas intermediate bilinguals aligned with Japanese monolinguals, emphasizing material-based categorization.

In Athanasopoulos (2007), cultural immersion and language of instruction were key variables. Bilingual participants included those studying in England for different durations, receiving instruction either in L1 (Japanese) or L2 (English). This study found that language of instruction had minimal impact on

categorization patterns, with advanced bilinguals consistently favoring shape-based categorization regardless of whether they were tested in L1 or L2. These findings underscored the importance of L2 proficiency over the testing language or immersion duration.

Athanasopoulos and Kasai (2008) designed their tests with more controlled conditions, examining bilingualism's influence on countability while concerning social variables such as the context of language acquisition. Half of the bilingual participants were tested and instructed in English in England, while the other half were tested in Japan using Japanese. The findings showed that L2 proficiency affected bilinguals' cognitive shifts, as advanced bilinguals consistently exhibited shape-based preferences similar to English monolinguals.

Cultural immersion was another variable examined in these studies. Cook et al. (2006) specifically focused on the duration of exposure to an L2 environment, comparing short-stay and long-stay Japanese-English bilinguals. Short-stay bilinguals, who had lived in an English-speaking country for less than three years, continued to show material-based categorization for simple objects[1], similar to Japanese monolinguals. However, long-stay bilinguals, with more than three years of immersion, displayed a notable shift toward shape-based categorization, aligning more closely with English monolinguals. This progression suggests that extended exposure to an English-speaking environment strengthens the cognitive influence of the L2. Thus, it has been shown that acquiring a second language influences categorization.

Not all findings were consistent, highlighting the complexities of studying bilingual cognition. Mazuka and Friedman (2000) challenged the idea that L2 acquisition consistently affects cognitive categorization. Their replication of Lucy (1992b)'s object classification experiment revealed that all groups—English monolinguals, Japanese monolinguals, and Japanese-English bilinguals—predominantly categorized objects based on shape, regardless of their linguistic

[1] Simple objects are, "simple shapes made out of a solid material (e.g., a pyramid made out of cork)."

background. The authors explained that the Japanese participants' long-term exposure to learning English may have influenced their cognitive categorization patterns. This finding suggests that exposure to an L2, even among monolingual participants, can affect speakers' cognition.

One possible explanation for this result could be the participants' linguistic background. In this study, the Japanese monolingual participants had been exposed to English education for an extended period, with some students achieving fluency in English, although the emphasis is on writing English. This prolonged language contact could have influenced their cognitive categorization, aligning their shape preferences more closely with those of English speakers. Consequently, the findings underscore the necessity of carefully qualifying participants in bilingual cognition studies, particularly when examining the influence of second language acquisition. This study highlights that exposure to a second language, even in a monolingual group, can significantly impact cognitive processes, complicating the interpretation of results in cross-linguistic research.

The studies on countability illustrate that acquiring a second language influences participants' cognition, with L2 proficiency serving as the strongest predictor of cognitive shifts. Advanced bilinguals often align with the cognitive patterns of their L2, while intermediate bilinguals and short-stay participants remain closer to their L1 patterns. However, the influence of cultural immersion, language of instruction, and linguistic background varies across studies, highlighting the interesting points between linguistic and sociocultural factors. These findings underscore the necessity of controlling for participant variables to get reliable conclusions about the relationship between language and cognition.

Grammatical tense has also been a focus in exploring bilingual cognition, particularly in understanding how grammatical tense affect bilinguals' cognition about time. Aemdit and Prasithrathsint (2016) investigated this phenomenon by examining Thai-English bilinguals, comparing their cognitive processing of time through the lens of English—a tense-marking language—and

Thai, a tenseless language. The study involved participants with varying levels of English proficiency (low, intermediate, and high) and employed a memory task to assess temporal cognition. The results revealed that bilinguals with higher English proficiency performed significantly better on the memory task related to time than those with lower proficiency. This finding suggests that proficiency in a tense-marking language leads participants to be aware of time, allowing for more accurate understanding about temporal representations. These results underscore the important role of language in influencing thought, with grammatical tense influencing bilinguals' cognition. Moreover, the study highlights L2 proficiency as a critical factor in bilinguals' cognitive, demonstrating how exposure to a tense-marking language allows bilinguals to adopt cognitive patterns distinct from their native tenseless language. This research provides compelling evidence between language and cognition, affirming the role of grammatical tense in influencing cognitive processes.

Grammatical gender has been employed to explore the cognition of bilinguals, as demonstrated by studies such as Alotaibii (2020); Bassetti (2007); Chen (2022); Thongnium (2017). These studies investigate how grammatical gender influences cognition, particularly in bilingual contexts, highlighting both shared patterns and distinct differences across research.

All studies emphasize the strong influence of grammatical gender on monolingual cognition. Bassetti (2007) showed that Italian monolingual children categorized objects based on Italian grammatical gender, associating objects with male or female voices according to their linguistic rules. Similarly, Thongnium (2017) found that Russian monolinguals, whose language includes a highly gendered grammatical system, relied heavily on grammatical gender to categorize objects. Chen (2022) demonstrated that French monolinguals' object perceptions were influenced by grammatical gender, supporting the idea that native language structures strongly influence thought. These findings consistently

show that monolingual speakers are aware of grammatical gender when performing cognitive tasks.

In bilingual contexts, all studies highlight that exposure to a second language affect bilinguals' cognition. Thongnium (2017) found that Russian-English bilinguals with high English proficiency categorized objects based on grammatical gender but less than Russian monolinguals. Similarly, Alotaibii (2020) observed that early and extensive English exposure decreased Arabic grammatical gender's influence on Arabic-English bilingual children even it still influences their cognition.

Additionally, cultural norms play a role in influencing bilinguals' cognition, even when grammatical gender influences are reduced. In Alotaibi's study, Arabic-English bilingual children associated soft or pretty objects with girls, showing cultural stereotypes about gender. Similarly, Chen (2022) found that French grammatical gender influenced gender stereotypes in object perception, illustrating the interplay between linguistic and cultural factors.

The studies differ in how factors such as age, language dominance, and proficiency influence bilingual cognition. Bassetti (2007) highlighted the unstable cognitive patterns of bilingual children due to developing proficiency in both languages. Italian-German bilingual children, learning different gender systems in both languages, did not categorize objects based on grammatical gender. This suggests children are in a transitional stage where neither language's system has a dominant influence. Chen (2022) highlighted the importance of language dominance, showing that French-dominant bilinguals were influenced by French grammatical gender, even if they were fluent in English. This contrasts with Thongnium (2017), where higher proficiency in English—a genderless language—significantly reduced the impact of Russian grammatical gender.

Terms in different areas have also been employed to study bilingualism and cognition, such as color terms. Athanasopoulos (2009) investigated the influence of color representation on bilingual cognition, specifically focusing on

the Greek language's distinction between two shades of blue: "ghalazio" (light blue) and "ble" (dark blue). The participants included English monolinguals and Greek-English bilinguals with varying levels of proficiency. The first experiment asked participants to name color chips in their first language to determine the category boundaries for "ble" and "ghalazio," allowing for a comparison between bilinguals and English monolinguals. The second experiment was a cognitive task where participants judged the similarity of Greek blue chips using Munsell color chips. The results showed that bilinguals' level of proficiency influenced a semantic shift in their category prototypes. Bilinguals' similarity judgments were also affected by the presence of color terms in semantic memory and the length of time spent in an L2-speaking country, highlighting the importance of language proficiency and cultural immersion in affecting cognitive processes.

Time metaphor has also been utilized to study bilingualism and cognition. Yang et al. (2022) examines how language shapes the way people perceive and think about time, focusing on English monolinguals, Mandarin monolinguals, and Mandarin-English (ME) bilinguals. Based on the Sapir-Whorf hypothesis, it investigates whether English and Mandarin speakers differ in their temporal thinking and whether learning English as a second language changes how Mandarin speakers process time. Participants included English speakers from the UK, Mandarin speakers from China, and Mandarin-English bilinguals with varying levels of English proficiency. Participants completed a questionnaire to assess their L2 experience and proficiency. They noted if they knew any languages other than their native one. If they did, they listed these languages and rated their proficiency on a scale from 1 to 4, where 1 represented minimal knowledge, 2 elementary proficiency, 3 intermediate proficiency, and 4 advanced proficiencies.

Using a temporal categorization task, participants viewed picture sequences representing temporal changes and determined the chronological order along front-to-back (sagittal) or top-to-bottom (vertical) axes. Results

showed that English speakers predominantly used the sagittal axis, while Mandarin speakers employed both sagittal and vertical axes, reflecting their language-specific metaphors. Mandarin-English bilinguals demonstrated similar patterns to Mandarin monolinguals, indicating that acquiring English did not significantly alter their native temporal cognition. The findings affirm that language influences temporal thought, supporting the Sapir-Whorf hypothesis, but also suggest that bilingualism may not fully override native languages, highlighting shared cognitive patterns across languages.

Counterfactual reasoning construction has also been employed to study bilinguals' cognition. Ruthirago (2011) examined the correlation between counterfactual reasoning construction and cognition among Thai monolinguals, German monolinguals, and Thai-German bilinguals. Counterfactual reasoning, an important feature in German grammar, was tested using a counterfactual story task, where participants' understanding and reaction times were measured. The results showed that German monolinguals scored higher and responded faster than Thai monolinguals, reflecting the differences in the grammatical structures of their respective languages. Furthermore, Thai-German bilinguals exhibited shorter reaction times than Thai monolinguals, though no significant difference was found between German monolinguals and bilinguals who spoke both German and Thai. These findings suggest that learning a foreign language can influence cognitive processes, particularly in tasks related to linguistic structures, although the effects may vary depending on the level of proficiency in the second language.

Emotional expression has also been used to study bilinguals' cognition. Inan (2019) examined the linguistic relativity hypothesis by analyzing how Kurdish-Turkish bilinguals and Turkish monolinguals express and categorize emotions in their native languages and in English as a foreign language. The study aimed to determine whether bilinguals differ from monolinguals in their emotional expression and categorization, and how linguistic structures influence cognitive processing, aligning with the linguistic relativity hypothesis. The

participants consisted of 40 Kurdish-Turkish bilingual adolescents from Van and 40 Turkish monolingual adolescents from Istanbul in Turkey, all attending secondary school. Data collection included a language background survey, an emoji-based affective norm scale, a similarity judgment task, and a verbal expression task, with each participant tested individually. Results showed that bilinguals and monolinguals demonstrated consistency in their emotional expressions across languages, but Turkish monolinguals categorized emotions more negatively compared to Kurdish-Turkish bilinguals. The findings indicate that bilinguals' exposure to multiple linguistic systems influences their emotional categorizations, supporting the linguistic relativity hypothesis.

Several studies, including those by Alotaibii (2020); Athanasopoulos (2009); Bassetti (2007); Inan (2019); Ruthirago (2011); Thongnium (2017), examined bilinguals' cognition without considering the potential influence of social factors that might affect their cognition. These studies consistently indicated that acquiring a second language impacts bilingual cognition, with most bilinguals displaying cognitive behaviors that differed from those of monolinguals. However, other research has explored how specific social factors, such as L2 proficiency (Aemdit & Prasithrathsint, 2016; Athanasopoulos, 2006, 2007; Athanasopoulos & Kasai, 2008; Cook et al., 2006), the context of L2 acquisition (Athanasopoulos & Kasai, 2008), the language of instruction (Athanasopoulos & Kasai, 2008), the length of staying in an L2-speaking country (Cook et al., 2006), may also influence bilinguals' cognition. These studies suggested that shifts in bilinguals' cognitive patterns were primarily driven by their L2 proficiency, with the other social factors exerting only a minor influence.

In alignment with this body of research, the importance of considering social factors, particularly L2 proficiency, in the study of bilingual cognition is recognized. Evidence suggests that social factors, with L2 proficiency being the most prominent, significantly influence cognitive differences among bilinguals.

Consequently, in this dissertation, L2 proficiency was adopted as a central variable. Participants were categorized based on their proficiency levels, and their cognitive processes were analyzed to determine whether grammatical structures in the second language influence cognition differently depending on proficiency. This approach is expected to offer deeper insights into whether the grammar of language affects bilinguals' cognition in each group based on their different levels of L2 language proficiency.

2.1.2.2 Bilingualism in other areas

Research on bilingualism has extended beyond linguistic studies to encompass fields such as education and social sciences. Prominent studies in these areas include the following:

García et al. (2011) investigated the expansion of bilingualism in secondary schools in the United States. The author aimed to study how some small secondary schools in New York drew bilingual programs on students despite the Department of Education in New York City did not recognize either “transitional bilingual education program” or “dual language.” The author found that bilingual programs emerged at these schools not from the policy proposed by the top-down process but from the negotiation and sense-making of students and educators. These schools adopted a more dynamic framework to support students’ needs and tried to familiarize children with various language practices. The success of these schools was focused on bilingual use or translanguaging at schools. They also focused on student-centeredness. Students were responsible for their language practices and the development of bilingualism. Bilingual students, for example, were given the choice of doing their homework or project in English, Spanish, or both. Some bilingual students who complete their projects in English can give an oral presentation in Spanish. It showed that students had the right to choose when and how to employ their language resources. Moreover, these schools also created a trustful, respectful, and supportive context for their bilingual education program among teachers, students, and school directors.

King (2013) explored the interplay of identities, language practices, negotiations, and ideologies within a bilingual transnational family. The study focused on language ideology and identity practices in a bilingual Ecuadorian family residing in the United States. Through interviews with three adolescent girls from the family, King found that parental expectations regarding second language acquisition exerted pressure that could negatively affect family dynamics. Additionally, the family's language practices were influenced by common ideologies surrounding language and language acquisition, particularly within migrant families. This study highlights how language identities shape and are shaped by broader social and ideological contexts in bilingual and multilingual households especially in migration families.

These studies illustrate that bilingualism has expanded to various societal domains, including educational settings and family dynamics. García et al. (2011) demonstrate that bilingual education can occur at schools, independent of formal educational policies. Similarly, King (2013) shows that bilingualism within families is intertwined with identity formation and ideological negotiations. These findings underscore the multifaceted nature of bilingualism and its significant implications across different areas of social life.

2.2 Language and cognition

In this section, the concept of language influencing cognition, known as the "linguistic relativity hypothesis," is clarified, serving as a foundational framework for this dissertation. A review of studies testing this hypothesis is provided, highlighting that while some findings support the idea, others do not. Furthermore, alternative perspectives on the relationship between language and cognition are explored, including views that language and thought are similar, that thought influences on language, that language and thought are separated, language is a part of cognition and the “thinking for speaking hypothesis”. The details are presented below.

2.2.1 Linguistic relativity hypothesis

The linguistic relativity hypothesis proposes that the language a person speaks influences their cognition, shaping how they perceive and interpret the world. This concept was originated around the 19th century by Wilhelm Von Humboldt, a German linguist, philosopher, diplomat, and educational reformer from Germany (1767-1835). (Encyclopaedia Britannica Online, 2020a)

Humboldt found the relationship between languages and thought, and argued that thought is inseparable from language, stating, "there is no thought without language, so all thought must be influenced by language" (Beek, 2006) According to Humboldt, the structure of a language has a significant impact on the way its speakers think.

Humboldt's ideas influenced Edward Sapir (1884–1939), an American linguist and anthropologist, who expanded upon this notion by introducing the concept of **linguistic determinism** (Encyclopaedia Britannica Online, 2020b). Sapir famously noted that "Language is a guide to social reality: Though language is not ordinarily thought of as of essential interest to the students of social science, it powerfully conditions all our thinking about social problems and processes." asserting that language determines not only individual thought and worldview but also how societies understand and address social problems (Sapir, 1957). He maintained that since each language constituted a complete system that was totally different, not in the component of each language. Thus, people who speak different languages tend to have different concepts in all aspects.

Moreover, he clarified his idea in detail, which has become the classic idea until the present.

"Human beings do not live in the objective world alone, nor alone in the world of social activity as ordinarily understood but are very much at the mercy of the particular language which has become the medium of expression for their society. It is quite an illusion to imagine that one adjusts to reality essentially

without the use of language and that language is merely an incidental means of solving specific problems of communication or reflection. The fact of the matter is that the 'real world' is to a large extent unconsciously built up on the language habits of the group. No two languages are ever sufficiently similar to be considered as representing the same social reality. The worlds in which different societies live are distinct worlds, not merely the same world with different labels attached."

Sapir (1957, p. p.69)

Lucy (1992a) built upon Sapir's ideas, noting that when considering the languages, Sapir coheres to formally complete systems. Linguistic differences lie not merely in vocabulary or classifications, but at the systemic level. Sapir viewed language as a powerful tool that determines the speakers' view both in physical and social reality. Gordon (2004) provided empirical support for this perspective through his research on the Pirahã tribe in the Lowland Amazonia region of Brazil. The Pirahã language features a limited counting system known as the "one-two-many system," which comprises only four terms: hoi (falling tone = one), hoi (rising tone = two), and baagi or aibai (many). Gordon investigated whether the limitations of this counting system would affect the tribe's ability to discern numbers beyond their linguistic capacity.

To explore this question, Gordon designed a series of eight experiments. The first four experiments involved matching tasks, where participants were required to match objects numbering from 1 to 9 in different configurations, such as one-to-one lime matches, cluster line matches, and orthogonal line matches. In the fifth experiment, participants were briefly shown a set of objects and asked to recall the quantity. The sixth experiment required participants to copy lines drawn by the experimenter. In the seventh experiment, an array of nuts was placed in a can, and after viewing the array for eight seconds, participants were asked to determine whether any nuts remained in the can after each one was removed.

Finally, the eighth experiment involved the experimenter placing candies into boxes, each labelled with a picture depicting a specific number of fish, then hiding the boxes. Participants were asked to identify which boxes contained the candies.

The results revealed that the Pirahã participants performed notably poorly when dealing with quantities beyond two, particularly with the number three. Their accuracy declined as the number of objects in each task increased. Gordon's findings demonstrated that the limited counting system of the Pirahã language had a significant impact on their numerical cognition, as they struggled to perceive and process quantities outside of their linguistic framework. This study underscores the role of language in shaping cognitive processes, lending support to the hypothesis that language can determine, certain aspects of thought.

Sapir's work also influenced Benjamin Lee Whorf (1897-1941), his student. (Encyclopaedia Britannica Online, 2020c) Originally, Whorf was a student of Mechanical Engineering at MIT, he later developed an interest in Anthropology, particularly in the languages and cultures of Native American communities. (Beek, 2006) While Whorf agreed with Sapir's idea that language could determine a person's worldview, he refined this notion by asserting that differences in cognitive systems are tied to differences in language. According to Whorf, the greater the linguistic difference, the more different the cognitive processes; conversely, the more similar languages are, the more similar their corresponding cognitive systems.

“The background linguistic system (in other words, the grammar) of each language is not merely a reproducing instrument for voicing ideas but rather is itself the shaper of ideas, the program and guide for the individual's mental activity, for his analysis of impressions, for his synthesis of his mental stock in trade. Formulation of ideas is not an independent process, strictly rational in the

old sense, but is part of a particular grammar, and differs, from slightly to greatly, between different grammars. We dissect nature along lines laid down by our native languages… no individual is free to describe nature with absolute impartiality but is constrained to certain modes of interpretation even while he thinks himself most free. The person most nearly free in such respects would be a linguist familiar with very many widely different linguistic systems. As yet no linguist is in any such position. **This idea introduced to a new principle of relativity, which holds that all observers are not led by the same physical evidence to the same picture of the universe, unless their linguistic background are similar.**"

Whorf (1956, pp. p.212-213)

Whorf's hypothesis implies that language plays a determining role in shaping human thought and that the structure of a language can significantly influence an individual's worldview. However, despite his alignment with Sapir on the concept of linguistic determinism, Whorf extended his argument beyond the formal system of language. He posited that language influences cognition at varying levels, depending on the linguistic differences between languages. According to Whorf, speakers of vastly different languages would exhibit significantly different cognitive patterns, whereas speakers of more similar languages would display more closely aligned cognitive processes.

To support his theory, Whorf (1956) conducted a comparative study of the Hopi language, a Native American language, and English, which he used as a representative of standard European languages (SAE). He noted that English has two types of plural forms: one for concrete entities such as humans and animals, and another for abstract concepts such as days, months, and years. In contrast, the Hopi language only employs plural forms for concrete entities. For example, while an English speaker might say, "I stayed five days," a Hopi speaker would say, "I stayed until the sixth day" or "I left on the fifth day." Similarly, English conveys time through grammatical tense, with verbal inflections indicating past,

present, and future events, which reflects a time-conscious worldview. The Hopi language, on the other hand, lacks grammatical tense. Whorf pointed out that "there are no words, grammatical forms, constructions, or expressions that directly refer to what we call time in English." Instead, the Hopi language distinguishes between momentary, recurring, and repeated events, shaping a worldview in which each day is perceived as a repeated cycle. This temporal understanding is evident in the careful performance of religious rituals, as there is no concept of a "next day" to repeat a task.

While Sapir and Whorf explained their notion about the relationship between language and cognition, they did not provide detailed explanations or supporting evidence (Penn (1972), cited in Beek (2006)). In the 1950s, over twenty years after Sapir's death and more than a decade after Whorf, several researchers, revisited the ideas initially proposed by Sapir and Whorf, seeking to convert them into hypotheses that could be scientifically tested. These efforts led to what is known as the Sapir-Whorf Hypothesis, which is divided into "strong" and "weak" versions. However, it's important to mention that Sapir and Whorf themselves never used this term. Some scholars argue that the modern understanding of the hypothesis little similar from the original ideas proposed by Sapir and Whorf. (Brown & Lenneberg, 1954, cited in Ferreira & Mozzillo, 2021).

The strong version, referred to as the **"Linguistic Determinism Hypothesis"**, assert that language entirely determines thought, shaping a person's worldview. However, little empirical studies support this version due to the difficulty of finding languages that are entirely different (Penn, 1972, cited in Beek (2006)). Linguistic Determinism eventually lost support among researchers. Although it is recognized that languages can influence the way people think, these differences are not strong enough to cause misunderstandings. The absence of a specific word in a language does not mean its speakers are incapable of understanding the concept it represents (Crystal, 2010, cited in, Ferreira & Mozzillo, 2021).

A weak version, known as the **"Linguistic Relativity Hypothesis."**, propose that language influences thought, with different languages affecting cognition to varying degrees (Penn (1972), cited in Beek (2006)). This perspective offers a more moderate interpretation of the Whorfian argument, a view that has been supported by multiple studies conducted since the 1980s (Ferreira & Mozzillo, 2021).

In critically evaluating the Sapir-Whorf hypothesis, both the linguistic determinism and linguistic relativity hypotheses warrant consideration.

The linguistic determinism hypothesis presents an extreme interpretation, suggesting that language entirely determines human cognition, implying that speakers of different languages have completely distinct worldviews. In my view, the use of the term "determine" in this context suggests that speakers are confined by the grammar of their language and cannot think beyond it, as language determines or limits their cognitive abilities.

However, research has shown that learning a second language can influence cognitive processes, as demonstrated by studies such as Aemdit and Prasithrathsint (2016); Archila-Suerte et al. (2011); Athanasopoulos (2006, 2007, 2009); Athanasopoulos and Kasai (2008); Bassetti (2007); Cook et al. (2006); Ruthirago (2011); Thongnium (2017). Learning foreign languages with different grammar from their native languages can lead them to access and understand speakers in that language. Additionally, it is rare to find languages that are entirely distinct in all aspects, as Sapir anticipated. Consequently, the linguistic determinism hypothesis seems overly rigid and extreme in explaining the relationship between language and thought.

The linguistic relativity hypothesis, a less extreme version of the Sapir-Whorf hypothesis, posits that language influences thought. In my view, the use of the term "influence" suggests that language affects cognition but does not wholly determine it. This notion can be supported or disproven based on empirical evidence and should also consider other factors that may influence cognition.

Therefore, the linguistic relativity hypothesis may be too weak to fully explain the intricate relationship between language and thought.

Sapir and Whorf's notions, while groundbreaking, were less popular due to their insufficient empirical support (Reines and Prinz, 2009; Carroll, 1994 as cited in Birjandi and Sabah (2012)). Both scholars presented ideas that were grounded in unreliable information about linguistic diversity, failing to rigorously test their hypothesis empirically to show how speakers of different languages exhibit distinct cognitive patterns. Carroll (1994), cited in Birjandi and Sabah (2012), said that while Whorf provided examples of how language might influence cognition through lexical and grammatical differences, he did not offer convincing empirical evidence to support his claims. These challenges made the hypothesis difficult to test, leaving its validity open to interpretation.

By the late 1950s, new studies on language universals and linguistic typology began to challenge the Whorfian hypothesis. Emerging perspectives in psychology, linguistics, and cognitive science, influenced by scholars such as Piaget and Chomsky, proposed three interrelated assumptions: the universality of cognitive processes, the notion that thought shapes language, and the belief that all languages share fundamental similarities (Piaget, 1967; Inhelder and Piaget, 1958; Chomsky, 1972 cited in Lucy (1996)). Scholars from a cognitive-dominated perspective, including Bowerman (1996); Pinker (1984), posited that language acquisition is driven by cognitive processes, with children creating semantic categories by observing over multiple uses of a form by fluent speakers. (Bowerman, 1996) It may indicate that language acquisition was considered to be driven by cognitive processes (Winskel & Luksaneeyanawin, 2013).

At the moment when cognitive perspective almost replaced the Sapir-Whorf hypothesis, some scholars tried to carefully reread this hypothesis leading to the revival of a neo-Whorfian notion such as Lucy (1992a), Slobin (1996), etc. According to Birjandi and Sabah (2012), "Neo-Whorfian scholarship seems to be more nuanced, probably more rigorous linguistically, and certainly less romantic

and sweeping than the original." Chandler (1994) cited in Birjandi and Sabah (2012), noted that few scholars support the strong version of the Sapir-Whorf hypothesis, or linguistic determinism, while many accept the weaker version, linguistic relativity. This moderate Whorfianism differs from the more extreme forms in several ways:

1. The focus is on how thought is influenced by language, rather than dictated by it.

2. The perception of the world influences the types of language that are used.

3. Language's influence is considered as a whole, not through comparisons between individual languages.

4. The social context of language use, rather than purely linguistic factors, is emphasized

Among the new interpretation of neo-Whorfian scholars, Lucy (1992a) introduced a systematic approach to empirically test the linguistic relativity hypothesis. Therefore, the Sapir-Whorf hypothesis became popular again because of Lucy's experimental design. His methodological guidelines for conducting such research include the following:

1. The research must be comparative, involving two or more languages with clear and strong differences.

2. The comparison of the cognitive pattern should take an external non-linguistic reality because a test of linguistic relativity hypothesis is to demonstrate whether different languages have an influence on non-linguistic reality, which is cognition.

3. The focus should be on habitual language patterns in everyday usage, which may reveal whether these patterns affect thought.

4. The researcher should focus on the semantic system or important grammar in languages. It should not focus on some vocabulary or some grammar that are not important and systematic.

5. The research should be experimental, allowing for controlled investigation of variables that may affect outcomes.

For a test of the linguistic relativity hypothesis, Lucy stated that cognitive pattern comparison should take an external non-linguistic reality, which is cognitive behaviors based on the cognitive psychology approach that can reflect people's cognition. This framework provides a reliable method for testing the correlation between language and thought, addressing the question: "Does language influence the thought or cognition of speakers?" Subsequent research has explored the influence of grammatical categories such as tense, number, gender, metaphor, and counterfactual reasoning on cognition. This revival of the linguistic relativity hypothesis was gained renewed interest through the work of John Gumperz and Stephen Levison, who were one of neo-Whorfian scholars, published a large volume titled **'Rethinking Linguistic Relativity'** (Gumperz & Levinson, 1996) Rather than attempting to definitively prove or disprove the hypothesis, Gumperz and Levinson shifted the focus to investigating how and to what extent language influences thought, sparking significant research in this area. This book sparked a large amount of research into the correlation between language and thought.

In my view, neo-Whorfian scholars do not seek to prove or disprove the linguistic relativity hypothesis, but rather to refine it. They endorse the weaker version of the Sapir-Whorf hypothesis, acknowledging that language influences cognition, but they also emphasize the importance of considering the social context in which language is used. Factors such as social background, educational experiences, and ways of life are all seen as influencing cognitive processes. Neo-Whorfian scholars employ systematic methods to empirically test the cognitive behaviors of speakers, which reflect their cognition, and thus contribute to understanding the relationship between language and thought.

In this dissertation, I adopt the linguistic relativity hypothesis and the perspectives of neo-Whorfian scholars as my theoretical framework. By utilizing

empirical methods to examine how grammar affects cognition, my research explores the relationship between language and thought. If the findings show that grammar influences cognition, it will support the linguistic relativity hypothesis. Otherwise, the results may indicate that factors other than grammar also influence cognition.

2.2.1.1 Research which support the linguistic relativity hypothesis

After the linguistic relativity hypothesis gained widespread acceptance, many studies have tested its validity across different aspects of language. These include nominal grammatical categories (such as grammatical number, countable and uncountable nouns, and classifiers), grammatical tense, grammatical gender, metaphorical terms, and semantic systems. These studies consistently used the linguistic relativity hypothesis and the theoretical frameworks developed by neo-Whorfian scholars. Lucy (1992a) experimental methodologies have been highly influential. They focus on comparative analyses, examining habitual language patterns in everyday use, designing non-linguistic tasks, selecting participants with similar backgrounds, and controlling extraneous variables.

Findings from these studies consistently show that differences in grammatical structures between languages are associated with differences in speakers' cognitive processes. This provides strong evidence supporting the linguistic relativity hypothesis. The following sections discuss some of these related studies in detail.

Research into **nominal grammatical categories** has been used in testing the linguistic relativity hypothesis, such as Charunrochana (2000); Kirjavainen et al. (2020); Lucy (1992b). These studies explore how nominal grammatical categories—grammatical number, countability, and classifiers—affect cognition. They highlight both common patterns and differences. Additionally, these studies

provide a deeper understanding of how linguistic structures influence attention, memory, and categorization, based on the linguistic relativity hypothesis.

All three studies consistently show that grammatical number significantly influences numerical cognition. J. A. Lucy (1992b) demonstrated that English speakers, whose language obligatorily marks grammatical number, outperformed Yucatec Maya speakers in attention, memory, and classification tasks related to numerical distinctions. To assess attention, participants were presented with pictures and asked to describe them. In the memory test, participants were later asked to recall the number of objects from the same pictures used in the attention test. Finally, the classification test involved a triad matching task, where participants were asked to categorize an alternate object with a target object. Similarly, Charunrochana (2000) found that English speakers paid greater attention to and remembered the number of objects better than Thai speakers, whose language, like Yucatec Maya, lacks obligatory number marking. Kirjavainen et al. (2020) supported these findings, showing that English speakers were more accurate than Japanese speakers in recalling plural entities, emphasizing that grammatical number heightens sensitivity to numerical differences.

The studies also reveal how linguistic aspects influence on shape versus substance preferences through the categorization test. J. A. Lucy (1992b) found that English speakers tended to classify objects by shape, while Yucatec Maya speakers preferred substance, reflecting the influence of grammatical systems. Charunrochana (2000), while hypothesizing that Thai speakers might focus more on shape due to their presence on classifiers, found that English speakers still outperformed Thai speakers in shape-based tasks. This finding supports Lucy's assertion that shape is more salient in non-classifier languages like English. However, Charunrochana found no significant differences in substance-based classification, challenging Lucy's claim that classifier languages inherently prioritize substance.

Kirjavainen et al. (2020) explored a distinct focus on numerical recall, emphasizing how grammatical number impacts memory. Unlike Lucy and Charunrochana, who explored broader cognitive tasks, Kirjavainen investigated the impact of grammatical number marking on cognitive processes in English and Japanese speakers. In English, grammatical number is obligatorily marked, with count nouns requiring explicit markers to denote singular (one entity) or plural (more than one entity) forms. In contrast, Japanese count nouns seldom take grammatical number markers, allowing plural entities to be referred to without any explicit number indication. In the first experiment, participants were shown pictures and asked to recall the number of objects depicted. The findings revealed that English speakers demonstrated significantly higher accuracy than Japanese speakers when recalling two objects (as opposed to one), suggesting that the obligatory grammatical number marking in English heightens attention to numerical distinctions. In the second experiment, participants were asked to provide explanations for the results observed in the first experiment. The results from this experiment correlated to the findings of the first, supporting the initial hypothesis.

A key difference across the studies lies in participant demographics and methodology. Lucy and Charunrochana compared speakers from different linguistic and cultural contexts, but this might have caused mixed results due to other influencing factors. For instance, Charunrochana criticized Lucy's comparison of English and Yucatec Maya speakers, suggesting that cultural and experiential differences might have influenced the results. In contrast, Kirjavainen et al. (2020) focused on monolingual speakers in more controlled environments, reducing the impact of cultural variables and providing clearer evidence of linguistic influence.

Additionally, **grammatical tense** has been used to test the linguistic relativity hypothesis. Aemdit (2013) examined the relationship between grammatical tense marking in English, Japanese (tense-marking languages), and

Chinese, Thai (tenseless languages). The study hypothesized that English and Japanese speakers would have greater awareness and memory of time compared to Chinese and Thai speakers. In the awareness test, participants described pictures, while in the memory test, they watched video clips and completed tasks such as picture selection, gap-filling, and multiple-choice questions. The results showed that English and Japanese speakers outperformed Chinese and Thai speakers in memorizing time, with Chinese speakers performing better than Thai speakers. However, no significant differences were found across groups in the multiple-choice task.

Regarding **grammatical gender**, Thongnium and Prasithrathsint (2020) explored its effects on cognition among Russian and Thai speakers. Russian, with grammatical gender, contrasts with Thai, which lacks this feature. The authors hypothesized that Russian speakers would categorize pictures based on grammatical gender, while Thai speakers would use size or shape as criteria. The findings supported this hypothesis, with Russian speakers grouping pictures according to grammatical gender and Thai speakers categorizing pictures according to size or shape of objects.

Time metaphor in language have been a focal point in studying how language influences cognition. Several studies, notably by Boroditsky (2001); Boroditsky et al. (2010); Chen (2007), have examined how metaphors for time in different languages shape speakers' cognitive processes related to temporal concepts.

Boroditsky (2001) examined how time metaphors in English and Mandarin affect cognitive representations of time. Both languages use horizontal metaphors to express time: in English, for example, one might "look forward" to the future or "think back" to the past, while in Mandarin, similar expressions use qián (front) for the future and hòu (back) for the past. However, Mandarin also employs vertical metaphors, such as shàng (up) for earlier times and xià (down) for later times, which are frequently used in temporal expressions involving

weeks, months, or events. In contrast, vertical metaphors for time in English are rare, with expressions like "hand down knowledge" being uncommon.

Boroditsky conducted three experiments to test whether these linguistic differences influenced cognitive processing. In the first experiment, 26 English speakers and 20 Mandarin speakers participated in this experiment. They were shown spatial pictures with either vertical or horizontal arrangements. Each picture was accompanied by a sentence, such as "The black worm is ahead of the white worm" (horizontal) or "The black ball is above the white ball" (vertical). Participants were then asked to answer time-related questions—either in a before/after format (e.g., "March comes before April") or an earlier/later format (e.g., "March comes earlier than April")—by pressing a key on the keyboard. The results revealed that Mandarin speakers responded faster when primed with vertical spatial arrangements, while English speakers responded faster when primed with horizontal ones. These results aligned with the predominant use of horizontal time metaphors in English and both horizontal and vertical metaphors in Mandarin.

In the second experiment, Boroditsky investigated whether learning a foreign language could alter cognitive patterns related to time if Mandarin learn English whose time metaphor is in horizontal primes. 25 bilinguals who were Mandarin-English were instructed to answer spatial questions about time. Pictures were presented with sentence descriptions that were either horizontally or vertically. However, sentence descriptions were changed into “X will win.” or “X will lose.”, for example, “The white fish will lose.” For questions about time, all questions were earlier/later questions, for example, “March comes earlier than April.” The result showed that the age of acquisition of English was related to the vertical primes. Mandarin-English bilinguals who acquired English at the middle/late age were slower than bilinguals who acquired English at the early age in vertical prime tasks, suggesting that language acquisition affects time cognition.

Although the results from two experiments showed that the grammar of a language influences the way people think, Boroditsky questioned a cultural factor of both languages, such as the writing direction, which could have led to those differences. English's writing style is horizontal from left to right, whereas Traditional Mandarin is from right to left vertically. To address potential cultural confounds, such as differences in writing direction (English is written left-to-right horizontally, while traditional Mandarin is written top-to-bottom vertically), Boroditsky trained English participants to use vertical metaphors for time. In this training, participants learned to associate "above" or "higher than" with past events and "below" or "lower than" with future events. After the training, participants completed a task similar to the one in Experiment 1. The results showed that English participants who had been trained to think about time vertically performed more like Mandarin speakers than untrained English participants. This finding suggests that exposure to new linguistic structures can modify cognitive representations of abstract concepts like time, supporting the linguistic relativity hypothesis.

Overall, Boroditsky's studies indicate that linguistic structures, particularly temporal metaphors, can influence how speakers of different languages conceptualize time. However, she also acknowledged that factors beyond language, such as cultural practices like writing direction, could also affect cognition.

Chen (2007) criticized Boroditsky's conclusion that language strongly determines cognition, particularly in abstract domains like time. Chen argued that Boroditsky had not sufficiently examined the frequency with which Mandarin and English speakers use vertical and horizontal metaphors. To address this, Chen analyzed Taiwanese news articles and found that while both vertical and horizontal metaphors were used to describe time, horizontal metaphors were more common in both languages. Then, Chen reduplicated Boroditsky (2001)'s experiment with Chinese and English participants. The results revealed no

significant differences between the two groups in their responses to vertically arranged pictures. Chen concluded that Chinese speakers did not process time differently from English speakers, despite Mandarin's use of vertical metaphors for time. This critique suggests that frequency of metaphor usage may moderate the extent to which linguistic structures influence cognition.

In a follow-up study, Boroditsky et al. (2010) adjusted the experiment based on Boroditsky (2001). Mandarin and English were asked to experiment. For the procedure, participants were shown two pictures. The second picture was presented after the first picture in the same location at the center of the screen. The second picture remained until participants answered the question. An example of a question is, "Does the second picture occur at the earlier or later of the first picture?" Participants had to make the response by pressing one of two adjacent keys. The first key was covered by a black sticker which represented 'earlier,' while the second key was covered by a white sticker which represented 'later.' However, the authors separated all participants into two groups. The response buttons in the first group were positioned horizontally on the left-right axis. For one block, a black sticker representing 'earlier' was placed on the left key, while a white sticker representing 'later' was placed on the right key. The mapping was reversed for another block. The response buttons in the second group were positioned vertically on the top-bottom axis. For one block, the top key was covered by a black sticker that represented 'earlier,' while the bottom key was covered by a white sticker that represented 'later.' For another block, the mapping was reversed. The results showed that when the "earlier" button was on the left (horizontal condition), both English and Mandarin speakers responded more quickly, consistent with their writing systems. However, in the vertical condition, only Mandarin speakers showed faster responses when the "earlier" button was on top, reflecting Mandarin's use of vertical metaphors for time. These findings further support the hypothesis that linguistic structures, such as spatial metaphors, influence cognitive representations of time.

In addition, **linguistic honorific terms** a have been key in testing the linguistic relativity hypothesis. Chandharath (2013) examined the relationship between linguistic honorific systems and cognitive categorization among English, Japanese, and Thai speakers. Japanese, unlike English and Thai, has a complex grammatical system of honorifics embedded in its morphosyntax, where politeness and social hierarchy are conveyed through specific forms. Thai also employs a more developed politeness system compared to English, but it lacks the grammaticalized honorific structures seen in Japanese. Chandharath indicated that the dominants of honorific terms are age and status. It was hypothesized that Japanese speakers might pay more attention to and categorize people and things based on age and status than Thai and English speakers. In the experiment of attention test, participants were asked to arrange four or five pictures or objects. In the experiment of categorization test, participants were asked to categorize two pictures that were the most similar. The results supported the hypothesis, showing that Japanese speakers paid more attention to age and status in both tasks, especially in comparison to English speakers. However, no statistically significant differences were found between Thai and the other two language groups, except in the age-related aspect of the attention test. Chandharath suggested that the similarities between Thai and Japanese honorific systems might explain why Thai speakers performed more like Japanese than English speakers.

Terms in the semantic system have also been used to test speaker's cognition, such as, Aemdit (2007); Chanyeam (2017); Nusartlert (2009).

Aemdit (2007) investigated the correlation between the semantic system of "hitting" terms and cognition in Thai and Khmu speakers. The study identified six dimensions along which "hitting" terms varied between the two languages: the animacy, the size of objects, the shape of objects, the hand shape of objects, the direction, and the weight when hitting. The attention and classification were adopted to test participants' behavior. The author hypothesized that Khmu

speakers tend to pay more attention to and classify objects based on animacy, the size of objects, the shape of objects, the hand shape of objects, the direction, and the weight, which correspond to the semantic system of hitting terms in Khmu. The attention test focused on testing the animacy, the size of objects, the shape of objects, the hand shape of objects, and the direction. Participants were asked to choose a picture that was different from the other two in each set of questions. For the attention test of weight, participants were asked to select if objects in their hands were similar or different when they closed their eyes. The categorization focused on testing the animacy, the size of objects, the shape of objects, the hand shape of objects, and the direction. Participants were asked to choose an object or picture similar to the given object or picture. For the categorization test of weight, participants were asked to classify two objects from three objects in the same category.

The result showed that Khmu speakers paid more attention to the animacy, the hand shape of objects, and the weight compared to Thai speakers, aligning with the distinctions in their language's "hitting" terminology. However, no significant differences were found in participants' attention to the size of objects, the shape of objects, and the direction. In addition, Khmu speakers classified objects depending on the animacy, the hand shape of objects, the direction, and weight more than Thai speakers. However, there were no statistically significant differences in the size of objects and the shape of objects between Khmu and Thai speakers. The findings suggest that linguistic structures—such as specific semantic distinctions in Khmu—correspond to cognitive patterns, with Khmu participants demonstrating behavior that mirrored the categories emphasized in their language.

Nusartlert (2009) explored the differences between "putting" terms in Japanese and Thai and their cognition. In Japanese, "putting" terms are categorized based on the animacy, parts of the body, and the fitting of body, and the fitting terms of objects. In contrast, “putting” terms in Thai are categorized

based on the shape of objects. The attention and classification were adopted to test participants' behavior. For the attention test, participants were asked to look at five pictures and select only one that differed from the other four. For the categorization test, participants were asked to select a picture different from the other two. The author hypothesized that Japanese speakers tend to pay more attention and classify objects depending on the animacy, the fitness of objects, and parts of the body than Thai speakers. The author also hypothesized that Thai speakers tend to pay more attention to and classify objects based on their shape of items than Japanese speakers.

The result showed that Japanese participants paid more attention and categorized the animacy, the fitness of objects, and parts of the body. However, there was no statistically significant difference in the shape of objects between Japanese and Thai participants. This suggests that most of the results supported that the different semantic systems of "putting terms" in Japanese and Thai affect Japanese and Thai's different cognitive behavior, which are compatible with their pattern of language.

Chanyeam (2017) investigated how the semantic system of "cutting" terms influenced cognition among northern Sgaw Karen and English speakers. The northern Sgaw Karen language differentiates "cutting" actions based on the instrument used and the weight involved, whereas English does not emphasize these factors as strongly. The author hypothesized that northern Sgaw Karen speakers tend to pay attention to and categorize based on the instrument and weight. In the attention experiment, participants were instructed to do the picture-describing task for investigating the awareness of the instrument and weight. In the categorization experiment, participants were asked to categorize two of three pictures that were the most similar in terms of the instrument. For the categorization of weight, participants were asked to classify two objects from three objects in the same category.

The results showed that northern Sgaw Karen speakers were more likely to categorize objects based on instrument and weight than English speakers, though no significant differences were found in the attention task. This study further supports the idea that linguistic structures, particularly in action-related terminology, influence cognitive processes like categorization.

The spatial term has also been used to investigate speakers' cognition. Spatial terms describe the location of objects in relation to other objects. Majid et al. (2004) examined whether the spatial frames of reference (FoR) used in different languages affect speakers' cognition. Dutch speakers typically use a relative FoR, describing the location of objects based on the egocentric viewpoint (e.g., "left," "right") The location also changes based on the perspective of viewers. For example, "The fork is to the left of the spoon." If the viewer goes to the opposite side of that table, the fork will be described as "The fork is to the right of the spoon." On the other hand, Tzeltal speakers use an absolute FoR, relying on fixed cardinal directions (e.g., "north," "south"). For example, "The fork is to the north of the spoon." For the experiment, Dutch and Tzeltal participants were asked to do the memory test for spatial configuration. In the experiment, Dutch and Tzeltal participants were asked to complete a memory test involving spatial configurations. Participants were shown a card with two dots—one large and one small—and instructed to remember the arrangement. It is noticeable that a small dot on the card is nearer to participants than a large dot. After rotating 180 degrees to face a new table, they were asked to identify which of four cards matched the original configuration. Four cards had been varied in the arrangement of the dot. The results indicated that Dutch participants relied on their egocentric perspective to recall the arrangement, while Tzeltal participants used cardinal directions. These findings demonstrate that the linguistic system used to describe space directly affects how individuals encode and recall spatial information, highlighting the cognitive impact of different spatial FoR in languages.

The studies reviewed provide strong evidence supporting the linguistic relativity hypothesis, showing that linguistic structures across various domains—such as grammatical number, tense, gender, metaphorical terms, honorifics, and semantic systems—significantly influence cognitive processes. Overall, the research confirms that language not only facilitates communication but also influences how individuals think, remember, and categorize the world around them.

2.2.1.2 Research that declines the linguistic relativity hypothesis

While most studies support the linguistic relativity hypothesis, some have yielded results that challenge it. Upon closer examination, it becomes evident that many of these studies, although these studies claimed that they adopted Lucy (1992a)'s experimental design for testing participants' cognition, most of them showed the different methodologies used in these studies. For testing the linguistic relativity hypothesis, the experiment should be in non-linguistic activities. (Boroditsky, 2001; Lucy, 1992b) However, experiments in some studies (Barner et al., 2009; Imai et al., 2010) still were stuck on linguistic tasks.

According to Lucy (1996)), cognitive behaviors should come from participants' awareness. A study of Doms (2004) was found that instructions given in this study revealed the research purpose, making participants aware of what is being tested. Dom investigated how English and Korean speakers categorize spatial actions, drawing on earlier research by Choi and Bowerman (1991), which found that English spatial verbs are categorized based on "containment" and "attachment," using verbs like "put in" or "put on." For instance, English speakers might use "put in" for placing an apple in a bowl or "put on" for placing a lid on a container. In contrast, Korean spatial verbs distinguish between 'tight' and 'loose' attachments, using terms like kkita for placing something tightly (e.g., a lid on a jar) and nehta for placing something loosely (e.g., placing an object in an open container). Doms' experiment involved two groups, English and

Korean speakers. Participants were shown a picture of a spatial action for ten seconds, followed by two additional pictures, and were asked which of the latter two best matched the action depicted in the first. For example, in one scenario, participants saw a picture of a hat being put on, and they had to choose between two pictures: one depicting the action kkita (tight attachment in Korean) and another showing the action ssuta (loose placement of the hat in Korean). Participants were then asked to explain their choices.

The results revealed that participants' categorizations were often inconsistent with the grammar of their respective languages. This suggests their decisions were not strongly influenced by linguistic structures, as predicted by the linguistic relativity hypothesis. Instead, participants gave different reasons for their choices that did not reflect the expected grammatical differences between English and Korean spatial verbs.

In my view, the instructions in this study may have unintentionally hinted at the research objective, which could have caused participants to consciously adjust their responses. As a result, their answers might not accurately reflect their natural cognitive patterns in a non-linguistic task like categorization. Additionally, the ten-second viewing period for each picture gave participants plenty of time to think, which could have led them to overanalyze the task rather than relying on instinctive cognitive processes. This may have further complicated the results, making it difficult to assess their true cognitive behavior.

Barner et al. (2009) aimed to investigate whether speakers of mass-count languages, such as English, conceptualize entities differently from speakers of classifier languages, such as Japanese. To test this hypothesis, three tasks were designed: the object-substance rating task, the quantity judgment task, and the word extension task.

In the object-substance rating task, participants from both language groups—Japanese and English—were shown pictures of 100 common nouns and asked to classify them as referring to "objects," "substances," "both," or "neither."

In the quantity judgment task, participants were shown pictures containing either distinct objects or portions of non-solid material and asked to determine which picture contained more "stuff." The results from these tasks suggested that mass-count syntax does not fundamentally influence how speakers conceptualize entities. Instead, the findings indicated that mass-count syntax selects from a universally available set of lexical meanings, demonstrating independence from cognitive processing.

In the word extension experiment, participants were divided into two groups. In the first condition, 16 English speakers and 16 Mandarin-English bilinguals were tested in English with mass-count ambiguous syntax. An additional 16 Mandarin-English bilinguals were tested in Mandarin, which does not employ mass-count syntax. Participants were shown a standard object and two alternate objects: one that shared the same shape as the standard object and another that shared the same material. Participants were asked to assign a novel name ("blicket") to the appropriate alternate object by answering, "Can you point at the blicket?" The results showed that English monolinguals extended words based on shape more frequently than Mandarin-English bilinguals tested in Mandarin. However, a significant difference was found between English monolinguals and Mandarin-English bilinguals tested in English, indicating that the language of instruction influenced bilingual participants' judgments.

In the second condition, a different group of 16 English speakers was tested using count syntax, while another group of 16 English speakers was tested with mass syntax. Participants were presented with phrases like "This is some/a wug," and the experiment aimed to determine whether count and mass syntax influenced word extension. The results revealed no significant difference between the groups tested with count syntax and those tested with ambiguous syntax. However, participants' judgments differed significantly in the mass syntax condition compared to the count and ambiguous syntax conditions.

The authors concluded that their findings did not support the Whorfian hypothesis as suggested by earlier studies, such as those by Lucy (1992b) and Imai and Gentner (1997)'s claims. Instead, the results aligned more closely with the notion that count and mass syntax do not substantially influence cognitive processes, consistent with findings from Gathercole and Whitfield (2001) and Imai and Mazuka (2003).

Imai et al. (2010) explored how classifiers in the Chinese language influence children's conceptual structures, focusing on shape similarity, taxonomy, and thematic relations as the main organizers of children's concepts. The study involved four groups of participants: 3-year-old Chinese children, 3-year-old German children, 5-year-old Chinese children, and 5-year-old German children. These groups were tested through three experiments: a non-lexical classification task, a label extension task, and a property inference task.

In the non-lexical classification task, participants were shown a standard object (e.g., an apple) and asked to choose one out of three objects that was similar to the standard object: a taxonomic object (e.g., a cucumber), a shape object (e.g., a ball), and a thematic object (e.g., a knife). The results showed that both 3- and 5-year-old Chinese children preferred to categorize objects based on shape similarity. However, 5-year-old German children preferred thematic categorization, while 3-year-old German children exhibited no clear preference.

In the label extension task, which followed a similar setup to the first experiment, children were tasked with helping a puppet learn new words. They were asked to assign a novel label to the standard object and then select which of three alternate objects should share the same label. The findings indicated that most 3- and 5-year-old children from both language groups extended the label based on shape similarity rather than taxonomy.

In the property generalization task, the same materials were used as in the previous experiments. Participants were taught a novel property associated with the standard object and then asked to determine which of the three alternate

objects also possessed that property. The results showed that 5-year-old Chinese and German children generalized the property based on taxonomic relations.

Overall, these results suggest that the classifier system in Chinese influences children's conceptual structures, particularly in the non-lexical classification task. However, this influence was not evident in the label extension or property inference tasks, where children from all groups exhibited inconsistent behavior. Thus, the impact of the classifier system seems limited to specific types of cognitive tasks, with shape preference playing a significant role in young children's conceptual organization across languages.

According to Barner et al. (2009) and Imai et al. (2010), both presented findings that did not support the linguistic relativity hypothesis. A key issue in these studies is that the tests relied heavily on linguistic tasks, which may have influenced the results. According to scholars like Boroditsky (2001); Lucy (1992b), testing the linguistic relativity hypothesis should be conducted through non-linguistic tasks to avoid the direct influence of language on cognition. Slobin (1996) similarly emphasized that the use of language should not be the primary means of evaluating cognitive differences. Barner et al. (2009); Imai et al. (2010) used tasks such as count-mass judgments, word extension, label extension, and property inference to study cognition through linguistic outputs. However, this approach may have limited access to the participants' true cognitive processes. By emphasizing linguistic categories, these studies might have focused more on language use rather than exploring the underlying cognitive structures.

Another noteworthy observation is that most studies testing the linguistic relativity hypothesis focus on monolingual speakers, despite the global rise of bilingualism due to increased cross-border communication. Bilingualism is an expanding area of study in cognitive research, with scholars like Athanasopoulos (2006), Athanasopoulos (2007), Cook et al. (2006), Athanasopoulos and Kasai (2008), Mazuka and Friedman (2000), Bassetti (2007) leading work in this field.

This dissertation adopts the linguistic relativity hypothesis as a framework to examine the influence of grammatical number on monolinguals and bilinguals. The central question was whether the cognition of monolinguals was affected by language, and whether bilinguals, who possessed knowledge of two grammatical systems, exhibited cognitive patterns similar to speakers of their first language, their second language, or a combination of both. To ensure the validity of the findings, cultural variables were controlled, and participants were drawn from languages that either had obligatory grammatical number or made grammatical number optional. The participants' cognition was assessed through non-linguistic tasks to ensure that their language behaviors did not influence the experimental results.

2.2.2 Language and cognition in other aspects

Apart from the linguistic relativity hypothesis, which posits that language may influence thought, other perspectives explore the relationship between language and cognition in various dimensions. These approaches examine different aspects of this correlation, and the details are outlined below.

2.2.2.1 Language and thought are similar.

Watson, cited in Arnold (2005), introduced the theory of "peripheralism," proposing that the thinking process is closely linked to speech. According to this view, thinking occurs on the periphery of the larynx, rather than in the brain's central regions. Watson suggested that the act of thinking happens simultaneously with the movement of the larynx, indicating that speech and thought are intertwined.

However, this notion has been challenged by other scholars. They argue that thinking can occur without the movement of speech organs. Smith (1947), cited in Arnold (2005), tested Watson’s theory by giving himself an injection a

drug that paralyzed his speech organs. After the drug's effects wore off, Smith reported that he was still able to think, even though his speech muscles were incapacitated. Similarly, Furth (1966) challenged Watson's theory, noting that deaf and mute individuals can think just as hearing and speaking individuals do, even without knowledge of sign language.

2.2.2.2 Thought influences language.

Piaget (1950) and Piaget and Inhelder (1969), cited in Arnold (2005), proposed that language is dependent on thought. They illustrated this through children's language acquisition, where children first observe the entities around them and later learn the language to express those observations. Piaget argued that children should begin to talk about permanent objects before discussing things that are not immediately present in their environment. At the same time, children understand liquid quantity because they understand words or phrases about the quantity, such as "more" or "bigger," etc. This development reflects the cognitive process that enables children to create semantic categories by observing the multiple uses of language by fluent speakers (Bowerman, 1996). Hence, Piaget suggested that language acquisition is driven by cognitive development (Winskel & Luksaneeyanawin, 2013).

However, Sinclair-de-Zwart (1969), cited in Arnold (2005), noted that children require linguistic training to improve their language use. Piaget acknowledged that children may be taught words or phrases but will not fully understand them until they reach a specific stage of intellectual development. Therefore, while language may exist without the influence of thought, it would be devoid of true meaning, akin to a parrot mimicking speech or "in the sense that a parrot can speak."

In contrast, Luria and Yudovich (1971), cited in Arnold (2005), challenged Piaget's view, arguing that language plays a crucial role in cognitive development. They observed five-year-old twin boys who were given limited

encouragement to speak and showed little progress in symbolic language use. After being separated and one receiving linguistic treatment, the treated twin experienced rapid cognitive and linguistic development, surpassing his brother after ten months. Then, when the twin boys made a linguistic improvement, and their problem with synpraxic speech disappeared. Their findings demonstrated how language training dramatically altered the cognitive structures of both twins, showing that language is integral to cognitive development. Twin boys were able to express themselves verbally after being trained in the language system. Luria and Yudovich saw the beginnings of the twin's meaningful activity after only three months.

2.2.2.3 Language and thought are separated.

Vygotsky (1972) cited in Arnold (2005), argued that language and thought are initially separate systems, with language occurring independently of thought and vice versa. He introduced the concepts of "prelinguistic thought" and "pre-intellectual language." Prelinguistic thought includes actions and perceptions that occur before children acquire language, while pre-intellectual language includes behaviors like crying and babbling, which happen before children gain linguistic competence. According to Vygotsky, these two systems eventually merge to form verbal thought, indicating that while language and thought are distinct, they are related through development.

Vygotsky further elaborated that between the ages of two and seven, language serves two functions: an internal function that monitors internal thoughts and an external function that allows communication with others. He noted that young children are egocentric in their communication and do not distinguish between private thoughts and public speech. By the age of seven, children begin to separate "speech for self" from "speech for others," indicating that language and thought, while initially separate, interact as cognitive development progresses. When children were two years old, they learned to speak about

everything. However, when they grew up until seven years old, they learned to think about what they will speak considering the public and privacy. Vygotsky's conclusion may indicate the correlation between language and thought when people think or speak through language.

2.2.2.4 Language is a part of cognition.

Chomsky (1983), cited in Birjandi and Sabah (2012), argued that language is considered to be one part of cognition, and its evolution is considered to be one aspect of cognitive development. Chomsky clarified that several cognitive systems appear to have different and distinctive features. These systems set the foundation for certain cognitive abilities, and one of these cognitive systems is language. The author referred to the human's capacity to encode the visual space with the number system, which is the abstract entity, to understand the creation of music and the capacity to understand the social systems in which one participates. They undoubtedly indicate the development of conceptual structures in the mind, as well as a variety of other mental capacities. Chomsky expressed his idea through the following quotation.

"Language is a mirror of mind in a deep and significant sense. It is a product of human intelligence... By studying the properties of natural languages, their structure, organization, and use, we may hope to learn something about human nature; something significant, if it is true that human cognitive capacity is the truly distinctive and most remarkable characteristic of the species."

Chomsky (1975) cited in Birjandi and Sabah (2012)

Chomsky famously described language as "a mirror of the mind", emphasizing that by studying natural languages—particularly their structure, organization, and use—researchers can gain insight into human cognitive capacities. Smith (1999), cited in Birjandi and Sabah (2012), expanded on this view, explaining that the verbal output provides knowledge about several aspects of the mental structure, such as, from mental theory to moral judgment,

from visual illusion recognition to facial recognition. The lexicon and concepts of visual perception and scent have nothing in common with those languages. Therefore, it may be considered that language is a reflection of the mind, not a mental model.

2.2.2.5 Thinking for speaking hypothesis

Slobin (1996) proposed the "thinking for speaking" hypothesis, arguing that cognition is dynamically influenced by the process of verbal communication. He said that both terms “thought”, and “language” have broad definitions which can be interpreted in different ways. Also, it is suggested that, “Language evokes idea, but it does not represent them.” (Slobin, 1979, cited in Clark (2003)).

Slobin clarified that there is a process of thinking for speaking in which cognition has a dynamic function within the context of verbal communication. Therefore, Slobin proposed different terms “thinking” and “speaking” to replace the terms “thought” and “language.” Slobin (2009), cited in Birjandi and Sabah (2012), said that although he refers to “thinking for speaking,” this framework encompasses all types of language production (e.g., speaking, signing) and reception (e.g., understanding, remembering).

Moreover, Slobin (1996) said, “Thinking for speaking is the special form of thought that is mobilized for communication.” It shows that the shift from abstract entity names to activity names has the effect of drawing attention to different types of mental processes that occur during the act of speech. The author instantiated the grammaticized distinctions of English, Spanish, German, and Hebrew. He said that when people who use these languages were shown the picture about different events, there is nothing in the picture leading them to express the grammar of language verbally. However, they will start to think about their language’s grammar by attending to features or events of pictures while speaking. It can be stated that the grammar of the language is used in the

speaking process. The language we know is the subjective orientation to human experience, which influences how we think while speaking.

However, Athanasopoulos (2007) debated the paradigm “thinking for speaking” belonging to Slobin (1996) on the issue of the nature of the apparent cross-linguistic influences on cognition. According to the notion of “thinking for speaking,” human thought should be restricted in the process of speech production, such as comprehending, speaking, etc. Thus, it might be assumed that bilinguals will show their categorization preferences based on the language of instruction that bilinguals engaged in the experiment. However, Athanasopoulos’s finding showed that bilingual cognitive shift, regardless of the language of instruction, may indicate that language, as Lucy (1992a, 1996) initially proposed, may influence habitual cognition at a deeper level.

As discussed, various perspectives exist regarding the relationship between language and thought. These include the ideas that language and thought are similar, that thought influences language, that language and thought are separate, that language is a part of cognition, and that thinking is mobilized specifically for speaking. While each theory offers distinct insights, many are contested by empirical findings. For example, Smith (1947), cited in Arnold (2005), opposed the idea that language and thought are identical, while Luria and Yudovich (1971), cited in Arnold (2005), challenged the notion that thought drives language. This underscores the importance of empirical evidence in determining the validity of these theories.

In this dissertation, the linguistic relativity hypothesis, initially proposed by Sapir and Whorf, was adopted. Although Whorf provided various lexical and grammatical examples suggesting that language affects cognition, he did not provide empirical support. This limitation led to the hypothesis being overshadowed. However, Lucy (1992a)’s introduction of a systematic approach

for testing linguistic relativity has revived interest in the hypothesis, leading to numerous studies (as discussed in sections 2.2.1.1 and 2.2.1.2).

Building on this, the dissertation tested the linguistic relativity hypothesis by examining both monolingual and bilingual groups. Previous studies have demonstrated that language influences monolingual cognition, but this research seeks to explore whether acquiring a second language alters these cognitive processes. The central question is whether bilinguals, knowing two languages that represent distinct ways of viewing the world, perceive the world differently than monolinguals.

2.3 Nominal grammatical categories between English and Thai (grammatical number, countability and classifier)

Nominal grammatical categories are essential in understanding how nouns interact with syntactic elements like determiners, quantifiers, and adjectives. Nominal grammatical categories consist of grammatical number, countability, and classifiers. The details are presented below.

2.3.1 Grammatical number

Grammatical number is the grammar aspect that has been adopted to examine the relationship between language and thought, specifically in the context of the linguistic relativity hypothesis in this dissertation. According to Kibort and Corbett (2008), “grammatical number is a grammatical category which encodes quantification over entities or events denoted by nouns or nominal elements. It derives from the ability to perceive something as a token, an instance of a class of referents, and the ability to differentiate between one and more than one (such as the ‘plurality’ of) instances of the referent.”

Languages like English, which have obligatory grammatical number marking, require speakers to explicitly indicate whether they are referring to one or more entities. This is achieved through plural suffixes (e.g., "-s" as in "apples"), articles (e.g., "a," "an," "the"), quantifiers (e.g., "some," "many," "several"), or

numerals (e.g., "1," "2," "3") (Kirjavainen et al., 2020). For example, English phrases such as "an apple," "two apples," or "some apples" make the quantity clear through these grammatical markers.

In contrast, languages like Thai lack grammatical number marking. In Thai, countable nouns typically remain unchanged regardless of whether they refer to singular or plural entities. For instance, a noun like “ʔép pə̂n” (apple) can be used without additional markers to indicate whether the reference is to one or multiple apples. This characteristic allows Thai speakers to construct grammatically correct words, phrases or sentences without explicitly specifying quantity. However, it may lead to ambiguity, as the precise meaning—whether singular or plural—depends on the context of the conversation.

These linguistic differences underscore the unique trade-offs in each language, where Thai prioritizes contextual interpretation and conversational flexibility, while English emphasizes explicitness and precision in conveying numerical distinctions.

2.3.2 Countability

Countability is a prominent feature in many languages, including English, for classifying and quantifying nouns. Certain nouns, such as cat or table, can be directly paired with numerals (e.g., three cats), whereas others, like furniture, cannot. This distinction is often interpreted as reflecting a conceptual difference between “objects” and “substances.” Count nouns generally refer to distinct, bounded entities with stable spatial properties, while mass nouns represent substances whose boundaries are shaped by their containers or usage context, such as water, mud, wood, or gold (Rothstein, 2010).

In English, the distinction between count and mass noun is evident in several grammatical patterns. For instance, count nouns, such as “dog”, can be pluralized and combined with numerals (e.g., "three dogs"), whereas mass nouns like mud cannot (e.g., "three muds" is incorrect). Mass nouns, however, can be

used with quantifiers like much and little (e.g., "much mud"). Both types of nouns are used to describe a range of entities. Count nouns typically refer to physical objects like dog but are also used for abstract ideas (e.g., idea, wish), events (e.g., party, explosion), and broad categories (e.g., animal, vehicle). Mass nouns, while often used to describe substances like mud, also apply to abstract concepts (e.g., evidence, insanity), actions (e.g., sleep, running), and categories like furniture or clothing. (Wisniewski et al., 2010) Therefore, count noun are perceived as individuated entities with distinct shapes and functions, while mass noun is perceived as non-individual entities with a distinct of material (Athanasopoulos, 2007)

In contrast to English, Thai does not differentiate grammatically between count and mass nouns. All nouns in Thai are grammatically treated as mass nouns. Additionally, there are no plural forms or specialized quantifiers for countable and uncountable nouns. Instead, quantity is expressed through classifiers (or measure words), which are used to quantify nouns that does not rely on a mass/count distinction (Charunrochana, 2000) While in English, for example, one would say "three apples," in Thai, one would say “ʔép pân săːm phŏn” (three apples), where “phŏn” is the classifier for apples. The classifier is a key grammatical tool that differentiates between different types of objects (e.g., an "apple" uses “phŏn”," but a "book" uses “lèm”. This system allows Thai to handle both countable and uncountable concepts under the same grammatical framework by using appropriate classifiers.

2.3.3 Classifier

A classifier is a grammatical element used in certain languages to categorize nouns based on specific attributes such as shape, size, or type. In languages that utilize classifiers, these words are used in conjunction with numerals to provide additional information about the noun being counted, often

indicating its shape, function, or other distinguishing characteristics (Aikhenvald, 2000).

The distinction between classifier and non-classifier languages is a key aspect of linguistic typology, revealing how languages influence the categorization and quantification of nouns. Classifier languages, such as Thai, and non-classifier languages, such as English, demonstrate distinct approaches to noun categorization. These differences reflect fundamental variations in linguistic typology (Aikhenvald, 2000; Piriyawiboon, 2008)

Thai, as a classifier language, requires a classifier when are counted and modified with numerals. These classifiers are chosen based on features such as the shape, size, or category of the noun. For example, when dogs are counted, “tuā”, is used, but when housed are counted a different classifier, “lăŋ”, is used instead (Shoichi & Ingkaphirom, 2005). In addition, classifiers in Thai can shift the interpretation of a noun from generic to specific. For instance, the classifier " tuā" transforms the noun “mæw” ("cat") into a specific referent, as in “mæw tuā lék” ("the black cat"), contrasting with the generic interpretation of “mæw sĭ dām” ("black cats") without a classifier (Piriyawiboon, 2008).

In contrast, English uses a non-classifier system, where countable nouns are modified directly by numerals, with their plural form marking number. (Athanasopoulos, 2006). For instance, the sentence “A dog is walking” refers to a single entity, whereas “Dogs are walking” denotes multiple entities (Kirjavainen et al., 2020). Mass nouns, however, behave differently. They cannot take grammatical number marking, cannot be directly modified by numerals, and require unitizers for quantification. For example, instead of saying three sands, one would say three piles of sand (Athanasopoulos, 2007).

This study aimed to investigate the influence of grammatical number on Thai-English bilinguals in comparison to Thai monolinguals and English monolinguals, with a particular emphasis on the linguistic distinctions between

English and Thai in alignment with the linguistic relativity hypothesis. English necessitates obligatory reference to number through grammatical markers, whereas Thai permits optional reference to quantity without explicit grammatical number marking. This study examines whether the mandatory grammatical number marking in English, compared to its optional usage in Thai, impacts cognitive processes related to numerical understanding, as suggested by the linguistic relativity hypothesis.

2.4 Cognitive behavior

This dissertation aims to test the linguistic relativity hypothesis. According to Lucy (1992a), the testing of this hypothesis requires the comparison of cognitive patterns through an external, non-linguistic reality, which can be reflected in cognitive behaviors, as understood within the framework of cognitive psychology. In this study, cognitive behaviors, specifically attention and memory, are used to investigate the linguistic relativity hypothesis. A comprehensive review of the background and theoretical framework of attention, memory, and related studies has been conducted, the details of which are presented below.

2.4.1 Attention

Friedenberg and Silverman (2006) define attention as the mental activity distributed across multiple sources of information. When we pay to attend to one source, that source will come to our consciousness and transcend to the stage of processing from the sensory store to the short-term memory for further processing. Two main types of attention are distinguished: selective attention and divided attention.

Selective attention involves focusing exclusively on one source of information while ignoring others. Arnold (2005) described that you were presented with two or more pieces of information, and you then were responded to only one of them. This aligns with Friedenberg and Silverman (2006)'s example.

They instantiated the situation that you decided to listen to what your teacher was talking about or your friends' conversation in class. On the other hand, divided attention refers to dividing the attention across multiple sources simultaneously. For example, you decided to listen to what your teacher is saying or your friends' conversation at the same time. However, the more sources you divide your attention to, the less attention is given to any particular source, leading to diminished performance in processing any single source.

Shiftability also relates to selective attention. For example, you can pay attention to source A while ignoring source B, then switch back to B while ignoring A. Besides, you can pay attention to source A, source B, source C, source D, and so on. It states that the focus of attention can be switched between several sources. Intentional or unintentional shifting is possible. Switching only one source at the moment leads to the sustainability of the information.

Two prominent theories have been proposed to explain attention: the bottleneck theory and the capacity theory. The notion of bottleneck theory explains why we receive only some information and describes how that information is chosen, which is in line with selective attention. Various models have been developed to describe this process, including Broadbent's filter model and Treisman's attenuation model.

Broadbent's filter model conceptualizes attention as a filter that permits only the attended information to the stage of consciousness. On the other hand, it could not allow unattended information to pass through the filter if you ignore it. According to James (1890), cited in Arnold (2005), the filter model aligns with the concept of the "span of consciousness." Information passing through the filter is subsequently analyzed, recognized, and transferred to the stage of motor effectors in order to give the appropriate reaction. The process of Broadbent's filter model has shown in Figure 1.

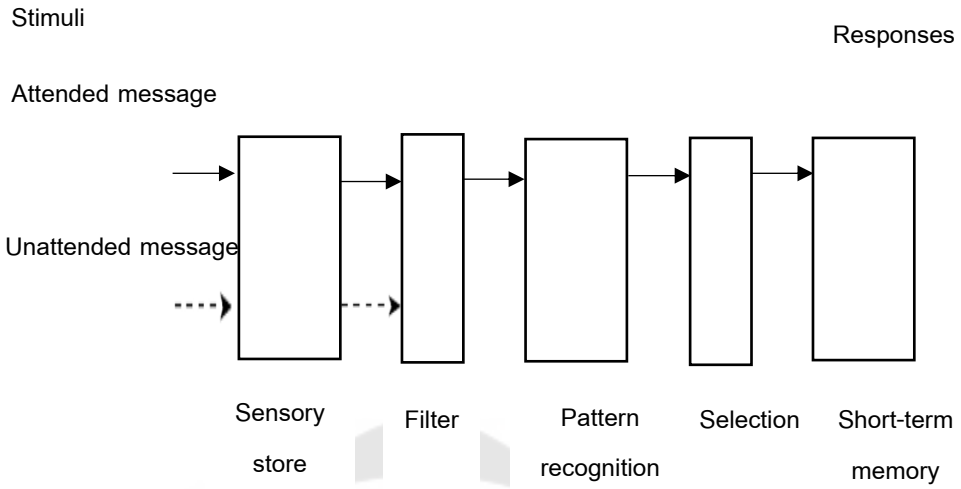


Figure 1 Broadbent's filter model (adapted from Reed (2000) and Friedenberg and Silverman (2006))

As shown in Figure 1, Friedenberg and Silverman explain that the physical properties of stimuli (e.g., location, pitch, loudness) determine which message is attended to. After passing the filter, the attended message goes to the stage of pattern recognition. The attended message passes through any selection mechanisms to the stage of the short-term memory, where it is stored for a longer duration of time before being processed and responded. It indicates that because the filter takes the unattended message out before it can be recognized, Broadbent's model is known as an "early selection model."

However, Cherry (1953), cited in Arnold (2005), examined the phenomenon known as the "cocktail party effect," to see how we select the attended message from several people and what happens to the unattended message. In fact, when someone across the room mentions your name, then you realize you hear him, or words about the urgent situation such as 'fire' etc. Moray (1959); Wood and Cowan (1995), cited in Friedenberg and Silverman (2006), also noted that unattended channels allow some information to get through the filter. Relevant words about personal information or danger are not blocked by the filter. Thus, Broadbent's filter model is still discussed.

In contrast to Broadbent's filter model, Treisman (1964), cited in Friedenberg and Silverman (2006), proposed that the filter weakens rather than completely blocks unattended messages. Figure 2 illustrates that while unattended messages still undergo processing, they are in a weakened state. Arnold (2005) supports this by noting that unattended information is not entirely rejected, but its volume would be reduced.

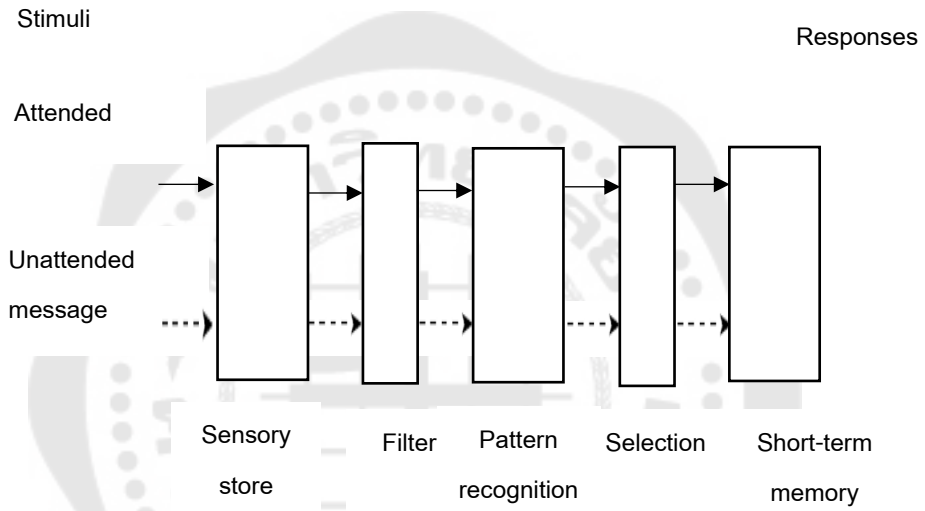


Figure 2 Treisman's attenuation model (adapted from Reed (2000) and Friedenberg and Silverman (2006))

The second theory, the capacity theory, posits that human processing capacity is limited. In this view, attention is considered as limited sources that must be distributed across multiple sources of information. Kahneman's capacity model of attention, as discussed by Arnold (2005), suggests that the distribution of capacity is linked to the process of determining how much effort is made. The amount of capacity required for a task is determined by factors such as the tasks' difficulty and that person's experience with it.

Kahneman (1973), cited in Friedenberg and Silverman (2006), described that there are some factors determining how much attention will be allocated to various tasks. The first one is enduring disposition. When there is a sudden

incident, it automatically grabs attention. The second one is momentary intention. It is an intentional decision to pay attention to something which reflects our current objectives at that time. For example, a mother who is driving in a car might divert her attention to a quarrel between her children in the back seat, but she would have to instantly return her focus to her main objective of driving. The third one is the evaluation of the attentional demands. The quantity of stimulus available and the importance of activity both influence how much attention will be paid to it. Three factors lead to the possible activities and responses. According to the driving example above, the mother's attention was temporarily diverted from the most demanding task of driving to the children in the back seat and then returned to driving.

The similarities between bottleneck and capacity theories have been noted by Reed (2000), cited in Friedenberg and Silverman (2006). Both theories suggest that focusing on two tasks simultaneously is challenging, with selection theory limiting attention to one piece of information at a time and divided attention theory describing the distribution of attention according to the significance of the information. If we pay attention to two pieces of information simultaneously, the capacity for perception will be less.

Attention is frequently used to assess cognitive processes, including in studies of monolingualism and bilingualism. Experiments designed to test cognition through attention have been conducted, such as Charunrochana (2000), Athanasopoulos (2006), Aemdit (2007), Chandharath (2013), Nusartlert (2009), Chanyeam (2017). Their findings support the notion that attention is a reliable method for assessing cognition. When participants are presented with detailed stimuli, their attention is directed to the elements they perceived only the message they paid attention to.

In this dissertation, the attention test was employed to assess the cognition of monolingual and bilingual participants. Both the bottleneck and

capacity theories are integrated into the experimental design. According to these theories, only the attended information from the sensory store proceeds to short-term memory before other unattended messages. Therefore, participants were shown pictures for a short periods and asked questions involving those pictures. It is expected that participants will first perceive and process the elements of the image to which they have directed the most attention, followed by secondary elements that received less attention.

It was hypothesized that participants whose language requires obligatory grammatical marking for number tend to pay more attention to and provide more accurate responses regarding the number of objects. In contrast, participants whose language allows optional expression of grammatical number tend to demonstrate less accuracy in responding to such questions. Additionally, for bilingual participants, it was hypothesized that proficiency in a second language (L2) may influence their attention to the number of objects, with varying degrees of proficiency yielding different levels of awareness.

2.4.2 Memory

Memory is recognized as one of the fundamental cognitive processes. Kalat (1991) defined memory as “the retention of information,” which is in line with Sternberg and Sternberg (2012). They indicated that memory is “what we retain and draw on our past experiences to use that information in the present.” Lieberman (2004) stated that “memory is an active system that receives, stores, organizes, alters, and recovers information.” Friedenberg and Silverman (2006) described memory as the mental process of remembering things for a long time, playing a crucial role in the ability to learn in humans, animals, and systems. Memory enables the storage and retrieval of knowledge and past experiences. When facing new problems and situations, memory can link new problems and situations with our knowledge and past experiences that have been stored.

Memory can be categorized into three types: sensory memory, working memory (short-term memory), and long-term memory. However, before examining these types, three key characteristics of memory should be understood: duration, capacity, and coding. Duration refers to the length of time that information can be processed within the memory system, capacity indicates how much information can be stored, and coding pertains to the types of information that are maintained in the system.

2.4.2.1 Sensory memory

Sensory memory functions as a temporary storage system for incoming sensory information. It captures raw and unanalyzed data long enough to allow the selection and recognition mechanisms to process it. Sensory memory can be further divided into iconic memory (visual sensory memory) and echoic memory (auditory sensory memory). Iconic memory serves as a brief snapshot of visual input, typically lasting around 250 to 300 milliseconds. Echoic memory, by contrast, retains auditory information longer than iconic memory, functioning as an "echo" of the sounds heard.

George Sperling (1960), cited in Friedenberg and Silverman (2006), was the first to investigate iconic memory through a study involving participants recalling letters from a “four letters x three letters” array as shown.

R G C P

L X N F

S B J Q

Sperling's study examined two distinct experimental conditions. The first, known as the whole-report condition, required participants to recall as many letters as possible from a briefly presented display. Results indicated that participants typically remembered approximately four to five letters. Sperling

concluded that participants likely recalled the letters based on what they retained in memory rather than what they initially perceived. Subsequently, the partial-report condition was developed. In this condition, participants were shown an array of letters and then heard one of three tones: a high-pitched tone signaling the top row, a medium-pitched tone for the middle row, and a low-pitched tone for the bottom row. The findings revealed that participants were capable of recalling all of the letters when cued by the tones. Despite previous research suggesting that iconic memory can remain for a longer duration, Sperling's work confirmed that iconic memory fades quickly. This gradual loss of memory over time is known as "decay.

2.4.2.2 Working memory (Short-Term Memory)

Working memory, or short-term memory, is responsible for temporarily holding information for cognitive processing. Short-term memory has a longer duration than visual memory. Furthermore, the capacity for information in long-term memory and short-term memory is limited, while sensory memory has an unlimited capacity. Friedenberg and Silverman (2006) clarified that data could be temporarily retained in short-term memory until they are processed by the cognitive process. Cognitive thinking is believed to occur in this memory store, which processes data before it decays or is transferred to long-term memory. The authors elaborated on the duration, capacity, and coding of working memory or short-term memory as follows.

The first characteristic is duration. Peterson and Peterson (1959), cited in Friedenberg and Silverman (2006), investigated the duration of items retained in short-term memory. In the first condition, participants were presented with items, followed by tones sounded at varying intervals after each item was shown. Participants were tasked with recalling the items upon hearing the tone. The results indicated that participants could correctly recall the items, a process known as "rehearsal," where the mental repetition of information helps retain it in

short-term memory, preventing decay. In the second condition, participants were shown a three-digit number and asked to count backward in threes from it (e.g., from "796" to "793," "790," and so on). Tones were again sounded at different times to cue recall. However, due to the backward counting task, participants could only recall 5% of the items, as rehearsal was interrupted. According to this paradigm, Brown (1958) and Peterson and Peterson (1959), cited in Friedenberg and Silverman (2006), estimated that the duration of short-term memory is approximately 18 seconds.

The second key characteristic of short-term memory is its capacity, which refers to the amount of working memory can hold. The author noted that It is relatively easy to test capacity. For example, participants are presented with lists of increasing length (e.g., four digits, then five digits, and so on) to assess how much they can retain. Miller (1956), cited in Friedenberg and Silverman (2006), found that most individuals can remember around seven items, plus or minus two (7±2), a phenomenon referred to as the "magical number seven," representing the limit of short-term memory capacity.

The third characteristic of short-term memory is its coding, or how information is encoded. Conrad (1964), cited in Friedenberg and Silverman (2006), conducted a study in which participants were shown a series of letters and asked to recall them immediately. Participants often made errors based on the sound of the letters (e.g., confusing ‘A’ with ‘K’), indicating that the letters were encoded acoustically. Second trial, Wickens (1972), cited in Friedenberg and Silverman (2006), presented participants with words. After participants learned words from a specific category, participants’ recall had been steadily declining since the first few trials. For example, after learning the word "apple," participants may confuse it with "orange," a word learned later. For the final trials, when participants were instructed to recall, they might switch from the category of fruits to flowers which are different semantic categories. In this case, it is called a semantic code.

2.4.2.3 Long-term memory

Long-term memory refers to the storehouse of information that can retain data for extended periods. The first type is procedural memory, which relates to the memory of skills, such as swimming or driving, and can be demonstrated without conscious recall. The second type is declarative memory, which involves memory for facts and events. Declarative memory is further divided into two subtypes: semantic memory, which stores factual knowledge learned in school, and episodic memory, which relates to personal experiences or events, such as recalling what happened on Christmas day last year. The authors provide detailed explanations of the duration, capacity, and coding of long-term memory as follows.

The first characteristic is the duration of long-term memory. There are three stages of how long the long-term memory lasts. First, if information stored in long-term memory is not used or rehearsed, it may decay over the first few years. Second, some learned information tends to remain stable over time. Finally, at a later stage in life, due to aging, some information may be lost. These three stages occur regardless of the level of training or proficiency participants possess.

The second characteristic is the capacity of long-term memory. Although long-term memory has a large capacity, recalling information can be difficult. These challenges may arise from problems in accessing the stored information or due to a failure or decay. According to Landauer (1986), cited in Friedenberg and Silverman (2006), the average adult's brain contains around a billion bits of information, and has a storage capacity that is a thousand to one million times more.

The third characteristic is the coding of long-term memory. Long-term memory coding involves how information is represented and stored. Some theorists suggest that information in long-term memory is encoded in a formulaic way. Implicit memory may be stored in the form of production rules, beginning with sensory input to the motor output, and is linked to the cerebellum, which

governs motor learning. On the other hand, explicit memory may be stored as a network of interconnected nodes, where each node represents a related fact or event.

Kalat (1991) identified several primary methods for testing memory, with three being particularly widespread: recall, recognition, and relearning. The details are presented below.

Recall is considered the simplest method for assessing memory and is subdivided into two types: free recall and cued recall. The free recall task is to recall something without stimulus or hints, such as the short-answer test or essay test. For instance, participants may be asked to recall all the names of their second-grade classmates. The cued recall task, on the other hand, involves recalling something with hints. For example, participants might be shown a photograph of their second-grade classmates to help them remember names.

Recognition refers to the ability to identify previously learned information. It is suggested that people can typically recognize more items than they can recall. In this method, participants might be presented with a list of 60 names and asked to check the correct names of their second-grade classmates.

Relearning, also known as saving, measures how quickly participants can reacquire previously learned information. For instance, if participants are unable to recall all their second-grade classmates' names, they may be asked to relearn them. The process of relearning is typically faster than remembering new things.

Several studies investigating language and cognition, particularly in monolinguals, employed memory tests to assess speakers' cognition, such as Aemdit (2013); Aemdit and Prasithrathsint (2016); Charunrochana (2000); Kirjavainen et al. (2020); Lucy (1992b). They have utilized short-term memory tests to explore cognitive processes. These studies suggest that data can be temporarily stored in short-term memory before being processed by the cognitive system, indicating that cognitive processing primarily occurs in short-term

memory. Sensory and long-term memory do not happen in this stage. These authors designed experiments where participants viewed detailed pictures for a few minutes and were then asked to answer questions about the pictures. The limited viewing time allowed the information to be transferred from sensory memory to short-term memory but not long-term memory. Their findings suggested that speakers of different languages might memorize different aspects of the same pictures based on their language's different grammar., demonstrating that cognitive processing can be accessed through short-term memory.

This dissertation focuses on testing the cognition of monolinguals and bilinguals using a short-term memory. Short-term memory is particularly suited for this study as it functions as a temporary storage space where information is held before being processed cognitively. As highlighted in the literature, it is in short-term memory that cognitive thinking actively occurs, making it critical for capturing the immediate influence of language on cognition.

The choice to concentrate on short-term memory, rather than other types of memory, is intentional. Short-term memory enables researchers to assess how quickly and accurately participants can store and retrieve information soon after exposure. During the memory test, participants were shown pictures for a duration long enough to allow the information to transfer from the sensory store to short-term memory. By analyzing their recall of the number of objects, the study investigates how cognitive processes are influenced by language use.

This focus on short-term memory is particularly effective because it captures real-time cognitive processing, which is essential for understanding the role of language in influencing cognition. In contrast, long-term memory involves more complex and prolonged encoding processes, introducing variables that are not directly related to the core research question concerning the impact of language on cognition.

It is hypothesized that participants who speak languages with obligatory grammatical number will exhibit better memory retention and provide more

accurate responses to questions regarding the number of objects. In contrast, those who speak languages with optional grammatical number may struggle to answer these questions accurately. For bilinguals, it is further hypothesized that varying degrees of proficiency in their second language (L2) may affect their memory retention of object numbers to different extents. This study aims to explore how language proficiency interacts with cognitive processes in bilingual individuals.

2.5 Common European Framework of Reference for Language (CEFR)

The Common European Framework of Reference for Languages (CEFR), developed by the Council of Europe in 2001, is a widely acknowledged international standard for evaluating and describing language proficiency across four key domains: reading, writing, speaking, and listening (Council of Europe, 2001).The CEFR offers a comprehensive and systematic framework that aids in identifying the needs of language learners, establishing specific learning objectives, guiding curriculum design, and assessing language proficiency outcomes (Little, 2006). By providing six distinct reference levels—A1, A2, B1, B2, C1, and C2—organized into three broad categories: Basic User (A1, A2), Independent User (B1, B2), and Proficient User (C1, C2), the CEFR facilitates the structuring of language courses and the monitoring of learner progress. These levels delineate clear stages of language competence, promoting a gradual and consistent advancement in language skills across diverse educational and institutional settings as shown in Table 1 (Council of Europe, 2001).

Table 1 CEFR Common Reference Levels (adapted from Council of Europe (2001))

Level	Descriptions
Proficient User	
C2	"Can understand with ease virtually everything heard or read. Can summarize information from different spoken and written sources, reconstructing arguments and accounts in a coherent presentation. Can express him/herself spontaneously, very fluently and precisely, differentiating finer shades of meaning even in more complex situations."
C1	"Can understand a wide range of demanding, longer texts, and recognize implicit meaning. Can express him/herself fluently and spontaneously without much obvious searching for expressions. Can use language flexibly and effectively for social, academic and professional purposes. Can produce clear, well-structured, detailed text on complex subjects, showing controlled use of organizational patterns, connectors and cohesive devices."
Independent User	
B2	"Can understand the main ideas of complex text on both concrete and abstract topics, including technical discussions in his/her field of specialization. Can interact with a degree of fluency and spontaneity that makes regular interaction with native speakers quite possible without strain for either party. Can produce clear, detailed text on a wide range of subjects and explain a viewpoint on a topical issue giving the advantages and disadvantages of various options."

Table 1 (Continued)

Basic User	
A2	"Can understand sentences and frequently used expressions related to areas of most immediate relevance (e.g. very basic personal and family information, shopping, local geography, employment). Can communicate in simple and routine tasks requiring a simple and direct exchange of information on familiar and routine matters. Can describe in simple terms aspects of his/her background, immediate environment and matters in areas of immediate need."
A1	"Can understand and use familiar everyday expressions and very basic phrases aimed at the satisfaction of needs of a concrete type. Can introduce him/herself and others and can ask and answer questions about personal details such as where he/she lives, people he/she knows and things he/she has. Can interact in a simple way provided the other person talks slowly and clearly and is prepared to help."

Table 1 demonstrates that the CEFR framework is structured along two principal dimensions: a horizontal axis that categorizes various language activities and competencies, and a vertical axis that represents the progression of proficiency within these categories. The vertical axis employs "can do" descriptors to outline six levels of communicative competence, spanning three bands—Basic (A1, A2), Independent (B1, B2), and Proficient (C1, C2). These levels embody a widely accepted consensus for organizing language learning and recognizing proficiency achievements.

The horizontal dimension emphasizes learners' communicative competences and the strategies that connect these competences to communicative activities. While competences and strategies are scaled in a manner analogous to communicative activities, they have not undergone independent empirical validation. For example, the A2 level includes an accuracy

descriptor stating that learners "can communicate in simple and routine tasks requiring a simple and direct exchange of information on familiar and routine matters," which aims to capture the grammatical proficiency necessary for productive tasks at this level. Behavioral scales within the framework focus on learners' abilities, whereas scales for competences and strategies are designed to aid teachers and assessors in diagnostic and evaluative processes. Additionally, the horizontal dimension provides taxonomies for analyzing various contexts of language use, including domains, situations, conditions, constraints, mental contexts, themes, and communicative tasks and purposes (Council of Europe, 2001)

In this dissertation, the Common European Framework of Reference for Languages (CEFR) was utilized to categorize Thai-English bilinguals based on their English language proficiency. To accurately assess and classify proficiency levels, standardized tests such as the Test of English as a Foreign Language (TOEFL), Test of English for International Communication (TOEIC), and the International English Language Testing System (IELTS) were employed. These tests provide quantitative scores that were systematically aligned with the CEFR scale, which ranges from A1 (Beginner) to C2 (Proficient). Specifically, bilinguals with basic English proficiency were classified at the A1 (Beginner) or A2 (Elementary) levels. Those demonstrating intermediate proficiency were assigned to the B1 (Intermediate) or B2 (Upper-Intermediate) levels, while bilinguals with advanced proficiency were categorized at the C1 (Advanced) or C2 (Proficient) levels according to the CEFR as shown as in Table 2.

Table 2 Comparison of different English language proficiency exams (TOEIC, TOEFL Paper, TOEFL CBT, TOEFL IBT, IELTS) and their corresponding levels in the Common European Framework of Reference for Languages (CEFR) (adapted from Council of Europe (2001))

TOEIC	TOEFL Paper	TOEFL CBT	TOEFL IBT	IELTS	CEFR
0-250	0-310	0-30	0-8	0-1.0	
	310-343	33-60	Sep/18	1.0-1.5	A1
255-400	347-393	63-90	19-29	20.-2.5	A1
	397-433	93-120	30-40	3.0-3.5	A2
					B1 (IELTS 3.5)
405-600	437-473	123-150	41-52	4.0	B1
	477-510	153-180	53-64	4.5-5.0	B1 (IELTS 4.5)
					B1 (IELTS 5.0)
605-780	513-547	183-210	65-78	5.5-6.0	B2
	550-587	213-240	79-95	6.5-7.0	C1
785-990	590-677	243-300	96-120	7.5-9.0	C2
Top score	**Top score**	**Top score**	**Top score**	**Top score**	**Top level**
990	677	300	120	9	C2

Notes: TOEIC: Scores range from 10 to 990, primarily assessing listening and reading skills.

TOEFL Paper: The traditional paper-based test with scores ranging from 310 to 677.

TOEFL CBT (Computer-Based Test): An older format of TOEFL with scores ranging from 0 to 300.

TOEFL iBT (Internet-Based Test): Modern TOEFL format with scores ranging from 0 to 120, evaluating reading, listening, speaking, and writing.

IELTS: Scores range from 1 (non-user) to 9 (expert user), assessing listening, reading, writing, and speaking.

The alignment of these standardized test scores with the CEFR levels is crucial for ensuring consistency and comparability in assessing language abilities. By employing the CEFR alongside these standardized assessments, the dissertation ensures a robust and standardized evaluation of English proficiency among bilinguals. This approach not only enhances the reliability of the classification but also allows for meaningful comparisons across different proficiency levels within the study, thereby contributing to a comprehensive understanding of bilingual language competence.

CHAPTER 3
METHODOLOGY

This chapter consists of six parts as follows.

3.1 Population

3.2 Participants

3.3 Qualifications of participants

3.4 Data collection

3.5 Analysis

3.1 Population

The population of this research is specified as follows.

3.1.1 Native speakers of Thai who live in Thailand

3.1.2 Native speakers of English who live in Thailand

3.2 Participants

According to the population, the purposive sampling was conducted to collect the data. Participants in this study were categorized into monolingual and bilingual speakers. Monolinguals consisted of Thai speakers and English speakers, which were control groups. Bilinguals consisted of Thai-English bilinguals who have English proficiency at the basic level, Thai-English bilinguals who have English proficiency at the intermediate level, and Thai-English bilinguals who have English proficiency at the advanced level. The details are shown in Table 3.

Table 3 Types of participants

Type	Number of participants
1. Monolingual speakers	
1.1 English speakers	30 participants
1.2 Thai speakers	30 participants
2. Bilingual speakers	
2.1 Thai-English bilinguals who have English proficiency at the basic level	30 participants
2.2 Thai-English bilinguals who have English proficiency at the intermediate level	30 participants
2.3 Thai-English bilinguals who have English proficiency at the advanced level	30 participants
Overall	150 participants

Table 3 shows two groups of monolinguals speakers and three groups of bilinguals. For monolingual groups, they consisted of 30 native English speakers and 30 native Thai speakers. For bilingual groups, they consisted of 30 Thai-English bilinguals who have English proficiency at the basic level, 30 Thai-English bilinguals who have English proficiency at the intermediate level, and 30 Thai-English bilinguals who have English proficiency at the advanced level. Additionally, a sample size of at least 30 participants is generally adequate for obtaining statistically significant results. For studies with a medium to large effect size, a group size of 30 participants typically ensures approximately 80% statistical power, which is the minimum threshold recommended for standard research (Cohen , 1988, as cited in, VanVoorhis and Morgan (2007)).

3.3 Qualifications of participants

Participants for this study were selected using a purposive sampling method to ensure a representative distribution of the specified qualifications. Recruitment was conducted via social media platforms, targeting individuals who met the inclusion criteria. The participants included both monolinguals and

bilinguals, all of whom were at least 18 years old. According to Bassetti (2007), language acquisition in children is not stable, meaning children's linguistic development can be inconsistent due to factors such as cognitive growth and varying levels of exposure to language. In contrast, much research has focused on participants aged 18 and above, as adult language patterns tend to be more stable (e.g., Athanasopoulos (2006, 2007); Athanasopoulos and Kasai (2008); Chanyeam (2017); Charunrochana (2000); Kirjavainen et al. (2020)). Therefore, this study followed this approach, collecting data from participants aged 18 and older to ensure more reliable results.

Monolinguals were defined as native speakers of Thai or English residing in Thailand, with minimal or no proficiency in a second language. Native English speakers were from countries where English is the official language (e.g., Australia, the United States, the United Kingdom, and Canada). However, identifying true monolinguals proved challenging due to the increasing prevalence of bilingualism in contemporary society. For the purposes of this study, monolingual participants were considered to be those with minimal or no proficiency in a second language, relying exclusively on their native language for daily communication.

Bilingual participants were all native Thai speakers living in Thailand, and their English proficiency was measured using standardized tests such as TOEFL, TOEIC, and IELTS. Language proficiency was categorized according to the Common European Framework of Reference for Languages (CEFR), ranging from A1 (Beginner) to C2 (Proficient). Thai-English bilinguals with basic proficiency were classified at the A1 (Beginner) or A2 (Elementary) levels, those with intermediate proficiency were classified at the B1 (Intermediate) or B2 (Upper-intermediate) levels, and those with advanced proficiency were classified at the C1 (Advanced) or C2 (Proficient) levels.

Participants were asked to provide their ages, years of birth, and language experience. To ensure the age requirement of at least 18 years was

met, participants were asked to provide their current age and year of birth. Information about language experience, including countries visited in the past six years, was also collected to assess exposure to different linguistic environments. Additionally, participants reported their fluency in foreign languages and the duration of their studies.

As research showed that L2 proficiency affects cognitive behavior (Athanasopoulos, 2006, 2007; Pavlenko, 2014), bilinguals with advanced proficiency in languages other than English were excluded to avoid influencing the experiment's outcomes. Additionally, the age of acquisition and L2 proficiency have been found to influence bilinguals' cognition, with those who learned a second language in childhood and achieved advanced proficiency exhibiting cognitive differences from monolinguals (Archila-Suerte et al., 2011). Therefore, participants' fluency in foreign languages and their years of study were carefully considered. For example, Thai-English bilingual participants with advanced proficiency in any foreign languages (other than English) were excluded, as their high proficiency in multiple languages might have affected the results.

Furthermore, participants who had extended stays in second-language countries, which could alter cognitive behavior (Athanasopoulos, 2007; Cook et al., 2006), were carefully considered. For example, a Thai-English bilingual participant who had lived in Quebec, Canada, for three years might have gained proficiency in French, which could influence the study's outcomes, as French is widely spoken alongside English in Quebec (Government of Quebec, 2022). That participant might have gained proficiency in French, potentially affecting the study.

Cultural factors, such as social background, educational experiences, and ways of life, as emphasized by neo-Whorfian scholars, may influence speakers' cognitive processes. These scholars underscore the importance of considering the social context in which language is used, as these factors can profoundly influence how individuals think and perceive the world. In testing the

linguistic relativity hypothesis, it is crucial to isolate the influence of grammar on cognition by controlling for these variables.

To minimize potential confounding factors, this study carefully ensured that the demographic characteristics of participants were as similar as possible. Data collection was conducted in a geographically homogeneous area, specifically Bangkok and its surrounding regions, to minimize the influence of regional variations on participants' worldviews and cognitive behaviors. This controlled approach enhances the reliability of the findings by focusing on the effects of linguistic structures rather than extraneous cultural or regional factors.

Another important factor is education level. For consistency and to control for personal background differences, participants were selected from those currently studied in undergraduate programs or those who have completed at least an undergraduate degree. This approach is in line with previous research (e.g., Athanasopoulos (2006, 2007); Athanasopoulos and Kasai (2008); Charunrochana (1997, 2000); Thongnium (2017)), which aims to reduce variability in educational background.

Since this study is focused on assessing numerical awareness, participants with extensive exposure to numbers were excluded. This includes participants majoring in mathematics-related fields or working in professions involving frequent numerical tasks, such as accounting, economics, engineering, or teaching mathematics, as such experience might introduce biases and skew the results of the experiment. By selecting participants with more comparable demographic backgrounds, the study aimed to ensure more reliable and consistent findings. Detailed demographic information of the participants is provided in Appendix B.

Finally, participants with known cognitive impairments, such as colorblindness, were excluded from the study. This was necessary because the experimental tasks involved color-based pictures, and accurate color perception was crucial for valid responses. Participants with colorblindness might have

struggled to correctly identify or count objects based on color, potentially compromising the accuracy of the data.

3.4 Data collection

This study aimed to investigate whether language affects participants' cognition based on the linguistic relativity hypothesis, using an experimental design modeled after Lucy (1992a). Lucy's framework for assessing cognition involves testing cognitive behaviors such as attention, memory, and categorization. However, this research focused exclusively on attention and memory tests to evaluate cognitive behaviors, following the methodologies of previous studies that employed attention tests (e.g., Aemdit (2007, 2013); Chandharath (2013); Chanyeam (2017); Charunrochana (1997, 2000); Lucy (1992b)), memory test using photo hunts (e.g., Aemdit (2013)), and memory test using short-answer questions (e.g., Aemdit (2013); Aemdit and Prasithrathsint (2016); Archila-Suerte et al. (2011); Boroditsky (2001); Boroditsky et al. (2010); Gordon (2004); Lucy (1992b); Ruthirago (2011)) The categorization test, though widely used in cognitive studies (e.g., Athanasopoulos (2006, 2007, 2009); Athanasopoulos and Kasai (2008); Chandharath (2013); Chanyeam (2017); Charunrochana (1997, 2000); Lucy (1992b); Ruthirago (2011); Thongnium (2017); Thongnium and Prasithrathsint (2020), was excluded from this study.

Recent studies by Aemdit (2013); Aemdit and Prasithrathsint (2016) found that most participants categorized objects based on basic instinct, which provided limited insight into their cognitive behaviors. They suggested that attention and memory tests are more effective and sufficient in evaluating cognitive processing. This informed the decision to focus on attention and memory tests in this study, as these tests are essential for assessing critical stages of cognitive processing, as discussed in Chapter 2. Attention tests measure participants' ability to filter and select relevant information from sensory input, while memory tests evaluate how well this information is retained and

processed in short-term memory. Together, these tests offer a comprehensive assessment of the cognitive functions required to understand and respond to stimuli. Therefore, attention and memory were incorporated into the experimental design.

Based on the notion of attention and memory tests, as well as previous studies that used these tests to assess participants' cognition, the experimental design was adapted. Multiple pilot studies were conducted to determine the most appropriate approach. For this study, in the attention test, participants were asked to view each picture for five seconds before it disappeared, followed by a question related to the picture. In the memory test using a photo hunt, participants were first asked to view a prototype picture for five seconds and were subsequently asked to select the picture most similar to the prototype from two alternatives. Additionally, another memory test using short-answer questions, where participants viewed each picture for ten seconds before it disappeared, followed by answering five related questions. Participants' responses were recorded by themselves or online systems depending on the online or offline version they were convenient and familiar with them.

The data collection process was structured into three stages: 3.4.1) a pilot study to outline the preliminary procedures before the main experiment, 3.4.2) experiment design, and 3.4.3) data collection for both the attention and memory tests.

3.4.1 Pilot study

Before conducting the main experiment, several pilot studies were undertaken to refine the methodology, focusing on three groups: Thai monolinguals, Thai-English bilinguals with basic English proficiency, and Thai-English bilinguals with advanced English proficiency. The primary aim was to assess the appropriateness of the test's difficulty level. This allowed for evaluating

the test's performance across participants with minimal and maximal English skills.

The pilot results provided valuable insights into potential issues with the test's design. For instance, if Thai-English bilinguals with basic proficiency performed too well, it could indicate that the test was too easy or that the visual elements were overly salient. Conversely, if Thai-English bilinguals with advanced English proficiency struggle, it could suggest that the test was too difficult or that the instructions required clarification. Feedback from these groups helped to refine the test, ensuring it was appropriately calibrated before extending it to Thai-English bilinguals with intermediate proficiency and native English speakers. By focusing on a specific group in the pilot phase, the test was optimized efficiently, saving time and resources for the main experiment. This process ensured that the test was appropriately challenging for participants across a range of proficiency levels, minimizing bias in the main study.

During the pilot studies, accuracy benchmarks were established for tasks involving the awareness of the number. Conversely, if these groups achieved accuracy above 80%, it suggested that the task was too easy, necessitating further adjustments. For Thai-English bilinguals with advanced proficiency, accuracy above 80% was expected, reflecting their higher awareness of the number.

Previous research supports the use of test and non-test pictures in cognitive tasks. Test pictures were used to analyze and evaluation. Non-test pictures were used to divert participants' awareness of test's objectives. In addition, a balanced ratio of test to non-test pictures is recommended to prevent participants from predicting the experiment's purpose. Time duration for viewing the pictures should also be carefully adjusted to avoid predicting the experiment's objectives, as extended viewing times could lead to participants recalling all picture details too easily.

One recurring issue during the pilot studies was participants' ability to predict the experiment's objectives, skewing the results by prompting them to focus on correct answers rather than exhibiting their natural cognitive responses. To counteract this, both test and non-test pictures were designed for all tasks. Questions in test pictures were related to the number of objects, while questions in non-test pictures were related to the color, size of objects and the situation in pictures. In the early pilot studies, participants' feedback revealed that some picture elements were too salient or unnatural, compared to the background. Also, certain questions were unclear and hard to understand when reading the first time. These issues were addressed through edits to both the pictures and questions based on participants' suggestions.

In the main experiment, participants were required to see pictures and answer related questions. However, prior research did not clearly specify how long participants needed to see a picture to be able to answer the questions. Most studies addressed this by conducting pilot tests to identify an appropriate time duration, typically ranging from two to ten seconds. Longer viewing times risked allowing participants to recall too many details, potentially skewing the results. In line with this approach, multiple pilot studies were conducted to refine the time duration for each test. The findings indicated that for tasks involving attention and memory tests using a photo hunt, a five-second time duration was sufficient for participants to observe a simple picture and respond to a question. In the memory test using short-answer questions, which included more complex pictures and five related questions, a ten-second time duration was found to be adequate.

Additionally, the pilot study revealed that when participants were aware of the objectives of the study, their focus primarily shifted to providing correct answers, limiting the observation of their natural, unconscious cognitive processes. To address this issue, the experiments were designed in the form of a game, allowing participants to relax and remain unaware of the objectives of the

study. The use of games in cognitive assessment has been employed in numerous studies, demonstrating its effectiveness in minimizing conscious response alterations. For example, research by Aemdit and Prasithrathsint (2016); Athanasopoulos (2006, 2007, 2009); Athanasopoulos and Kasai (2008); Bassetti (2007); Cook et al. (2006); Thongnium (2017) highlights how game-based methods successfully facilitate the investigation of cognitive processes. These studies affirm the utility of such an approach in minimizing bias and encouraging participants to respond more naturally, making it an essential technique in studies of this kind. The details of the main experiments are presented in 3.4.2.

3.4.2 Designing the experiment

Due to the different linguistic backgrounds of the participants, which included Thai speakers, English speakers, and Thai-English bilinguals with varying levels of English proficiency (basic, intermediate, and advanced), three different language versions of the experiment were developed: English, Thai, and bilingual (Thai-English) version. The English version was designed for monolingual English speakers (see Appendix F), while the Thai version was designed for monolingual Thai speakers (see Appendix G). The bilingual version was designed for Thai-English bilinguals (see Appendix H). Each version was carefully adapted to match the participants' language proficiency, ensuring consistency and reliability across all versions. While Athanasopoulos (2007) suggested that language instruction does not significantly affect experimental outcomes, this factor was controlled to ensure consistency in this study.

Concerning the circumstances and convenience of participants, both offline and online versions of the experiment were designed. The procedures for both formats were nearly identical, ensuring consistency across testing conditions.

The offline version was created using Microsoft PowerPoint and administered by myself. This version utilized PowerPoint's slide timing function to

control the display duration of each slide, which varied depending on the specific task. Participants viewed the presentation on either a notebook computer or a projector screen, and their responses were recorded on paper answer sheets.

The online version was developed by a web designer, following the same principles as the offline version. A timing function was employed to control the duration for which each webpage was displayed on the screen. Participants in the online version provided their responses directly on the website using a keyboard. This version was designed for participants to complete the experiment individually, with a stable internet connection required for website access.

The offline version was suitable for groups of participants, especially those with limited time for the experiment. For small groups (2-5 participants), the presentation was viewed on a notebook computer. For larger groups (more than five participants), the presentation was displayed using a projector in a classroom or conference room setting. Additionally, it was noted that some participants, unfamiliar with computers, preferred the offline version over the online version.

The details of the experiments used in the study are presented below.

3.4.2.1 Attention test

The attention test were designed based on the notion of the bottleneck theory and the capacity theory (Broadbent, 1958; Kahneman, 1973; Treisman, 1964). Both theories propose that attention functions as a filter, allowing only the attended stimuli to be processed while filtering out unattended information. According to these theories, individuals perceive only what they focus on. Consequently, when participants view pictures for a short period and answer related questions, they are expected to first perceive the components of the objects to which they directed the most attention. The experiment was therefore designed in accordance with these theoretical frameworks.

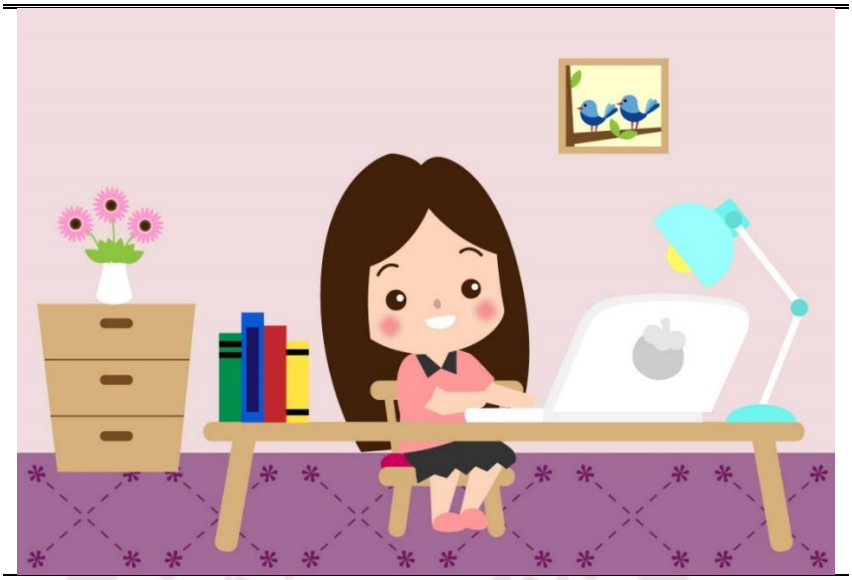
There were 10 pictures in the attention test, each measuring 14.8 x 21.0 cm (A5). The research aimed to examine participants' ability to view pictures on a

screen and respond to related questions. To determine the optimal picture size for the test, an experiment was conducted using pictures in various sizes, including A4 (29.7 x 21.0 cm), A5 (14.8 x 21.0 cm), and A6 (14.85 x 10.10 cm). Five participants were tasked with viewing pictures in these different sizes and answering corresponding questions. The experiment was conducted using appropriate display devices, such as a laptop screen and a projector. The results indicated that most participants found the A5 size to be sufficiently large to observe the picture details within the given time frame and answer the questions. As a result, the A5 size was selected for the attention test.

Among the 10 pictures used in the attention test, five were designed for testing and evaluation and are referred to as "test pictures." The other five, referred to as "non-test pictures," were included to minimize participants' awareness of the test's purpose, and their scores were excluded from the calculations. The sequence of test and non-test pictures was arranged randomly.

Examples of a test picture and a non-test picture for the attention test are presented in Table 4 and Table 5 (see the full details in Appendix C).

Table 4 An example of a test picture used for the attention test



Question 1: how many birds are there in the picture frame?

Answer: Two

Table 5 An example of a non-test picture used for the attention test

Question 6: What are the colors of the dogs in this picture?

Answer: Brown, black and grey.

Participants received one point for each correct answer concerning the number of objects in each of the test pictures. The scores of non-

test pictures were not calculated. The total number of points that a participant could obtain in the test was five points.

3.4.2.2 Memory test

The memory test was designed based on the notion of short-term memory. (Friedenberg & Silverman, 2006) In order to test memory, the “recall” technique proposed by Kalat (1991) was utilized, which includes two types of recall: free recall and cued recall. The free recall task is to recall something without hints, such as in a short-answer test. The cued recall task is to recall something with hints. For this dissertation, two tasks were developed for the memory test. The first task involved memory test using photo hunt, for which cued recall was implemented. The second task involved memory test using short-answer questions, employing free recall. The details are presented below.

3.4.2.2.1 Testing memory using photo hunt

There were 10 picture sets in this test. The first five, referred to as "test picture sets," were used for testing and evaluation. The remaining five, referred to as "non-test picture sets," were included to minimize participants' awareness of the test's purpose, and their scores were excluded from the calculations. The sequence of test and non-test pictures was arranged randomly.

For the test picture sets, each picture set consisted of three pictures in the same situation. Three pictures are composed of a prototype picture and two alternate pictures. Both alternate pictures were different from the prototype picture in one aspect. The number of objects in the first alternate picture differed from the prototype picture. One aspect of the second alternate picture differed from the prototype picture in other aspects, such as the color of objects, the size of objects, the shape of objects, and the different objects.

For non-test picture sets, each set consisted of three pictures with the same situation, including a prototype picture and two alternate pictures.

Both alternate pictures were different from the standard picture in one aspect, such as the color of objects, the size of objects, the shape of objects, and the different objects.

Examples of a test picture set and a non-test picture set for the memory test using photo hunt are presented in Table 6 and Table 7 (see the full details in Appendix D).

Table 6 An example of a test picture used for the memory test using photo hunt

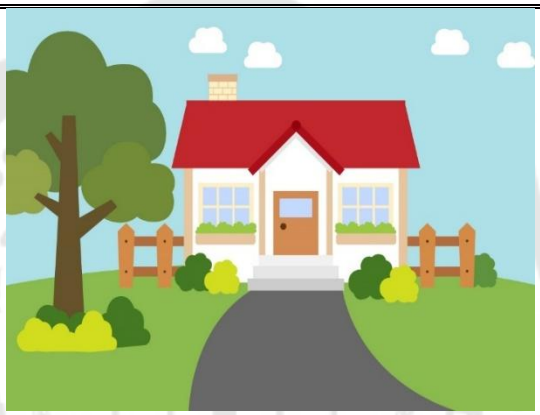
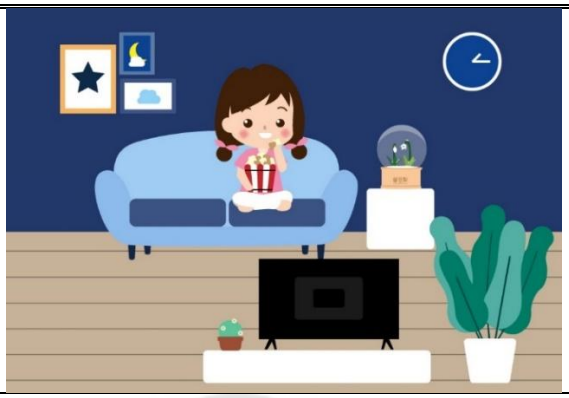
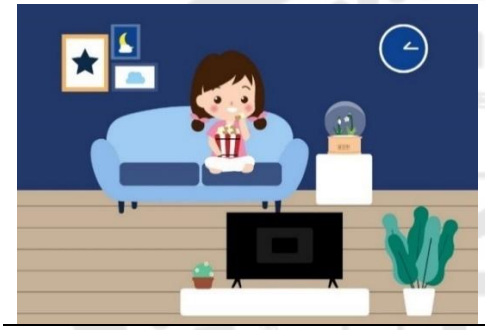
	
Prototype picture	
	
Alternate picture 1	Alternate picture 2
Prototype picture and alternate picture 1 = Different colors of doors Prototype picture and alternate picture 2 = Different number of trees	

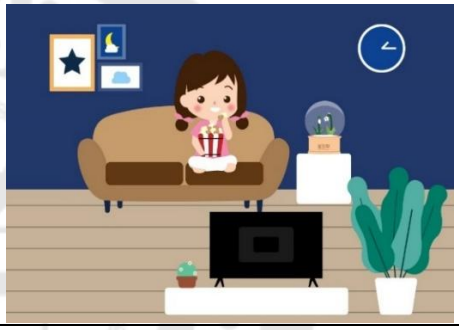
Table 7 An example of a non-test picture used for the memory test using photo hunt



Prototype picture



Alternate picture 1



Alternate picture 2

Prototype picture and alternate picture 1 = Different color of sofa beds

Prototype picture and alternate picture 2 = Different sizes of trees

3.4.2.2.2 Testing memory using short-answer questions

There were five pictures in the memory test using short-answer questions. This test was designed to assess participants' ability to view pictures on a screen and respond to related questions. An initial experiment was conducted to determine the optimal picture size by testing various dimensions, specifically A4 (29.7 x 21.0 cm), A5 (14.8 x 21.0 cm), and A6 (14.85 x 10.10 cm).

Five participants were asked to view pictures in these different sizes and answer corresponding questions. The experiment utilized appropriate display devices, such as a laptop screen and a projector. The results indicated that most participants found the A5 size to be large enough to distinguish picture details

within the given time and answer the questions effectively. As a result, the A5 size was selected for further testing.

Among the five pictures, three were designated for testing and evaluation, referred to as "test pictures." The other two, known as "non-test pictures," were included to minimize participants' awareness of the test's purpose, and their scores were excluded from the calculations. The sequence of test and non-test pictures was arranged randomly.

Examples of a test picture and a non-test picture for the memory test using short-answer questions are presented in Table 8 and Table 9 (see the full details in Appendix E).

Table 8 An example of a test picture used for the memory test using short-answer questions.

Question 1: How many toys are there on the cabinet?

Answer: Two

Question 2: How many balls are there in this picture?

Answer: Four

Question 3: How many picture frames are there in this picture?

Answer: Two

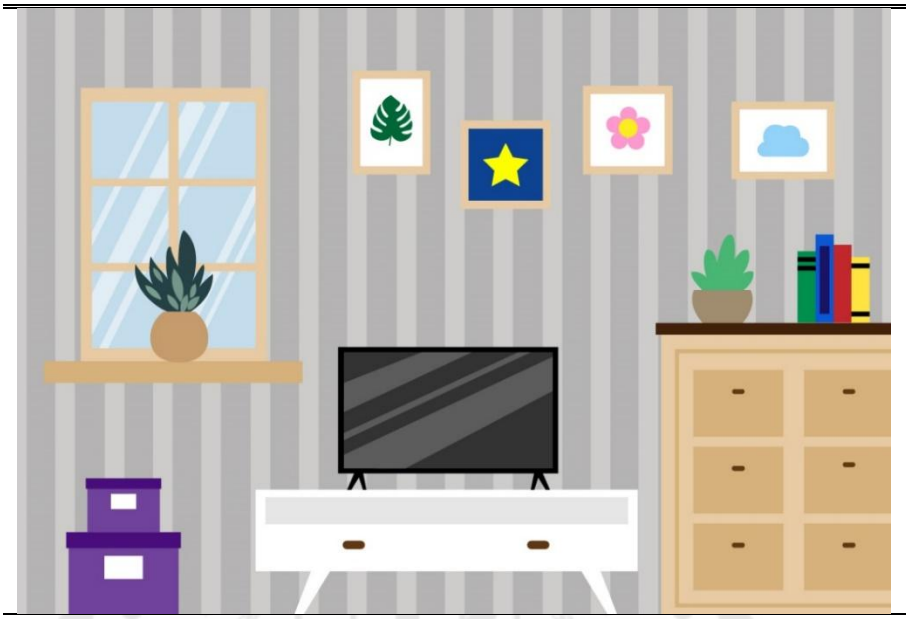
Question 4: Why is this child crying?

Answer: It depends on participants' vision.

Question 5: What is the color of the bed?

Answer: Yellow, blue, and white.

Table 9 An example of a test picture used for the memory test using short-answer questions.



Question 1: What pictures do picture frames hold?

Answer: A leaf, a star, a flower and a cloud.

Question 2: What kind of room should it be?

Answer: A living room.

Question 3: What is on the right hand of the tree pot?

Answer: Books

Question 4: What is the color of the television?

Answer: Black

Question 5: Where are boxes?

Answer: They are on the left hand of the television.

After designing all experiments for the attention test, the memory test using short-answer questions, and the memory test using photo hunt, three experts were asked to check all experiments. I then edited them following experts' suggestions.

3.4.3 Collecting the data

Following the design of the experiment, it was employed to assess the cognitive behavior of participants across five groups of participants. Prior to conducting the experiment, participants' qualifications were checked in accordance with the criteria outlined in section 3.3, with the screening process conducted by myself. Only participants who met the qualification requirements were permitted to participate. The experiment started with the attention test, followed by the memory test using the photo hunt, and ended with the memory test using short-answer questions.

3.4.3.1 Attention test

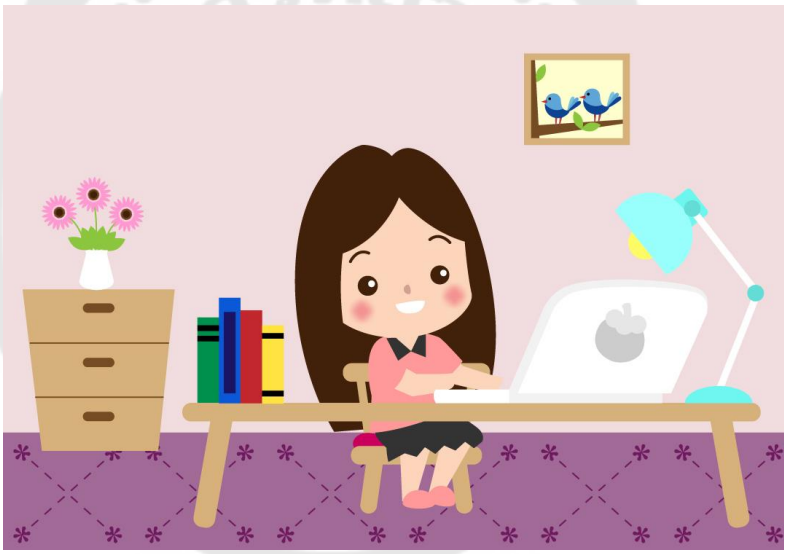
Participants were shown the first picture on the screen for a duration of five seconds, after which the picture disappeared. They were then required to answer a question related to the picture. The instructions specified that if participants did not know the answer, they were free to leave the response blank or write "uncertain." If participants tried to guess answers and they were correct, the experiment might fail because those answers could not reflect participants' cognition. Before and during the experiment, I repeatedly reminded participants that if they were unsure of the answer, they could leave the response blank or write "uncertain." During the experiment, it was observed that when participants were unsure of their answers, they either left the response blank, wrote a dash, or noted "uncertain." An example of the attention test process is presented below.

Stage 1: The instruction of the attention test.

Instruction:

1. There are 10 pictures in this test.
2. The picture will be shown for 5 seconds, then it will disappear.
3. A question involving this picture will be displayed, please answer the question.
4. If you do not know the answer, please leave blank or write “uncertain”.

Stage 2: The picture was shown for five seconds, then it disappeared.



Stage 3: A question related to picture has shown.

Please answer the question.

Question 1: how many birds are there in the picture frame?

Answer: ……

In the example of the attention test process described above, participants first viewed a picture, which then disappeared, followed by a question related to that picture. In the offline version of the experiment, participants recorded their answers on provided answer sheets, while in the online version, they submitted their responses using a keyboard. In this example, if participants had focused on the number of objects in the picture, they would have answered "two," which was the correct response.

After completing the first question, participants were shown the second picture and again asked to answer a question related to that picture. This process continued sequentially through the tenth picture. Before the actual test, participants were required to complete a practice run to ensure they fully understood the procedure. The scores from the practice run were not included in the calculations.

3.4.3.2 Memory test

There were two tasks in the memory test, which were the memory test using photo hunt and the memory test using short answer questions. The details are presented below.

3.4.3.2.1 Memory test using photo hunt

In the memory test using the photo hunt task, participants were first shown a prototype picture for five seconds, after which it disappeared. Following this, both alternate pictures were displayed, and participants were asked to identify which alternate picture differed from the prototype. The instructions clarified that participants could answer "uncertain" if they were unsure of the correct response. If participants tried to guess answers and they were correct, the experiment might fail because those answers could not reflect participants' cognition. Before and during the experiment, I repeatedly reminded participants that if they were unsure of the answer, they could leave the response blank or write "uncertain." It was observed that when participants were unsure of

their answers, they either left the response blank, wrote a dash, or noted "uncertain."

It was observed that when participants were unsure of their answers, they either left the response blank, wrote a dash, or noted "uncertain." Participants received one point for each correct answer regarding the number of objects in each test picture set. The maximum possible score for the test was five points. An example of the process for the memory test using photo hunt is shown below.

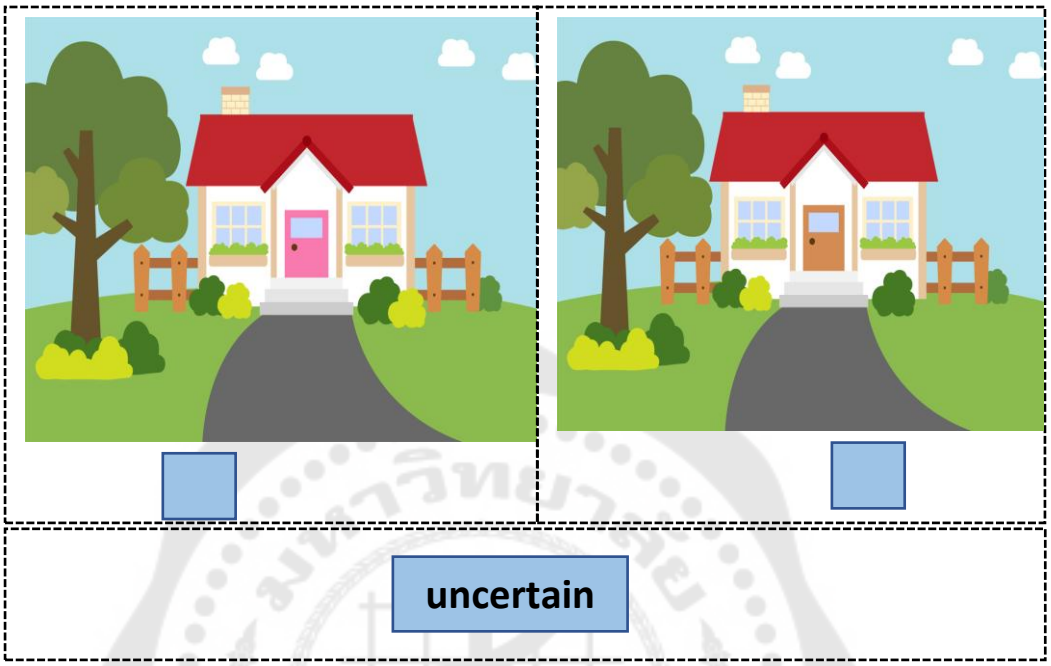
Stage 1: The instruction of the memory test using photo hunt

Instruction:

1. There are 10 sets in this test. Each set consists of 3 pictures.
2. A prototype picture will be shown for 5 seconds, then it will disappear.
3. Two alternate pictures will be shown. Please select one of two alternate pictures that differs from the prototype picture.
4. If you do not know the answers, please answer “uncertain”.

Stage 2: The first picture was shown for five seconds, then it disappeared.

Stage 3: Please select one of two alternate pictures that differ from the prototype picture. If you do not know the answers, please answer “uncertain”



In the memory test using the photo hunt task process, as described in the example above, participants were initially shown a prototype picture for five seconds, which then disappeared. Following this, two alternate pictures were presented, and participants were asked to select the alternate picture that differed from the prototype by answering the question, "Please select one alternate picture that is different from the prototype picture." In the offline version, participants recorded their answers on paper answer sheets, while in the online version, answers were provided using a keyboard. In this example, if participants focused on the number of objects, they would have selected the second alternate picture, which differed from the prototype picture based on the number of objects.

After completing the first picture set, participants were shown subsequent sets and asked to repeat the process of selecting the alternate picture that differed from the prototype. This procedure continued for a total of ten

picture sets. Before starting the actual test, participants completed a practice run to ensure they fully understood the task. Scores from the practice run were not included in the calculations.

3.4.3.2.2 Memory test using short-answer questions

In the memory test using short-answer questions, participants were shown the first picture for 10 seconds before it disappeared. They were then asked to answer five questions related to that picture. The instructions clearly stated that participants could leave the answers blank or write "uncertain" if they did not know the correct answers. If participants tried to guess answers and they were correct, the experiment might fail because those answers could not reflect participants' cognition. Before and during the experiment, I repeatedly reminded participants that if they were unsure of the answer, they could leave the response blank or write "uncertain."

During the experiment, it was observed that when participants were unsure of their answers, they either left the responses blank, wrote a dash, or indicated "uncertain." Participants received one point for each correct answer concerning the number of objects in each test picture. The maximum score a participant could achieve for the memory test using short-answer questions was nine points, with a maximum of three points for each picture.

An example of the process for the memory test using short-answer questions is shown below.

Stage 1: The instruction of the memory test using short-answer questions

Instruction:

1. There are 5 pictures in this test.
2. The picture will be shown for 10 seconds, then it will disappear.
3. Five questions involving this picture will be shown, please answer these questions.
4. If you do not know the answers, please leave blank or write “uncertain”

Stage 2: The picture was shown for ten seconds, then it disappeared.

Stage 3: Five questions involving this picture has shown.

Please answer the questions.

Question 1: How many toys are there on the cabinet?

Answer: ……

Question 2: How many balls are there in this picture?

Answer: ……

Question 3: How many picture frames are there in this picture?

Answer: ……

Question 4: Why is this child crying?

Answer: ……

Question 5: What is the color of the bed?

Answer: ……

In the process of the memory test using short-answer questions, as described in the example above, participants were first shown a picture, which then disappeared, followed by five questions related to that picture. In the offline version, participants wrote their answers on answer sheets, while in the online version, answers were provided using a keyboard. This example demonstrates that if participants memorized the number of objects, their responses would be "two toys" (for question 1), "four balls" (for question 2), and "two picture frames" (for question 3), which were the correct answers.

After completing the first picture, participants were shown the second picture and were required to answer related questions again. This process continued through the fifth picture. To ensure that participants understood the procedure, they completed one practice run before starting the actual test. The scores from the practice run were not included in the calculations.

Upon completing all tests, participants were randomly chosen for interviews to discuss the reasoning behind their answer selections during the experiment. Their responses were analyzed to confirm and gain further insight into their cognitive processes. This approach provided a more diverse understanding of how different participants approached the tasks and the factors influencing their responses. For instance, some participants reported concentrating on numerical details, which enabled them to answer number-related questions more accurately. This suggests that their cognitive processes focused attention and memory on specific elements of the stimuli, like numerical information, which influenced their ability to recall and respond accurately.

The entire testing process took approximately 15–20 minutes. However, participants were informed that they could terminate the experiment at any point, in accordance with the ethical agreement.

3.5 Analysis

In this study, a quantitative approach was employed, utilizing ANOVA (Analysis of Variance) to compare the differences in average scores both among and between the groups of participants. A p-value (probability value) of 0.05 was set as the significance threshold. If statistically significant differences were observed in the means of the five groups of participants in the attention and memory tests, this would indicate that the cognitive behaviors of each group differed significantly overall. The data of participants in the ANOVA are presented in Table 10.

Table 10 The data of participants in the ANOVA

ANOVA	Groups of participants (X)				
	English speakers (X11)	Thai speakers (X21)	Thai-English bilinguals who have English proficiency at the basic level (X31)	Thai-English bilinguals who have English proficiency at the intermediate level (X41)	Thai-English bilinguals who have English proficiency at the advanced level (X51)
The scores of number preference	$X11_1$	$X21_1$	$X31_1$	$X41_1$	$X51_1$
	$X11_2$	$X21_2$	$X31_2$	$X41_2$	$X51_2$
	$X11_3$	$X21_3$	$X31_3$	$X41_3$	$X51_3$
	$X11_4$	$X21_4$	$X31_4$	$X41_4$	$X51_4$
	.	.	.	.	.
	.	.	.	.	.
	.	.	.	.	.
	$X11_{30}$	$X21_{30}$	$X31_{30}$	$X41_{30}$	$X51_{30}$
Total	30	30	30	30	30

X11 was a group of English speakers (30 participants).

X21 was a group of Thai speakers (30 participants).

X31 was a group of basic Thai-English bilinguals (30 participants).

X41 was a group of intermediate Thai-English bilinguals (30 participants).

X51 was a group of advanced Thai-English bilinguals (30 participants).

To examine differences between groups, multiple comparisons using Scheffe's test were performed to determine which pairs of groups showed statistically significant differences. A p-value of 0.05 was set as the threshold for statistical significance. The following seven group comparisons were made:

1) Native English speakers versus native Thai speakers

2) Native English speakers versus basic Thai-English bilinguals

3) Native English speakers versus intermediate Thai-English bilinguals

4) Native English speakers versus advanced Thai-English bilinguals

5) Native Thai speakers versus basic Thai-English bilinguals

6) Native Thai speakers versus intermediate Thai-English bilinguals

7) Native Thai speakers versus advanced Thai-English bilinguals

Suppose statistically significant differences were observed between any pair of groups in the attention and memory tests, this would indicate that the cognitive behaviors of those groups differed significantly.

CHAPTER 4
RESULT

In this chapter, the results of the experiments are presented to examine the influence of grammatical number on the cognition of Thai-English bilinguals at basic, intermediate, and advanced proficiency levels compared to native Thai and English speakers, in alignment with the linguistic relativity hypothesis. According (Lucy, 1992a), cognition can be observed through participants' cognitive behavior. To explore this, three experiments were conducted: an attention test, a memory test using a photo hunt and a memory test using short-answer questions.

The participant distribution across groups and study versions revealed variations in language proficiency and mode of participation. The English speakers (N=30) were evenly split between online (18 participants) and offline (12 participants) participation in the English version of the study. In contrast, all 30 Thai speakers completed the Thai version exclusively online. Thai-English bilinguals with basic English proficiency (N=30) predominantly participated offline (22 participants), with only 8 completing the online version. Similarly, bilinguals with intermediate English proficiency (N=30) slightly preferred the online version (17 participants) over offline participation (13 participants). Conversely, bilinguals with advanced English proficiency (N=30) primarily participated offline (20 participants), with only 10 completing the online version.

This dissertation had two primary objectives. The first was to investigate how grammatical number marking influences performance in attention and memory tasks involving number across native Thai speakers, native English speakers, and Thai-English bilinguals. It was hypothesized that native monolingual English speakers, whose language has obligatory grammatical number marking, will perform better than native Thai speakers and Thai-English bilinguals in tasks requiring attention and memory of numerical distinctions.

The results mostly support this hypothesis. English speakers demonstrated superior attention and memory for the number of objects compared to Thai-English bilinguals at all proficiency levels (advanced, intermediate, and basic) and Thai speakers. This pattern was consistent across the attention test and the short-answer memory test. However, in the photo hunt memory test, no significant differences were observed between English speakers, advanced bilinguals, and intermediate bilinguals, slightly weakening the hypothesis. Additionally, no significant difference was found between bilinguals with basic proficiency and Thai speakers, although bilinguals with basic proficiency performed better overall across tasks.

The second objective was to analyze the relationship between bilingual proficiency in English and performance on attention and memory tasks involving number in Thai-English bilinguals. It was hypothesized that Thai-English bilinguals with higher English proficiency will perform closer to native English speakers in tasks requiring attention and memory of numerical distinctions. The results mostly support this hypothesis. Thai-English bilinguals with advanced English proficiency outperformed those with intermediate and basic proficiency on the attention test and short-answer memory test. Higher English proficiency correlated with cognitive patterns more closely resembling those of native English speakers. However, in the photo hunt memory test, while advanced bilinguals performed better than intermediate bilinguals, the difference was not statistically significant.

Overall, these findings support the influence of grammatical number on participants' cognitive processes, supporting the linguistic relativity hypothesis. They also demonstrate that second language acquisition impacts cognition in bilinguals at varying proficiency levels.

The detailed results from these tests are presented below.

4.1 The result of attention test

The response in the attention test from five groups of participants were analyzed using the average, standard deviation, ANOVA, and Scheffe's test. The participants' scores on the attention test are presented in Table 11 and Figure 3.

Table 11 Participants' scores of responses in the attention test

Group of participants	Sum of Scores (out of 150)	Average (out of 5)
30 Thai speakers	23.00	0.77
30 Thai-English bilinguals who have English proficiency at the basic level	40.00	1.33
30 Thai-English bilinguals who have English proficiency at the intermediate level	76.00	2.53
30 Thai-English bilinguals who have English proficiency at the advanced level	98.00	3.27
30 English speakers	120.00	4.00

Note: The participants' scores were calculated by summing individual participants' scores for their responses to the number of objects they paid attention to, across the 30 participants in each group.

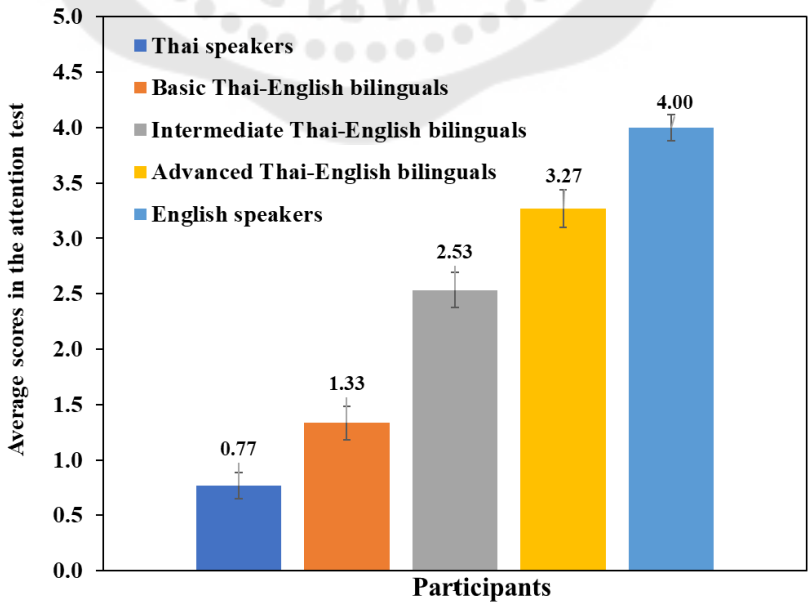


Figure 3 Participants' average scores of responses in the attention test

Table 11 and Figure 3 show that English speakers scored the highest in the attention test, followed by Thai-English bilinguals with advanced proficiency, intermediate proficiency, and basic proficiency, and finally Thai speakers.

Specifically, 30 English speakers answered questions about the number of objects correctly, achieving a total of 120 scores, with an average score of 4.00. In comparison, 30 Thai-English bilinguals who have English proficiency at the advanced level achieved a total of 98 scores, averaging 3.27. 30 Thai-English bilinguals who have English proficiency at the intermediate level achieved a total of 76 scores, averaging 2.53. 30 Thai-English bilinguals who have English proficiency at the basic level achieved a total of 40 scores, averaging 1.33. Lastly, 30 Thai speakers achieved a total of 23 scores, averaging 0.77.

To further analyze individual performance, participants within each group were arranged by their scores, from first to thirtieth, to observe individual results on the attention test. The maximum possible score that a participant could obtain on the test was five points. Table 12 presents individual scores of responses for each group, and the results are visualized in Figure 4.

Table 12 Participants' individual scores of responses in the attention test

No.	Participants' individual scores of responses in the attention test				
	Thai speakers	Thai-English bilinguals who have English proficiency at the basic level	Thai-English bilinguals who have English proficiency at the intermediate level	Thai-English bilinguals who have English proficiency at the advanced level	English speakers
1	0	0	1	2	3
2	0	0	1	2	3
3	0	0	1	2	3
4	0	0	2	2	3
5	0	1	2	2	3
6	0	1	2	2	3
7	0	1	2	3	4
8	0	1	2	3	4
9	0	1	2	3	4
10	0	1	2	3	4
11	0	1	2	3	4
12	1	1	2	3	4
13	1	1	2	3	4
14	1	1	2	3	4
15	1	1	2	3	4
16	1	1	2	3	4
17	1	1	3	3	4
18	1	1	3	3	4
19	1	1	3	3	4
20	1	2	3	4	4
21	1	2	3	4	4
22	1	2	3	4	4

Table 12 (Continued)

No.	Participants' individual scores of responses in the attention test				
	Thai speakers	Thai-English bilinguals who have English proficiency at the basic level	Thai-English bilinguals who have English proficiency at the intermediate level	Thai-English bilinguals who have English proficiency at the advanced level	English speakers
23	1	2	3	4	4
24	1	2	3	4	4
25	1	2	3	4	5
26	1	2	4	4	5
27	2	2	4	4	5
28	2	3	4	5	5
29	2	3	4	5	5
30	2	3	4	5	5
Sum	23.00	40.00	76.00	98.00	120.00
Average	0.77	1.33	2.53	3.27	4.00
S.D.	0.68	0.84	0.90	0.91	0.64

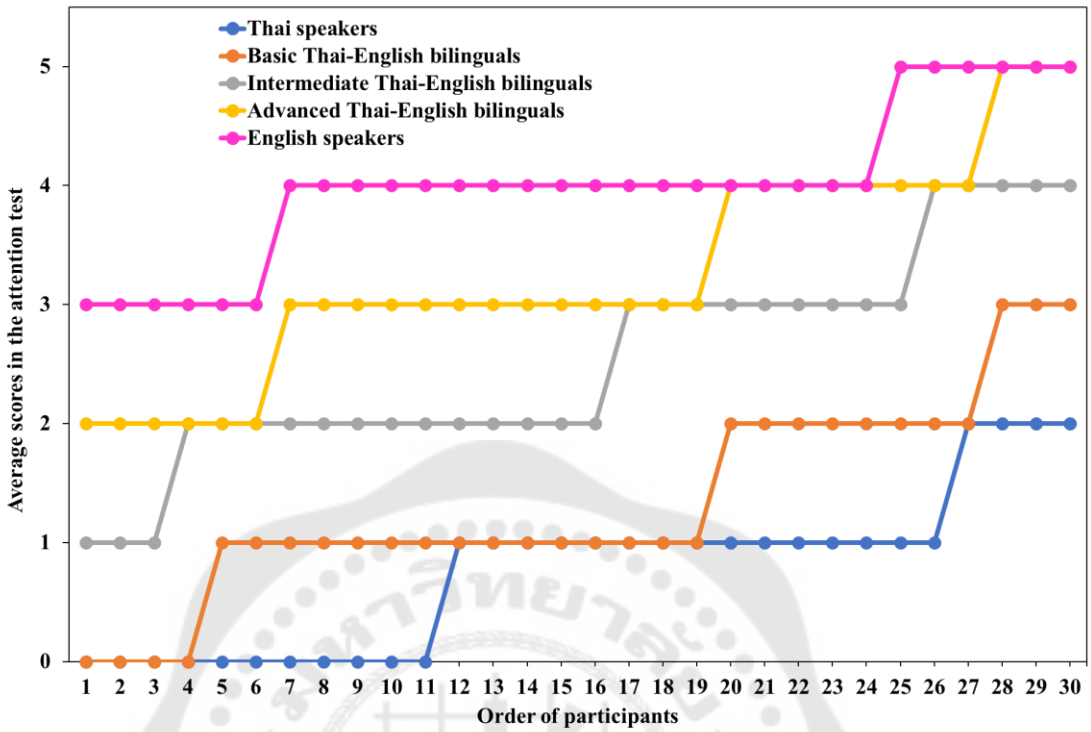


Figure 4 Participants' individual average scores of responses in the attention test

In Table 12, the individual scores on the attention test revealed a clear pattern across the participant groups. Thai speakers exhibited scores ranging from 0 to 2, with a mean score of 0.77. In contrast, English speakers displayed a range of scores between 3 and 5, with an average of 4.00. Among the Thai-English bilinguals, those with basic English proficiency scored between 0 and 3, while individuals with intermediate proficiency scored between 1 and 4. Advanced bilinguals exhibited scores between 2 and 5. These data suggest a positive correlation between English proficiency and attention test performance. As participants' proficiency in English increased, their attention test scores increased accordingly. Advanced Thai-English bilinguals outperformed intermediate and basic bilinguals, as well as Thai monolinguals, and nearly matched the performance levels of native English speakers.

Figure 4 illustrates the attention test scores for five distinct groups of participants, ordered from the first to the thirtieth participant. The X-axis

represents the participants' order (1 to 30), while the Y-axis shows their attention test scores (ranging from 0 to 5).

The graph reveals that English speakers consistently outperformed other groups, demonstrating a superior level of attention. A particularly notable comparison is between English speakers and Thai speakers, where a significant performance gap is observed. English speakers scored much higher, indicating greater attention to the task compared to the Thai-speaking group.

Within the bilingual group, there are notable distinctions based on English proficiency levels. Bilinguals with advanced English proficiency consistently scored higher than those with intermediate or basic proficiency, with an increasing trend in scores from the first to the thirtieth participant. However, within the bilingual group, there were specific instances where the performance of the intermediate and advanced proficiency groups closely aligned. For example, the scores of participants 4–6, 17–19, and 26–27 in both the intermediate and advanced bilingual groups were very similar. This suggests that while the advanced proficiency group generally performed better, there were instances where the intermediate group's performance nearly matched the advanced group.

When comparing monolinguals and bilinguals, it is evident that some bilingual participants with advanced English proficiency exhibited scores nearly identical to native English speakers. For instance, the scores of bilinguals with advanced English proficiency closely resembled those of English speakers, particularly for the scores of participants 20–24 and 28–30. This suggests that, at certain points, these bilinguals performed similarly to native English speakers in terms of attention.

Furthermore, the performance of Thai-English bilinguals with basic English proficiency mirrored that of native Thai speakers, particularly for the scores of participants 1–4, 12–19, and 27. This suggests that bilinguals with basic English proficiency did not show significantly better attention scores than Thai

speakers, indicating their ability to focus on numerical details was similar to that of native Thai speakers.

To further analyze the data, a 5-group ANOVA and Scheffé test were performed. The ANOVA revealed a significant main effect of group ($F = 83.08$, $p < .05$), indicating that the participant groups differed significantly in their attention to the number of objects overall. The results of the Scheffé test, which identify the pairs of groups that showed significant differences, are presented in Table 13.

Table 13 Accuracy rate in paying attention to the number of objects

Groups of participants	Thai-English bilinguals who have English proficiency at the basic level	Thai-English bilinguals who have English proficiency at the intermediate level	Thai-English bilinguals who have English proficiency at the advanced level	English speakers
Thai speakers	.119	*.00	*.00	*.00
Thai-English bilinguals who have English proficiency at the basic level		*.00	*.00	*.00
Thai-English bilinguals who have English proficiency at the intermediate level			*.017	*.00
Thai-English bilinguals who have English proficiency at the advanced level				*.017

*Scheffe's test, p = .05

Table 13 shows the significant differences in attention to the number of objects among the groups. English speakers paid significantly more attention to object quantity compared to all other groups ($p < .05$). Among bilinguals, those with advanced proficiency paid significantly more attention to the number of objects than those with intermediate or basic proficiency ($p < .05$). There was no significant difference between Thai speakers and bilinguals with basic proficiency ($P > 0.05$).

These findings support the hypothesis that English speakers, as expected, are more aware of the number of objects compared to Thai speakers and Thai-English bilinguals. Among bilinguals, higher proficiency in English led to greater attention to object numbers, aligning their cognitive behaviors more closely with native English speakers. However, bilinguals with basic proficiency showed attention patterns similar to Thai speakers, suggesting that significant cognitive changes may occur only at higher levels of bilingual proficiency.

4.2 The result of memory test

According to the memory test, there were two tasks in this test, which were the memory test using photo hunt and the memory test using short-answer questions. The results of these tests are presented below.

4.2.1 The result of memory test using photo hunt

The response in the memory test using photo hunt from five groups of participants were analyzed using the average, standard deviation, ANOVA, and Scheffe's test. The participants' scores in the memory test using photo hunt are presented in Table 14 and Figure 5.

Table 14 Participants' scores of responses in the memory test using photo hunt

Group of participants	Total score (out of 150)	Average (out of 5 scores)
30 Thai speakers	30.00	1.00
30 Thai-English bilinguals who have English proficiency at the basic level	41.00	1.37
30 Thai-English bilinguals who have English proficiency at the intermediate level	90.00	3.00
30 Thai-English bilinguals who have English proficiency at the advanced level	93.00	3.10
30 English speakers	106.00	3.53

Note: The participants' scores were calculated by summing individual participants' scores for their responses to the number of objects they recalled from the memory test using photo hunt, across the 30 participants in each group.

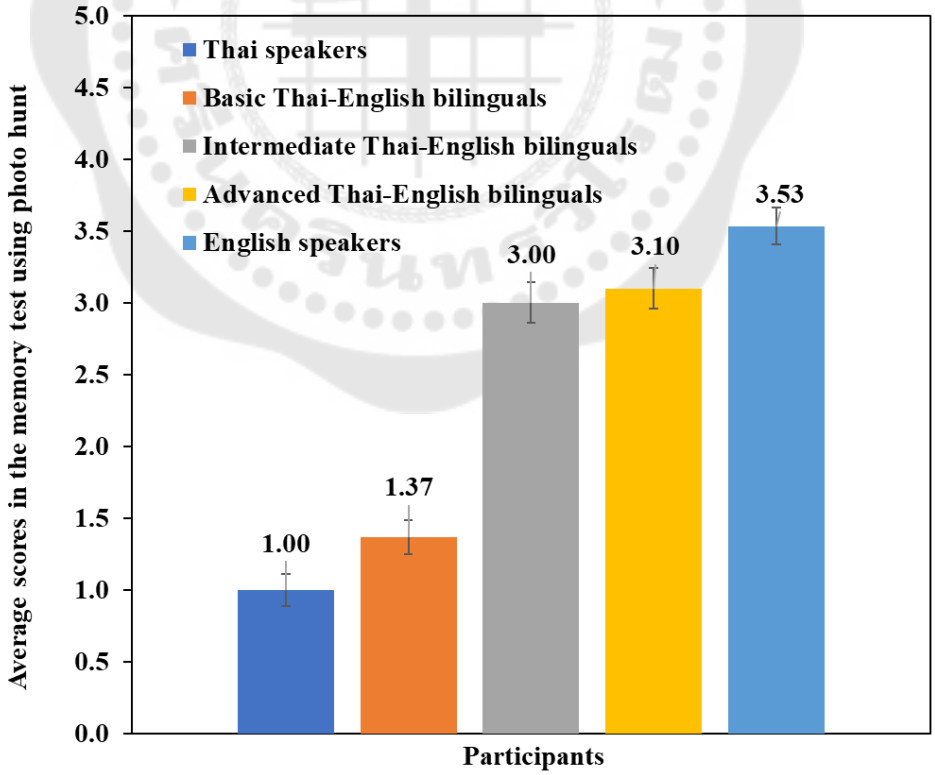


Figure 5 Participants' scores of responses in the memory test using photo hunt

Table 14 and Figure 5 indicate that English speakers outperformed other participant groups in memorizing the number of objects in the photo hunt task. Following them were Thai-English bilinguals with advanced English proficiency, then intermediate-level bilinguals, basic-level bilinguals, and finally Thai speakers.

Specifically, 30 English speakers correctly answered questions about the number of objects, resulting in a total of 106 scores with an average score of 3.53. 30 Thai-English bilinguals who have English proficiency at the advanced level achieved a total of 93 scores, averaging 3.10. 30 Thai-English bilinguals who have English proficiency at the intermediate level achieved a total of 90 scores, averaging 3.00. 30 Thai-English bilinguals who have English proficiency at the basic level achieved a total of 41 scores, averaging 1.37. Lastly, 30 Thai speakers achieved a total of 30 scores, averaging 1.00.

To further analyze individual performance, participants within each group were arranged by their scores, from first to thirtieth, to observe individual results on the memory test using photo hunt. The maximum possible score that a participant could obtain on the test was five points. Table 15 presents individual scores of responses for each group, and the results are visualized in Figure 6.

Table 15 Participants' individual scores of responses in the memory test using photo hunt

No.	Participants' individual scores of responses in the memory test using photo hunt				
	Thai speakers	Thai-English bilinguals who have English proficiency at the basic level	Thai-English bilinguals who have English proficiency at the intermediate level	Thai-English bilinguals who have English proficiency at the advanced level	English speakers
1	0	0	1	2	3
2	0	0	1	2	3
3	0	1	2	2	3
4	0	1	2	2	3
5	0	1	2	2	3
6	0	1	3	2	3
7	1	1	3	2	3
8	1	1	3	3	3
9	1	1	3	3	3
10	1	1	3	3	3
11	1	1	3	3	3
12	1	1	3	3	3
13	1	1	3	3	3
14	1	1	3	3	3
15	1	1	3	3	3
16	1	1	3	3	3
17	1	1	3	3	3
18	1	1	3	3	3
19	1	2	3	3	4
20	1	2	3	3	4
21	1	2	3	4	4

Table 15 (Continued)

No.	Participants' individual scores of responses in the memory test using photo hunt				
	Thai speakers	Thai-English bilinguals who have English proficiency at the basic level	Thai-English bilinguals who have English proficiency at the intermediate level	Thai-English bilinguals who have English proficiency at the advanced level	English speakers
22	1	2	3	4	4
23	1	2	3	4	4
24	1	2	4	4	4
25	2	2	4	4	4
26	2	2	4	4	4
27	2	2	4	4	5
28	2	2	4	4	5
29	2	2	4	4	5
30	2	3	4	4	5
Sum	30	41	90	93	106
Average	1	1.37	3.00	3.10	3.53
S.D.	0.64	0.67	0.79	0.76	0.73

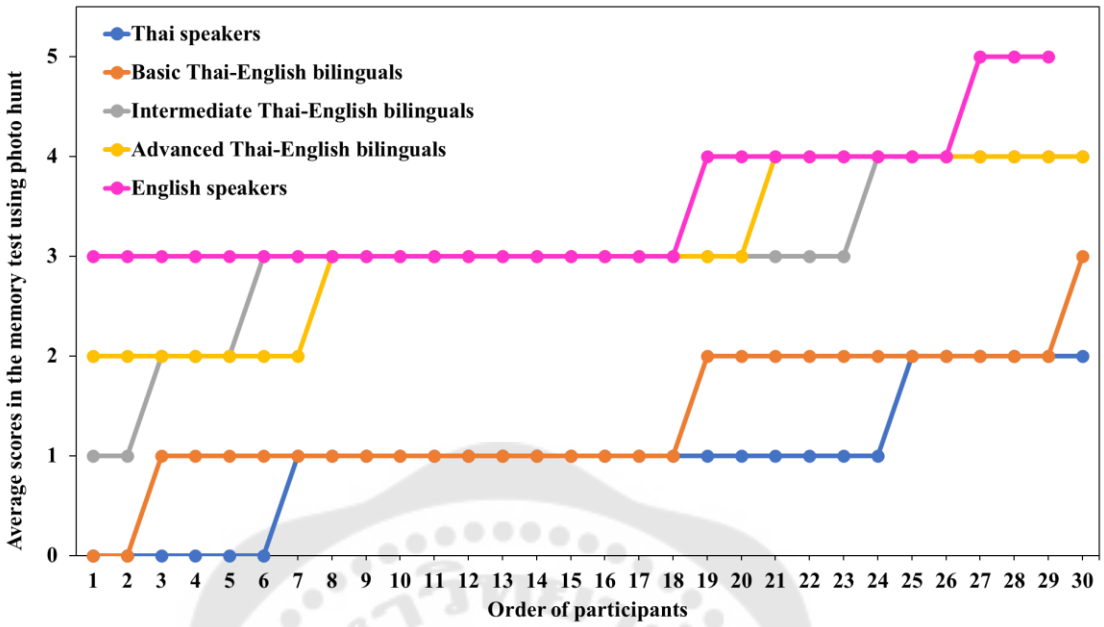


Figure 6 Participants' individual scores of responses in the memory test using photo hunt

Table 15 presents the individual scores of participants in the memory test using the photo hunt. The results indicate that native Thai speakers scored ranging from 0 to 2, with a total of 30 correct responses, an average score of 1.00. Thai-English bilinguals with basic proficiency scored from 0 to 3, with a total of 41 correct responses, an average of 1.37. Intermediate proficiency bilinguals scored between 1 and 4, accumulating 90 correct responses, with an average of 3.00. Advanced proficiency bilinguals scored between 2 and 4, with 93 correct responses, an average of 3.10. Native English speakers had scores ranging from 3 to 5, achieving a total of 106 correct responses, an average of 3.53. These results suggest that higher English proficiency is associated with better performance in the memory test using photo hunt.

Figure 6 illustrates the memory test scores across five participant groups, arranged from the first to the thirtieth participant. The X-axis represents the order of participants (1 to 30), while the Y-axis shows their memory test scores (ranging from 0 to 5) based on the photo hunt task.

English speakers consistently scored higher than all other groups. Their performance clearly surpassed that of Thai speakers, who demonstrated lower

scores on average. This across-group comparison highlights the significant performance gap between these two groups, with English speakers recalling more objects in the task than Thai speakers.

When comparing English speakers to Thai speakers, there is a noticeable performance gap, with English speakers consistently outperforming Thai speakers in recalling the number of objects. Thai speakers generally had lower scores, as indicated by their line graph.

Among bilinguals, a clear trend was observed: scores increased with higher English proficiency. Advanced bilinguals performed the best, followed by those with intermediate proficiency, and then those with basic proficiency.

Comparing monolinguals and bilinguals, Thai-English bilinguals with basic proficiency performed similarly to native Thai speakers. This was particularly evident in the line graphs for the scores of participants 7–19 and 25–29, where their performance closely mirrored that of Thai speakers. However, for advanced proficiency bilinguals, their scores approached or even matched those of native English speakers, especially in the scores of participants 8–18, where the line graphs for English speakers, advanced-level bilinguals, and intermediate-level bilinguals were nearly identical. This indicates that bilinguals with higher English proficiency can perform on par with native English speakers in the memory test using photo hunt.

To further analyze the data, a 5-group ANOVA and Scheffé test were conducted. The ANOVA revealed a significant main effect of group ($F = 74.72$, $p < .05$), indicating that the participant groups differed significantly in their ability to memorize the number of objects during the memory test using photo hunt. The results of the Scheffé test, which highlight significant differences between pairs of groups, are presented in Table 16.

Table 16 Accuracy rate in memorizing using photo hunt

Groups of participants	Thai-English bilinguals who have English proficiency at the basic level	Thai-English bilinguals who have English proficiency at the intermediate level	Thai-English bilinguals who have English proficiency at the advanced level	English speakers
Thai speakers	.424	*.00	*.00	*.00
Thai-English bilinguals who have English proficiency at the basic level		*.00	*.00	*.00
Thai-English bilinguals who have English proficiency at the intermediate level			.990	.089
Thai-English bilinguals who have English proficiency at the advanced level				.251

*Scheffe's test, p = .05

Table 16 presents the accuracy rates for memorizing the number of objects in a photo hunt task different participant groups. Among monolinguals, English speakers significantly outperformed Thai speakers in memorizing the number of objects (P < .05). Within the bilingual groups, participants with advanced English proficiency performed significantly better than those with basic proficiency (P < .05), though no significant difference was observed between advanced and intermediate-level bilinguals (P > .05).

When comparing monolinguals to bilinguals, English monolinguals scored significantly higher than Thai-English bilinguals with basic proficiency

($P < .05$). However, their scores did not significantly differ from those of bilinguals with advanced or intermediate proficiency ($P > .05$). Additionally, no significant difference was found between the scores of Thai speakers and basic-level bilinguals ($P > .05$).

These results partially support the hypothesis. The superior performance of English speakers compared to Thai speakers suggests a possible connection between grammatical number and cognitive behavior related to number. Among bilinguals, higher English proficiency was associated with better memory performance in recalling the number, particularly in the comparison between advanced and basic proficiency levels. However, the similar scores between bilinguals with basic proficiency and Thai speakers suggest that cognitive changes related to second-language acquisition may become more aware as proficiency increases. Notably, the comparable performance of English speakers, advanced bilinguals, and intermediate bilinguals suggests that test instructions or other factors may have influenced the outcomes, as discussed in section 4.4.

4.2.2 The result of memory test using short-answer questions

The response in the memory test using short-answer questions from five groups of participants were analyzed using the average, standard deviation, ANOVA, and Scheffe's test. The participants' scores in the memory test using short-answer questions are presented in Table 17 and Figure 7.

Table 17 Participants' scores of responses in the memory test using short-answer questions

Group of participants	Total score (out of 270)	Average (out of 9 scores)
30 Thai speakers	54	1.80
30 Thai-English bilinguals who have English proficiency at the basic level	81	2.70
30 Thai-English bilinguals who have English proficiency at the intermediate level	158	5.27
30 Thai-English bilinguals who have English proficiency at the advanced level	194	6.47
30 English speakers	229	7.63

Note: The participants' scores were calculated by summing individual participants' scores for their responses to the number of objects they recalled from the memory test using short-answer questions, across the 30 participants in each group.

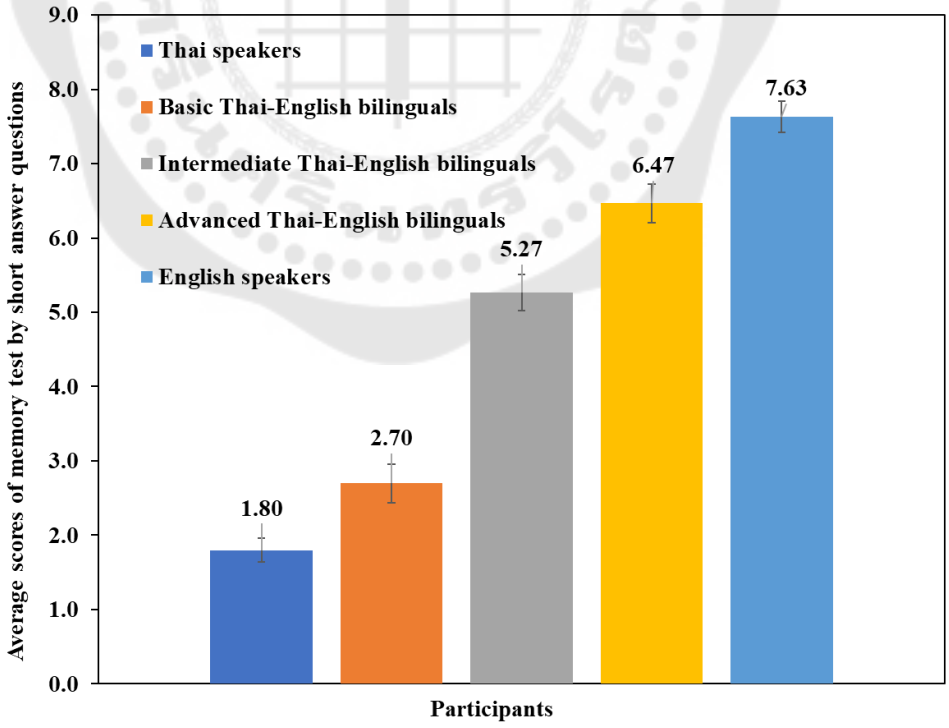


Figure 7 Participants' scores of responses in the memory test using short-answer questions

Table 17 and Figure 7 demonstrate that English speakers outperformed other groups in memorizing the number of objects using short-answer questions. They were followed by Thai-English bilinguals with advanced English proficiency, intermediate English proficiency, basic English proficiency, and finally, Thai speakers.

Specifically, 30 English speakers answered questions about the number of objects correctly, achieving a total of 229 scores, with an average score of 7.63. In comparison, 30 Thai-English bilinguals who have English proficiency at the advanced level achieved a total of 194 scores, averaging 6.47. 30 Thai-English bilinguals who have English proficiency at the intermediate level achieved a total of 158 scores, averaging 5.27. 30 Thai-English bilinguals who have English proficiency at the basic level achieved a total of 81 scores, averaging 2.70. Lastly, 30 Thai speakers achieved a total of 54 scores, averaging 1.80.

To further analyze individual performance, participants within each group were arranged by their scores, from first to thirtieth, to observe individual results on the memory test using short-answer questions. The maximum possible score that a participant could obtain on the test was nine scores. They are presented in Table 18 and Figure 8

Table 18 Participants' individual scores of responses in the memory test using short-answer questions

No.	Participants' individual scores of responses in the memory test using short-answer questions				
	Thai speakers	Thai-English bilinguals who have English proficiency at the basic level	Thai-English bilinguals who have English proficiency at the intermediate level	Thai-English bilinguals who have English proficiency at the advanced level	English speakers
1	0	1	3	4	6
2	0	1	3	4	6
3	1	1	4	5	6
4	1	1	4	5	6
5	1	1	4	5	6
6	1	1	4	5	6
7	1	1	4	5	7
8	1	1	4	5	7
9	1	1	4	5	7
10	1	2	4	6	7
11	2	2	4	6	7
12	2	2	5	6	7
13	2	2	5	6	7
14	2	2	5	6	7
15	2	3	5	6	7
16	2	3	5	7	8
17	2	3	5	7	8
18	2	3	6	7	8
19	2	3	6	7	8
20	2	4	6	7	8

Table 18 (Continued)

No.	Participants' individual scores of responses in the memory test using short-answer questions				
	Thai speakers	Thai-English bilinguals who have English proficiency at the basic level	Thai-English bilinguals who have English proficiency at the intermediate level	Thai-English bilinguals who have English proficiency at the advanced level	English speakers
21	2	4	6	7	9
22	2	4	6	7	9
23	2	4	7	7	9
24	2	4	7	8	9
25	2	4	7	8	9
26	3	4	7	8	9
27	3	4	7	8	9
28	3	5	7	9	9
29	3	5	7	9	9
30	4	5	7	9	9
Sum	54	81	158	194	229
Average	1.8	2.70	5.27	6.47	7.63
S.D.	0.89	1.42	1.34	1.43	1.16

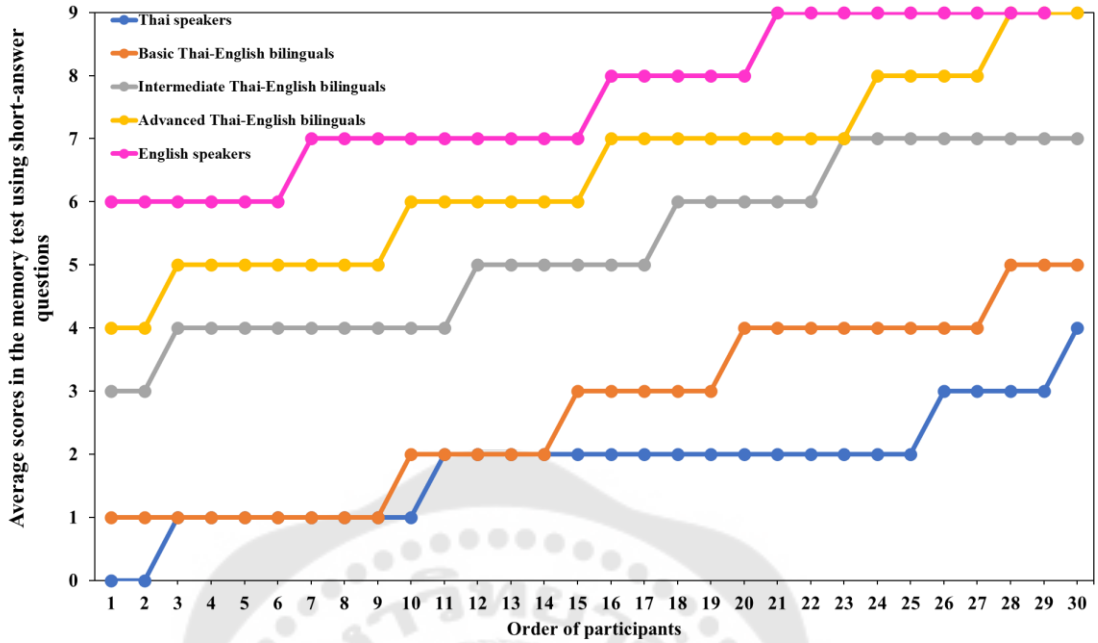


Figure 8 Participants' individual scores of responses in the memory test using short-answer questions

Table 18, the results in the memory test using short-answer questions reveal clear differences across participant groups. Native Thai speakers scored ranging from 0 to 4, with a total of 54 correct responses, an average score of 1.80. Thai-English bilinguals with basic proficiency scored from 1 to 5, with a total of 81 correct responses, an average of 2.70. Intermediate proficiency bilinguals scored between 3 and 7, accumulating 158 correct responses, with an average of 5.27. Advanced proficiency bilinguals scored between 4 and 9, with 194 correct responses, an average of 6.47. Native English speakers had scores ranging from 6 to 9, achieving a total of 229 correct responses, an average of 7.63. The results suggest that higher English proficiency is associated with better memory test performance, with English speakers and advanced bilinguals performing the best, while Thai speakers and basic bilinguals performed the worst.

Figure 8 illustrates the scores of a memory test using short-answer questions for five groups of participants, arranged from the first to the thirtieth participant. The X-axis represents the order of participants (1 to 30), while the Y-axis indicates their scores on the memory test (ranging from 0 to 9).

Native English speakers consistently scored higher than all other groups, with the greatest difference observed between English speakers and Thai speakers. This significant performance gap underscores the superior memory test performance of English speakers compared to native Thai speakers.

Among bilinguals, scores increased progressively from the first to the thirtieth participant. Advanced proficiency bilinguals achieved the highest scores, followed by those with intermediate proficiency, and then those with basic proficiency. This within-group comparison shows a clear positive correlation between English proficiency and performance on the short-answer memory test. Interestingly, intermediate and advanced proficiency bilinguals showed closely aligned scores at one instance, particularly the scores of participants 23, where their performance was nearly identical.

Comparing monolinguals to bilinguals, basic proficiency bilinguals performed similarly to native Thai speakers, particularly in the scores of participants 3-9 and 11-14. This suggests that basic-level bilinguals performed at a comparable level to Thai speakers on the memory test, contrary to the initial hypothesis. In contrast, advanced proficiency bilinguals and native English speakers showed similar scores only once, in the scores of participants 29. This indicates that, while advanced bilinguals performed better than basic bilinguals, their performance was still lower than native English speakers in most instances.

Overall, the results of the memory test using short-answer questions align with the findings from the attention test. The slightly higher scores of basic-level bilinguals compared to Thai speakers suggest cognitive shifts related to second language acquisition. However, significant cognitive changes are expected as bilinguals attain higher levels of proficiency, particularly in the advanced proficiency group.

To further analyze the data, a 5-group ANOVA and Scheffé test were conducted. The ANOVA indicated a significant main effect of group ($F = 114.81$, $p < .05$), demonstrating that participants in different groups exhibited varying

abilities to remember the number of objects. The results of the Scheffé test, which identify significant differences between specific groups, are presented in Table 19.

Table 19 Accuracy rate in memorizing using short-answer questions

Groups of participants	Thai-English bilinguals who have English proficiency at the basic level	Thai-English bilinguals who have English proficiency at the intermediate level	Thai-English bilinguals who have English proficiency at the advanced level	English speakers
Thai speakers	.113	*.00	*.00	*.00
Thai-English bilinguals who have English proficiency at the basic level		*.00	*.00	*.00
Thai-English bilinguals who have English proficiency at the intermediate level			*.011	*.00
Thai-English bilinguals who have English proficiency at the advanced level				*.015

*Scheffe's test, p = .05

Table 19 shows the significant differences in memorizing the number of objects using short-answer questions. English speakers demonstrated significantly better memory accuracy compared to all other groups ($P < 0.05$). Among bilinguals, those with advanced proficiency performed significantly

better than those with intermediate or basic proficiency ($p < 0.05$). There was no significant difference between Thai speakers and bilinguals with basic proficiency ($P > 0.05$).

These findings support the hypothesis that English speakers outperform both Thai-English bilinguals and Thai speakers in memory tests using short-answer questions. Additionally, Thai-English bilinguals with advanced proficiency displayed superior memory performance in recalling the number compared to those with intermediate or basic proficiency, suggesting that higher second-language proficiency is linked to cognitive performance about recalling the number. Interestingly, bilinguals with basic proficiency exhibited memory patterns similar to Thai speakers, suggesting that cognitive changes related to bilingualism may become more noticeable at higher proficiency levels.

4.3 The relationship between grammatical number and the cognition of monolinguals and bilinguals in the attention test

The results of the attention test provide preliminary insights into how grammatical number may influence cognitive processing. They highlight patterns and trends in how bilingual and monolingual participants focus on numerical details.

4.3.1 Grammatical number and cognitive attention in monolinguals

Among the monolingual groups, an interesting trend emerged in the way English and Thai speakers were aware of the number of objects. English speakers appeared more focused on numerical details, paying significantly more attention to the number of objects compared to Thai speakers. This observation aligns with the grammatical number in both languages: English explicitly marks grammatical number, while Thai does so optionally. As a result, English speakers focused more on counting objects, making numerical information central to their cognitive processing during the experiment. On the other hand, Thai speakers demonstrated a tendency to focus more on other visual or contextual features of

the objects, such as their color or situational context. They were more likely to hesitate or revise their answers about the number of objects.

The result suggests that the explicit marking of number in a language may be associated with a heightened cognitive focus on numerical details. This aligns with the linguistic relativity hypothesis, which posits that the grammar of a language influences the way its speakers think and perceive the world. However, these findings should be considered as part of an ongoing exploration, as further research is needed to explore whether these trends hold consistently across different contexts and methodologies.

4.3.2 Grammatical Number and Attention in Bilinguals

In the case of bilinguals, a clear trend was observed linking English proficiency with attention to grammatical number. Thai-English bilinguals with advanced English proficiency appeared to show more pronounced attention to the number of objects compared to those with intermediate or basic proficiency in English. This suggests that higher proficiency in English may be associated with cognitive patterns more closely resembling those of English monolinguals. Bilinguals with lower proficiency, in contrast, displayed a more mixed pattern of attention, which was more similar to that of Thai monolinguals.

This pattern of results indicates that the acquisition of a second language may influence cognitive processes related to grammatical number, with proficiency level playing a potential role in shaping attention to numerical details. However, the findings in bilinguals are preliminary and suggest that the relationship between second language proficiency and cognitive attention to grammatical number is not straightforward. At lower proficiency levels, the cognitive effects of the second language may be less pronounced, potentially due to the influence of the dominant language or other contextual factors. As bilinguals' proficiency in the second language increases, their attention to

grammatical number appears to shift in a direction more closely aligned with the cognitive patterns observed in native speakers of that language.

4.3.3 Comparison between monolingual and bilingual groups

When comparing the attention patterns of monolinguals and bilinguals, a trend emerged suggesting that English monolinguals were more focused on numerical details than either Thai monolinguals or Thai-English bilinguals at all proficiency levels. Interestingly, bilinguals with basic English proficiency paid more attention to object numbers than Thai monolinguals, although this difference was not statistically significant. This finding suggests that while second language acquisition does seem to influence cognitive processing, the effects are likely to be more pronounced at higher levels of proficiency. For bilinguals with basic proficiency, the impact of English on cognitive attention to grammatical number might not be strong enough to create significant differences in cognitive behavior compared to monolinguals.

These preliminary findings underscore the potential relationship between grammatical number and cognitive processing, particularly in the context of bilingualism. They highlight trends and patterns that warrant further investigation. Future research could expand on these findings by including larger sample sizes, testing a broader range of languages, and employing more refined measures of cognitive processing.

The results suggest that as bilinguals' proficiency in a second language increases, their cognitive patterns related to grammatical number may shift in the direction of the grammatical structures in that language. However, the influence of proficiency in the second language appears to be more pronounced at higher levels, with more mixed patterns observed among bilinguals with lower proficiency. These trends emphasize the potential role of language proficiency in shaping cognitive attention, particularly in areas related to language-specific features such as grammatical number.

4.4 The relationship between grammatical number and the cognition of monolinguals and bilinguals in the memory test

This study involved two memory tasks: the photo hunt task, which used hints (cued recall), and the short-answer memory task, which required participants to recall information freely, without hints (free recall). The results from these two tasks revealed important patterns that help us understand how the different grammatical number system in each language might influence memory performance.

4.4.1 Results from the memory tests

The results from both memory tasks showed some notable trends. Among the monolingual groups, the patterns observed in the memory tasks were similar to those from the attention test. English speakers generally demonstrated better recall of the number of objects compared to Thai speakers in both tasks. This aligns with the grammatical number in English, which explicitly marks number, leading English speakers to focus more on object quantity. In contrast, Thai speakers tended to remember other features of the objects, such as color, size, or the situational context of the pictures, rather than focusing on the number of objects. These findings provide additional support for the linguistic relativity hypothesis, which suggests that language structures—such as how a language marks number—might influence cognitive processes like memory.

4.4.2 Bilinguals' memory performance

When looking at bilinguals, the results from the short-answer memory task were consistent with those from the attention test. Specifically, Thai-English bilinguals with advanced English proficiency exhibited better recall of the number of objects compared to bilinguals with intermediate or basic proficiency. This suggests a potential relationship between second language proficiency and memory performance related to grammatical number, with bilinguals who are more proficient in English showing cognitive patterns more similar to those of

English monolinguals. Interestingly, bilinguals with intermediate proficiency also performed better than those with basic proficiency, indicating that higher proficiency levels might be associated with more effective memory recall in tasks related to number.

4.4.3 Comparison between monolinguals and bilinguals

When comparing the performance of monolinguals and bilinguals, the results remained consistent with those from the attention test. English speakers again outperformed all other groups, showing notable differences in memory recall compared to bilinguals at all proficiency levels and Thai monolinguals. While bilinguals with basic proficiency showed better recall of object numbers than Thai monolinguals, the difference was not statistically significant. This suggests that while second language acquisition may influence cognitive processes, the most noticeable effects seem to emerge at higher levels of second language proficiency.

4.4.4 Differences in the photo hunt test

English speakers performed significantly better than Thai speakers and bilinguals with basic proficiency; however, no significant differences were observed between advanced and intermediate proficiency bilinguals and English speakers. This outcome suggests that the photo hunt task, which relied on visual cues and options, might not effectively capture cognitive differences influenced by grammatical number. The task design may have prompted guessing when participants were unsure, which could have hidden their real cognitive behaviors. This finding contrasts with the attention test and the short-answer memory task, where participants were required to recall information independently, without visual aids or hints. The implications of these results, along with their alignment with other tasks, will be explored further in Chapter 5.

The findings overall revealed interesting trends: English speakers tended to focus more on numerical details, which aligns with the grammatical number in English that explicitly marks number. In contrast, Thai speakers were more likely to attend to other attributes, such as color or context, which reflects the more flexible use of number in Thai. These observations suggest that grammatical number may influence cognitive attention, supporting the idea of linguistic relativity.

For bilinguals, the study found that those with advanced English proficiency demonstrated cognitive patterns similar to those of English monolinguals, particularly in their attention to number. However, bilinguals with lower English proficiency did not show clear differences from Thai monolinguals, suggesting that proficiency in a second language might gradually influence cognitive processing, but the effect is more pronounced at higher proficiency levels.

These results highlight the relationship between grammatical number and cognition but also underscore the complexity of this interaction. The differences observed in the memory test using photo hunt, for example, point to the potential influence of task-specific factors, such as the presence of visual cues and the possibility of guessing. These elements could have affected participants' performance, especially when they were uncertain of the correct answer. Additionally, participants' anxiety levels, which increased as the experiment progressed, might have further influenced task performance, particularly in the photo hunt task.

As a result, this study provides initial insights into the cognitive effects of grammatical number in bilinguals and sets the stage for future investigations. In the future, it will be important to refine experimental designs to control for confounding factors like anxiety and to develop tasks that more precisely isolate the cognitive impact of language structure. By doing so, future research can

offer clearer insights into how bilingualism and language structure influence cognitive processes such as attention and memory.

CHAPTER 5
SUMMARY DISCUSSION IMPLICATION LIMITATION AND FUTURE DIRECTION

5.1 Summary

This study aimed to explore the influence of grammatical number on speakers' cognition based on the linguistic relativity hypothesis and investigate whether knowledge of a second language with differing grammar in the first and second languages influences bilinguals' cognitive processes. The study involved five groups of participants: monolingual Thai speakers, monolingual English speakers, Thai-English bilinguals who have English proficiency at the basic level, Thai-English bilinguals who have English proficiency at the intermediate level and Thai-English bilinguals who have English proficiency at the advanced level. Cognitive behaviors were assessed through attention and memory tests, including photo hunt and short-answer questions.

The study has two main objectives. The first objective was to investigate how grammatical number marking influences performance in attention and memory tasks involving number across native Thai speakers, native English speakers, and Thai-English bilinguals. It was hypothesized that native monolingual English speakers, whose language has obligatory grammatical number marking, will perform better than native Thai speakers and Thai-English bilinguals in tasks requiring attention and memory of numerical distinctions.

The second objective of the study was to analyze the relationship between bilingual proficiency in English and performance on attention and memory tasks involving number in Thai-English bilinguals. It was hypothesized that Thai-English bilinguals with higher English proficiency will perform closer to native English speakers in tasks requiring attention and memory of numerical distinctions.

The study included 150 participants: 30 monolingual Thai speakers, 30 monolingual English speakers, 30 Thai-English bilinguals who have English proficiency at the basic level, 30 Thai-English bilinguals who have English proficiency at the intermediate level and 30 Thai-English bilinguals who have English proficiency at the advanced level. Data collection was conducted in Thailand, and participants were selected using purposive sampling. Cognitive tests included attention tests, memory tests using photo hunt, and memory test using short-answer questions designed to assess participants' focus on and recall of object quantities.

This study tested participants' cognition through their attention and memory tests. The tests started from attention tests, memory tests using photo hunt, and memory tests using short-answer questions. According to the attention test, there were 10 pictures in this test. Participants were shown the first picture within five seconds, and it then disappeared. After that, they answered one question related to that picture.

For the memory test using photo hunt, there were 10 picture sets in this test. Each picture set consisted of the prototype picture and two alternate pictures. For each picture set, both alternate pictures differed from the prototype picture in one aspect. Participants were shown the prototype picture for five seconds, and then it disappeared. After that, both alternate pictures appeared, and participants were asked which alternate picture differed from the prototype picture. The last test is the memory test using short-answer questions. There were five pictures in this test. Participants were shown the first picture within 10 seconds, and it then disappeared. After that, they answered five questions related to that picture.

5.1.1 Results showing the relationship between grammatical number and monolinguals and bilinguals' cognition through the attention test

The results of the attention test mostly supported the hypothesis. English speakers paid significantly more attention to the number of objects than Thai speakers, aligning with the grammatical number of the languages. Among bilinguals, those with advanced English proficiency paid significantly more attention to the number of objects than those with intermediate or basic proficiency. When comparing monolinguals and bilinguals, the results partially supported the hypothesis. English speakers outperformed all bilingual groups and Thai speakers in paying attention to the number of objects. However, there were no significant differences between bilinguals with basic English proficiency and Thai monolinguals, despite the bilinguals showing slightly better attention to the number of objects

5.1.2 Results showing the relationship between grammatical number and monolinguals and bilinguals' cognition through the memory tests using photo hunt

The results of the memory tests using photo hunt, partly supported the hypothesis. English speakers remembered the number of objects better than Thai speakers, reflecting the obligatory grammatical number in English. Among bilinguals, those with advanced English proficiency outperformed those with basic proficiency in recalling the number of objects, with a significant difference between these groups. Bilinguals with advanced proficiency also performed better than those with intermediate proficiency, although no significant difference was found between the advanced and intermediate groups. When comparing monolinguals and bilinguals, English speakers outperformed both Thai-English bilinguals with basic proficiency and Thai speakers in recalling the number of objects, but no significant difference was found between English speakers and bilinguals with intermediate or advanced proficiency. Also, there were no significant difference between Thai speakers and Thai-English bilinguals who

have English proficiency at the basic level, despite the bilinguals showing slightly better attention to the number of objects

5.1.3 Results showing the relationship between grammatical number and monolinguals and bilinguals' cognition through the memory tests using short-answer questions

The results of the memory test using short-answer questions mostly supported the hypothesis. English speakers significantly outperformed Thai speakers in recalling the number of objects, reflecting their language's grammatical number. Among bilinguals, those with advanced English proficiency had better recall than those with intermediate and basic proficiency, with statistically significant differences. Comparisons between monolinguals and bilinguals showed that English speakers significantly outperformed all bilingual groups and Thai speakers in recalling the number of objects. However, there was no significant difference between bilinguals with basic English proficiency and Thai monolinguals, despite the bilinguals performing slightly better.

Overalls, English speakers paid more attention to and better memorized the number of objects compared to Thai speakers, consistent with the grammatical number in English and Thai. These findings support the hypothesis.

For bilinguals, Thai-English bilinguals who have English proficiency at the advanced level significantly outperformed those with intermediate and basic proficiency, in terms of the number of objects, as evidenced by both attention tests and memory tests using short-answer questions. In the memory test using photo hunt, although Thai-English bilinguals who have English proficiency at the advanced level outperformed those with intermediate proficiency bilinguals, there was no significant difference between both groups. These findings suggest that second language acquisition affects cognitive behaviors at different levels. The more advanced the participant's proficiency in English, the more they would pay

attention to and memorized the number of objects in the task. These findings overall partly support the hypothesis.

Comparisons between monolinguals and bilinguals showed that English speakers more paid attention to better memorized the number of objects than Thai-English bilinguals with advanced, intermediate, and basic English proficiency, as well as Thai speakers, respectively. This trend was evident in both the attention test and the memory test using short-answer questions. In the memory test using the photo hunt, while most results were generally similar across groups, no significant differences were observed among English speakers, Thai-English bilinguals with advanced proficiency, and those with intermediate proficiency. Interestingly, there was no significant difference between Thai-English bilinguals who have English proficiency at the basic level and Thai speakers, despite the former performing better in all tasks. Most results support the notion that grammar in languages influence cognitive processes, and that second language acquisition influence cognitive behaviors. These findings overall partly supporting the hypothesis.

These results showed that while most results aligned with the hypotheses, some did not. This discrepancy does not imply that grammatical number does not affect cognition or that bilingualism does not influence cognitive processes at different levels. It may be attributed to certain limitations of the multiple-choice test like the memory test using photo hunt or factors such as participants' anxiety and fatigue, which will be discussed further.

In conclusion, the findings of the present study support the linguistic relativity hypothesis, demonstrating that grammatical number affects cognitive systems. Additionally, second language acquisition influences cognitive behaviors at different levels. The higher the proficiency of a bilingual in a second language, the more similar their cognitive processes are to native speakers of that language.

5.2 Discussion

The discussion in this section interprets the findings of the study in light of the hypotheses proposed, drawing connections between language, cognition, and bilingualism. The discussion is structured according to the two hypotheses outlined.

5.2.1 How language influences cognition: the influence of grammatical number on cognition in monolingual speakers

In case of monolinguals, the first hypothesis posited that native monolingual English speakers, whose language has obligatory grammatical number marking, will perform better than native Thai speakers. The results of this study support this hypothesis. English speakers consistently performed better in tasks involving attention to and memory for object numbers, while Thai speakers showed more focus on other attributes, such as color or size, rather than the number of objects. These results align with previous studies of Charunrochana (2000); Kirjavainen et al. (2020); Lucy (1992b) indicating speakers of languages with obligatory grammatical number showed their cognitive behaviors aligning the grammatical number in their languages than speakers of languages with optional grammatical number. The results confirm that grammatical number, when obligatory, heightens speakers' sensitivity to the number of objects, thus influencing their cognition. In contrast, Thai speakers, whose language allows for grammatical number to be optional, showed less awareness to the number of objects. This supports the linguistic relativity hypothesis, demonstrating that linguistic grammar, such as grammatical number, influences speakers' cognition.

5.2.2 The influence of grammatical number on bilinguals' cognition compared to monolinguals

When comparing bilinguals to monolinguals, the first hypothesis also proposed that native monolingual English speakers, whose language has obligatory grammatical number marking, will perform better than native Thai

speakers and Thai-English bilinguals in tasks requiring attention and memory of numerical distinctions. This hypothesis was also supported by the results. Bilinguals with advanced proficiency demonstrated cognitive behaviors more influenced by grammatical number than Thai speakers and bilinguals with lower proficiency, yet they did not reach the level of native English speakers.

The findings mostly align with the linguistic relativity hypothesis by showing that language influences cognition, but bilinguals operate within a spectrum, depending on their proficiency. The more proficient they become in the second language, the more their cognitive processes reflect the grammatical aspects of that language. This reinforces the idea that bilinguals develop a unique cognitive system influenced by both languages, as supported by previous research (Athanasopoulos & Kasai, 2008; Bassetti, 2007).

While the influence of English grammatical number on bilinguals' cognition was significant, the results also suggest that second language acquisition does not completely overwrite the cognitive effects of the first language, especially at lower proficiency levels. This indicates that bilinguals' cognitive systems are flexible, influenced by their proficiency in each language, supporting the concept of cognitive integration (Cook et al., 2006).

5.2.3 The effect of English proficiency on cognitive behaviors of Thai-English bilinguals

The second hypothesis posited that Thai-English bilinguals with higher English proficiency will perform closer to native English speakers in tasks requiring attention and memory of numerical distinctions. The finding for bilinguals overall revealed that most Thai-English bilinguals showed cognitive behaviors that differed from monolingual Thai speakers and were somewhat similar to English speakers, varying according to their second language proficiency. This suggests that acquiring a second language influences bilinguals' cognition, aligning with previous studies (e.g., Aemdit and

Prasithrathsint (2016); Athanasopoulos (2006, 2007); Athanasopoulos and Kasai (2008); Bassetti (2007); Cook et al. (2006); Ruthirago (2011); Thongnium (2017)). It implies that language influences the cognitive system of its speakers, beyond their native language acquired from birth. According to the linguistic relativity hypothesis, speakers of languages with similar grammar have similar cognitive systems, while those with different grammatical structures have different cognitive systems. This is evidenced by the fact that bilinguals start to have cognitive systems that resemble those of second-language speakers more than their first language, demonstrating that a language learned later in life can influence speakers' thought.

When considering different English proficiency of bilinguals, the findings mostly supported this hypothesis, revealing proficiency in a second language plays a crucial role in affecting the cognitive behaviors of bilinguals. Bilinguals with advanced English proficiency in this study paid significantly more attention to the number of objects than those with intermediate or basic proficiency. This is consistent with studies by Aemdit and Prasithrathsint (2016); Athanasopoulos (2006, 2007); Athanasopoulos and Kasai (2008), which also found that higher second language proficiency results in cognitive behaviors more aligned with the grammar of the second language. Aemdit and Prasithrathsint (2016) also discovered that bilinguals who have a second language proficiency at the advanced level exhibited cognitive behavior more aligned with the grammar of their second language compared to those of basic-level and intermediate-level bilinguals. However, Aemdit and Prasithrathsint did not compare their bilingual findings with monolingual speakers of the two languages.

As a result, this dissertation added a new dimension by comparing across different proficiency levels including basic, intermediate and advanced levels and highlights the nuanced differences in cognitive awareness between bilinguals and monolinguals. It found that bilinguals with advanced proficiency exhibited cognitive behaviors that were closer to those of English monolinguals,

suggesting that their second language proficiency influences how they process numerical information. However, although bilinguals at the advanced level showed more sensitivity to grammatical number, their performance did not completely match that of native English speakers, indicating that while proficiency in a second language can significantly influence cognition, the effect may not fully equal that of native speakers. These evidences strengthen the argument that higher second language proficiency leads to cognitive processes more aligned with those of native speakers of the second language, further building on the insights from Aemdit and Prasithrathsint (2016).

5.2.4 Degrees of second language acquisition: how proficiency level in a second language affects cognitive behavior in bilinguals

The degrees of second language acquisition and their influence on bilingual cognition is a subject of considerable interest. When examining second language acquisition, a key question arises to what extent does the level of second language proficiency influence bilingual cognition. Most results of the study showed that Thai-English bilinguals who have English proficiency at the advanced level, as well as those with intermediate proficiency, showed their cognitive behaviors concerning the number of objects more than Thai speakers, with these differences being statistically significant. Although no statistically significant differences were found between Thai-English bilinguals who have English proficiency at the basic level and Thai speakers, Thai-English bilinguals who have English proficiency at the basic level still behaved their cognitive behaviors concerning the number of objects more than Thai speakers across all tasks.

The overall results suggest that cognitive changes may begin as bilinguals start learning a second language, with significant changes emerging as their proficiency increases. Therefore, second language proficiency affects bilinguals' cognition at varying levels. Increased proficiency correlates with

enhanced awareness of the number of objects in cognitive tasks, comparable to that of monolingual English speakers. This pattern is consistent with the findings of Athanasopoulos (2006), which indicated that cognitive changes can occur even among bilinguals with low levels of second language proficiency but significant changes occur at higher proficiency levels.

Additionally, this study supports the idea proposed by Thongnium (2017) that cognitive changes are not permanent but can vary according to proficiency in a second language. For instance, a Thai-English bilingual who has lived abroad and attained advanced English proficiency, exhibiting cognitive behaviors similar to native English speakers, may experience a cognitive reversion to that of monolingual Thai speakers upon returning to Thailand and ceasing the use of English. They may then begin to forget English vocabulary and grammar. This raises interesting questions about how such cognition might revert to resemble that of monolingual Thai speakers if tested again. Additionally, the duration of time spent abroad should be considered in further study. A comparative study could examine the cognitive processes of bilinguals who spent a short period abroad versus those who spent a prolonged period abroad, followed by a return to an environment in Thailand where English is rarely used. The cognitive differences between these two groups warrant further investigation.

5.2.5 Cognitive flexibility in bilinguals: Why language of instruction does not affect cognitive tasks

One of the more unexpected findings of this study was the lack of a significant influence of the language of instruction on the cognitive behavior of bilinguals. Thai-English bilingual participants were given the option to respond in either English or Thai, despite the tasks being presented in both languages. Interestingly, 40% of participants with advanced English proficiency and 16.67% with intermediate proficiency chose to respond in English, while the remainder opted for Thai. However, statistical analysis revealed no significant differences in

cognitive performance between those responding in Thai and those responding in English. This finding underscores the cognitive flexibility of bilinguals, who appear equally adept at navigating tasks in either language. These results align with prior research by Athanasopoulos (2007); Athanasopoulos and Kasai (2008), which similarly found no significant cognitive shifts based on the language used in cognitive tasks.

The preference for one language over another seems to reflect the participants' comfort or personal choice in using a particular language. Participants choosing English may have been more accustomed to using it in academic or formal settings, while those responding in Thai might have found it easier for doing the tasks. These choices show that bilinguals adapt their language use based on context and personal preferences, rather than fixed cognitive processes.

The results importantly indicate that language choice during tasks does not cause cognitive shifts, supporting the idea that bilinguals can handle tasks equally well in either language. Earlier studies, such as those by Athanasopoulos and colleagues, emphasized the effects of language on cognition, these findings suggest the cognitive process is not affected by the language being used.

These outcomes also challenge Slobin (1996)'s "thinking for speaking" hypothesis, which proposes that linguistic structure shapes thought during language production and comprehension. The results of this study suggest that bilinguals do not exhibit preferences based on the language of instruction, as both my study and Athanasopoulos's found that cognitive shifts occur regardless of the language used. Instead, they support Lucy (1992a)'s proposal that language may influence habitual cognition at a deeper level.

5.3 Implication

The findings that grammatical number affects speakers' cognition, and that proficiency in a second language also influenced bilinguals' cognition, carry significant implications that could have profound impacts on educational practices. The findings suggest that grammatical number influences participants' cognitive processes, such as attention and memory related to numerical awareness. For instance, English speakers performed with slightly higher accuracy in numerical recall tasks compared to Thai speakers, which could be related to the grammatical distinctions between singular and plural forms. Furthermore, bilingual individuals' cognitive behaviors seemed to be influenced by their level of proficiency in English, which highlights the relationship between grammatical number and participants' cognition.

In terms of language education policy, it should aim at improving English proficiency from incorporating teaching methods that make learners aware of how certain grammar number, such as distinctions between singular and plural forms, can potentially affect cognitive processes. Emphasizing this difference is crucial because previous studies reveal that speakers of languages with optional grammatical number, such as Thai, often struggle when learning a second language like English, where grammatical number is mandatory (e.g., Chaiyasit et al. (2019); Promsupa et al. (2017); Yordchim and Gibbs (2014)). However, it is important to approach this with a balanced perspective, ensuring that language education policies focus not only on fluency but also on fostering a deeper understanding and appreciation for the nuances and complexities of different languages.

Incorporating activities that raise awareness of cognitive differences in language structures could enhance the learning experience. However, these should be carefully added to existing curricula to align with broader educational objectives. By adopting a thoughtful and well-balanced approach, language education can support both linguistic proficiency and cultural understanding,

without overemphasizing the direct cognitive advantages of second-language proficiency.

5.4 Limitation and Future Directions

The study aimed to address the research questions by using robust and appropriate methods. However, the results should be interpreted carefully, considering the limitations. Based on these limitations, suggestions for future research are provided.

5.4.1 Limitations in methodology

While this study was carefully designed and implemented with an appropriate methodology, there are areas that offer opportunities for further refinement and exploration.

First, although the study controlled the time duration for participants to view each picture in the tasks, it did not control the response time for answering questions about the pictures. This approach aligns with previous research, and the questions used were intentionally straightforward, ensuring that participants could understand and respond promptly after viewing the questions. On average, participants took only 5–7 seconds per question, as they were instructed not to guess if they were unsure of the answers. Nonetheless, future research could incorporate measurements of response time to investigate whether this variable provides additional insights into participants' cognitive processing during the tasks.

Second, regarding the objects in the pictures, this study followed the principle that any components questioned should not be overly dominant in the visual scene, which was in line with previous studies (e.g., Aemdit (2007, 2013); Chanyeam (2017); Charunrochana (1997, 2000); Lucy (1992b); Nusartlert (2009)). Additionally, my pilot study revealed that if a target component stood out too prominently, participants across all groups were more likely to detect it and

answer correctly, regardless of their awareness of the number corresponding to the grammatical number in their language. To maintain the integrity of the tasks, questions were designed to focus on components that were not overly salient. This ensured that participants had to rely on cognitive processing rather than visual prominence to detect and recall the target information. However, future studies might consider designing tasks that explicitly compare responses to questions about both salient and non-salient components. This approach could test whether participants' ability to detect and recall target information aligns with findings from previous studies, potentially uncovering new insights into how visual salience interacts with cognitive processes in different groups of participants.

Third, while this study provides valuable insights into the relationship between linguistic aspects and cognition, its scope is limited to grammatical number as the primary focus. This study does not capture the full range of nominal grammatical categories that may influence bilingual and monolingual cognition. This limitation highlights the need for future studies to expand beyond grammatical number to investigate broader and more factors. For example, future research could examine distinctions like countability (countable vs. uncountable nouns), the conceptualization of abstract versus concrete objects, and the role of classifiers in shaping cognitive patterns. Additionally, examining the differences in how bilinguals and monolinguals process nominal grammatical categories could offer valuable insights into the cognitive behaviors influenced by this linguistic aspect in both groups.

Methodologically, future research could include specific tasks designed to directly test attention and memory to explore these broader questions. For instance, when investigating the influence of grammatical number on cognition, experiments could ask participants to describe pictures, focusing on their awareness and descriptive patterns. Similarly, to study the effect of countability on cognition, participants could be presented with stimuli featuring mass nouns and count nouns, assessing whether bilingual and monolingual speakers differ in

their ability to associate numerical concepts with uncountable entities. To ensure reliable and valid results, it will be essential to control for cognitive factors such as working memory capacity, attention span, and stimulus saliency, enabling the isolation of linguistic features' specific effects on cognitive processes.

Fourth, the memory test using photo hunt task may have limitations as a cognitive assessment tool. Its reliance on visual cues and options likely made it less effective at capturing how grammatical number influences cognition. The design of the task may have encouraged guessing when participants were unsure, which could have hidden their real cognitive behaviors. This is different from the attention test and short-answer memory task, where participants had to recall information on their own without any visual help.

The potential for guessing in the photo hunt task may have been influenced by participants' anxiety levels as the experiment progressed. Some participants reported feeling frustrated when struggling to recall answers, which could have impacted their performance. Additionally, the photo hunt task was done immediately after the attention test, and this abrupt shift in task type might affect participants' cognitive performance. These factors—task design, guessing, and anxiety—likely contributed to the observed performance differences and may have affected the accuracy of the results related to the cognitive processing of grammatical number.

These observations underscore the limitations of the photo hunt task as a tool for assessing cognitive differences associated with grammatical structures such as grammatical number. The reliance on visual cues and the likelihood of guessing suggest that the photo hunt task may not adequately capture these cognitive differences. Future research would benefit from employing more controlled tasks that specifically target grammatical number processing while minimizing unnecessary distractions.

Fifth, this study controlled for several cultural factors, including social background, education, professional experience, and lifestyle—elements

identified by neo-Whorfian scholars as influencing cognitive behavior. To ensure that the results reflected the influence of grammatical number on participants' cognition, the participants' backgrounds were deliberately kept relatively similar. All participants were at least 18 years old, either enrolled in or had completed undergraduate programs, or employed in fields unrelated to the number. The geographically homogenous sample, drawn from Bangkok and surrounding areas, helped to standardize some variables but may have introduced regional cultural biases.

Certain cultural factors, such as differences in educational background, age, or exposure to numerical concepts, were controlled in this study since they could affect participants' cognitive performance. Additionally, participants' familiarity with tasks similar to those used in the study were also controlled to minimize their impact on the results.

Previous research has investigated cultural influences on cognitive processes, such as time metaphors and grammatical gender (e.g., Boroditsky (2001); Chen (2022)). Despite these efforts, findings remain inconclusive due to limited diversity and insufficient clarity in participant selection, which weakens the reliability and generalizability of the conclusions. Key cultural variables, including language, regional customs, and societal attitudes toward numeracy, remain underexplored in their connection to cognitive behavior.

To address these gaps, future research should adopt a broader and more inclusive approach, exploring how diverse cultural factors shape cognitive processing, particularly in relation to language and numerical reasoning. By expanding the range of cultural contexts and participant characteristics, researchers could achieve a deeper and more comprehensive understanding of these influences and their implications for cognitive outcomes.

5.4.2 Future directions in linguistic relativity hypothesis

5.4.2.1 Comparative studies on bilinguals and monolinguals

Future research should focus on comparing bilinguals with varying levels of proficiency in their second language in both ways. For example, investigating Thai-English and English-Thai bilinguals across different proficiency levels could yield valuable insights into how second-language proficiency influences cognitive processes. Similarly, comparisons between monolingual Thai speakers and monolingual English speakers could help determine the extent to which language grammar affects cognition. Such studies would provide a deeper understanding of how bilingualism at different stages of proficiency shapes cognitive behaviors and whether linguistic structures contribute to these differences.

5.4.2.2 Immersive experiences and cognitive effects

Further research is needed to explore the impact of varying durations spent in second-language-speaking environments on bilingual cognition. Examining how extended immersion in a second language influences cognitive processes could reveal whether the length of exposure correlates with changes in cognitive patterns. This would help clarify the dynamic nature of bilingual cognition and the role of immersive experiences in shaping cognitive processes at different levels of language proficiency.

5.4.2.3 Studies about cognitive changes in bilinguals

Cognitive changes from monolingualism to bilingualism would provide interesting insights into how acquiring a second language affects cognitive processes. Investigating cognitive shifts across proficiency levels—beginner, intermediate, and advanced—would further elucidate the relationship between language acquisition and cognitive flexibility. Additionally, examining bilinguals who, after achieving high proficiency in a second language, reduce its use and regress to lower proficiency levels could offer evidence on the fluidity of cognitive adaptations. This would support the idea that cognitive changes linked

to language use are not permanent but instead fluctuate with proficiency and contextual factors.

5.4.2.4 Addressing gaps in testing the linguistic relativity hypothesis

Future research should address unexamined aspects and limitations in previous studies on the linguistic relativity hypothesis. By expanding the scope of inquiry, researchers could develop a more comprehensive understanding of the interactions between language, thought, and culture. This would provide a robust framework for evaluating the hypothesis and its broader implications for cognitive science and linguistic theory.

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Appendix

Appendix A Certificate of Ethical Approval

MF-04-version-2.0
วันที่ 18 ต.ค. 61

หนังสือยืนยันการยกเว้นการรับรอง
คณะกรรมการจริยธรรมสำหรับพิจารณาโครงการวิจัยที่ทำในมนุษย์
มหาวิทยาลัยศรีนครินทรวิโรฒ

(เอกสารนี้เพื่อแสดงว่าคณะกรรมการจริยธรรมสำหรับพิจารณาโครงการวิจัยที่ทำในมนุษย์ ได้พิจารณาโครงการวิจัยนี้)

ชื่อโครงการวิจัย : อิทธิพลของประเภททางไวยากรณ์พจน์ต่อปริชานของผู้พูดสองภาษาไทย-อังกฤษ

ชื่อหัวหน้าโครงการวิจัย : นางสาวฉัตรชนก จันทร์แย้ม

หน่วยงานต้นสังกัด : คณะมนุษยศาสตร์

รหัสโครงการวิจัย : SWUEC-G-215/2566X

โครงการวิจัยนี้เป็นโครงการวิจัยที่เข้าข่ายยกเว้น (Research with Exemption from SWUEC)

วันที่ยืนยัน : 22 สิงหาคม 2566

ยืนยันโดย : คณะกรรมการจริยธรรมสำหรับพิจารณาโครงการวิจัยที่ทำในมนุษย์
มหาวิทยาลัยศรีนครินทรวิโรฒ

คณะกรรมการจริยธรรมสำหรับพิจารณาโครงการวิจัยที่ทำในมนุษย์ มหาวิทยาลัยศรีนครินทรวิโรฒ ดำเนินการรับรองโครงการวิจัยตามแนวทางหลักจริยธรรมการวิจัยในคนที่เป็นสากล ได้แก่ Declaration of Helsinki, the Belmont Report, CIOMS Guidelines และ the International Conference on Harmonization in Good Clinical Practice (ICH-GCP)

ออกให้ ณ วันที่ 18 กันยายน 2566

(ลงชื่อ).....
(ผู้ช่วยศาสตราจารย์ ดร.พันตแพทย์หญิงณปภา เอี่ยมจิรกุล)
กรรมการและเลขานุการคณะกรรมการจริยธรรม
สำหรับพิจารณาโครงการวิจัยที่ทำในมนุษย์

(ลงชื่อ).....
(แพทย์หญิงสุรีพร ภัทรสุวรรณ)
ประธานคณะกรรมการจริยธรรม
สำหรับพิจารณาโครงการวิจัยที่ทำในมนุษย์

หมายเลขรับรอง : SWUEC/X/G-215/2566

Appendix B Demographic Information of Participants

Native Thai Speakers (N = 30)

No.	Age	Birthplace	Educational Level / Working Experience	Mother Tongue	Second Language Proficiency and Study Duration			Experience Abroad Within the Past Six Years		
					Language	Fluency Level	Study Duration	Country	Year	Duration
1	29	Thailand	A bachelor's degree in a major that is not primarily focused on mathematics yet does not involve work related to number.	Thai	Thai speakers in this study, who are monolingual in their native language, have acquired English as a second language. However, their proficiency is limited to a set of basic, commonly used expressions, such as 'hello,' 'thank you,' and 'sorry,' which are primarily employed for routine communication.					
2	52	Thailand		Thai						
3	36	Thailand		Thai						
4	37	Thailand		Thai						
5	34	Thailand		Thai						
6	37	Thailand		Thai						
7	40	Thailand		Thai						
8	52	Thailand		Thai						
9	45	Thailand		Thai						
10	31	Thailand		Thai						
11	31	Thailand		Thai						
12	31	Thailand		Thai						
13	33	Thailand		Thai						
14	33	Thailand		Thai						
15	37	Thailand		Thai						
16	40	Thailand		Thai						
17	35	Thailand		Thai						
18	34	Thailand		Thai						
19	46	Thailand		Thai						
20	27	Thailand		Thai						
21	37	Thailand		Thai						
22	38	Thailand		Thai						
23	47	Thailand		Thai						
24	32	Thailand		Thai						
25	37	Thailand		Thai						
26	33	Thailand		Thai						
27	35	Thailand		Thai						
28	35	Thailand		Thai						
29	53	Thailand		Thai						
30	31	Thailand		Thai						

English Speakers (N = 30)

No.	Age	Birthplace	Educational Level / Working Experience	Mother Tongue	Foreign Language Proficiency and Study Duration			Experience Abroad Within the Past Six Years		
					Language	Fluency Level	Study Duration	Country	Year	Duration
1	71	Australia	A bachelor's degree in a major that is not primarily focused on mathematics yet does not involve work related to number.	English	French	Basic	unspecified	Thailand	2023	<1 week
2	59	England		English	German	Basic	unspecified	Thailand	2023	<1 week
3	51	Australia		English	German	Basic	unspecified	Thailand	2023	<1 week
4	39	Australia		English				Thailand	2023	<1 week
5	47	Australia		English	German	Basic	unspecified	Thailand	2023	<1 week
6	25	Australia		English				Thailand	2023	<1 week
7	28	Australia		English				Thailand	2023	<1 week
8	31	Australia		English				Thailand	2023	<1 week
9	26	Australia		English				Thailand	2023	<1 week
10	26	England		English	Spain	Basic	unspecified	Thailand	2023	<1 week
11	63	England		English				Thailand	2023	<1 week
12	38	England		English				Thailand	2023	<1 week
13	31	England		English	Spain	Basic	unspecified	Thailand	2023	<1 week
14	27	England		English	French	Basic	unspecified	Thailand	2023	<1 week
15	54	England		English				Thailand	2023	<1 week
16	48	England		English				Thailand	2023	<1 week
17	28	England		English				Thailand	2023	<1 week
18	29	England		English				Thailand	2023	<1 week
19	29	England		English				Thailand	2023	<1 week
20	28	England		English				Thailand	2023	<1 week
21	27	England		English				Thailand	2023	<1 week
22	43	England		English				Thailand	2023	<1 week
23	28	England		English				Thailand	2023	<1 week
24	26	England		English				Thailand	2023	<1 week
25	42	England		English				Thailand	2023	<1 week
26	32	Australia		English				Thailand	2023	<1 week
27	32	Australia		English				Thailand	2023	<1 week
28	32	Australia		English				Thailand	2023	<1 week
29	43	England		English				Thailand	2023	<1 week
30	40	England		English				Thailand	2023	<1 week

Thai-English bilinguals who have English proficiency at the basic level (N=30)

No.	Age	Birthplace	Educational Level	Mother Tongue	Foreign Language Proficiency and Study Duration			Experience Abroad Within the Past Six Years		
					Language	Fluency Level	Study Duration	Country	Year	Duration
1	23	Thailand	Currently pursuing a bachelor's degree that is not primarily focused on mathematics.	Thai	English	A1	Since K.1			
2	23	Thailand		Thai	English	A1	Since K.1			
3	22	Thailand		Thai	English	A1	Since K.1			
4	22	Thailand		Thai	English	A1	Since K.1			
5	22	Thailand		Thai	English	A1	Since K.1			
6	22	Thailand		Thai	English	A1	Since K.1	Japan	2020	<1 week
7	23	Thailand		Thai	English	A1	Since K.1			
8	22	Thailand		Thai	English	A1	Since K.1			
9	25	Thailand		Thai	English	A1	Since K.1			
10	23	Thailand		Thai	English	A1	Since K.1			
11	24	Thailand		Thai	English	A1	Since K.1			
12	22	Thailand		Thai	English	A1	Since K.1			
13	24	Thailand		Thai	English	A1	Since K.1			
14	23	Thailand		Thai	English	A1	Since K.1			
15	22	Thailand		Thai	English	A2	Since K.1			
16	20	Thailand		Thai	English	A2	Since K.1			
17	20	Thailand		Thai	English	A1	Since K.1			
18	22	Thailand		Thai	English	A1	Since K.1			
19	22	Thailand		Thai	English	A1	Since K.1			
20	25	Thailand		Thai	English	A2	Since K.1			
21	22	Thailand		Thai	English	A1	Since K.1			
22	22	Thailand		Thai	English	A1	Since K.1			
23	23	Thailand		Thai	English	A1	Since K.1			
24	22	Thailand		Thai	English	A1	Since K.1			
25	23	Thailand		Thai	English	A1	Since K.1			
26	23	Thailand		Thai	English	A1	Since K.1			
27	23	Thailand		Thai	English	A2	Since K.1			
28	23	Thailand		Thai	English	A1	Since K.1			
29	23	Thailand		Thai	English	A1	Since K.1	Hongkong	2017	<1 week
30	20	Thailand		Thai	English	A1	Since K.1			

Thai-English bilinguals who have English proficiency at the intermediate level (N=30)

No.	Age	Birthplace	Educational Level	Mother Tongue	Foreign Language Proficiency and Study Duration			Experience Abroad Within the Past Six Years		
					Language	Fluency Level	Study Duration	Country	Year	Duration
1	21	Thailand	Currently pursuing a bachelor's degree that is not primarily focused on mathematics.	Thai	English	B2	Since K.1			
2	21	Thailand		Thai	English	B2	Since K.1			
3	21	Thailand		Thai	English	B1	Since K.1			
4	21	Thailand		Thai	English	B1	Since K.1			
5	20	Thailand		Thai	English	B1	Since K.1			
6	20	Thailand		Thai	English	B1	Since K.1			
7	20	Thailand		Thai	English	B1	Since K.1			
8	21	Thailand		Thai	English	B1	Since K.1			
9	23	Thailand		Thai	English	B2	Since K.1	China	2018	<1 week
10	20	Thailand		Thai	English	B1	Since K.1			
11	21	Thailand		Thai	English	B1	Since K.1			
12	21	Thailand		Thai	English	B1	Since K.1			
13	20	Thailand		Thai	English	B2	Since K.1			
14	20	Thailand		Thai	English	B1	Since K.1			
15	21	Thailand		Thai	English	B1	Since K.1			
16	20	Thailand		Thai	English	B1	Since K.1			
17	21	Thailand		Thai	English	B1	Since K.1			
18	21	Thailand		Thai	English	B1	Since K.1			
19	20	Thailand		Thai	English	B1	Since K.1			
20	21	Thailand		Thai	English	B2	Since K.1			
21	20	Thailand		Thai	English	B1	Since K.1			
22	22	Thailand		Thai	English	B1	Since K.1			
23	21	Thailand		Thai	English	B1	Since K.1			
24	21	Thailand		Thai	English	B1	Since K.1			
25	21	Thailand		Thai	English	B1	Since K.1			
26	21	Thailand		Thai	English	B1	Since K.1			
27	20	Thailand		Thai	English	B1	Since K.1			
28	22	Thailand		Thai	English	B2	Since K.1			
29	21	Thailand		Thai	English	B1	Since K.1			
30	25	Thailand		Thai	English	B1	Since K.1	Sudan	2017	<1 week

Thai-English bilinguals who have English proficiency at advanced level (N=30)

No.	Age	Birthplace	Educational Level	Mother Tongue	Foreign Language Proficiency and Study Duration			Experience Abroad Within the Past Six Years		
					Language	Fluency Level	Study Duration	Country	Year	Duration
1	21	Thailand	Currently pursuing a bachelor's degree and master's degree that is not primarily focused on mathematics.	Thai	English	C1	Since K.1	USA	2023	<1 week
2	22	Thailand		Thai	English	C1	Since K.1			
3	22	Thailand		Thai	English	C1	Since K.1			
4	22	Thailand		Thai	English	C1	Since K.1			
5	22	Thailand		Thai	English	C1	Since K.1			
6	22	Thailand		Thai	English	C1	Since K.1			
7	22	Thailand		Thai	English	C1	Since K.1	USA	2022	3 months
8	22	Thailand		Thai	English	C1	Since K.1	Germany	2023	3 months
9	21	Thailand		Thai	English	C1	Since K.1			
10	23	Thailand		Thai	English	C1	Since K.1	Switzerland	2017	2 weeks
11	21	Thailand		Thai	English	C1	Since K.1			
12	22	Thailand		Thai	English	C1	Since K.1	Japan	2018	<1 week
13	21	Thailand		Thai	English	C1	Since K.1	USA	2022	3 months
14	22	Thailand		Thai	English	C1	Since K.1			
15	22	Thailand		Thai	English	C1	Since K.1			
16	21	Thailand		Thai	English	C1	Since K.1			
17	22	Thailand		Thai	English	C1	Since K.1			
18	22	Thailand		Thai	English	C2	Since K.1			
19	21	Thailand		Thai	English	C1	Since K.1			
20	21	Thailand		Thai	English	C1	Since K.1			
21	22	Thailand		Thai	English	C1	Since K.1			
22	22	Thailand		Thai	English	C1	Since K.1			
23	22	Thailand		Thai	English	C1	Since K.1			
24	22	Thailand		Thai	English	C1	Since K.1	USA	2023	3 months
25	22	Thailand		Thai	English	C1	Since K.1			
26	21	Thailand		Thai	English	C1	Since K.1	Taiwan	2023	<1 week
27	22	Thailand		Thai	English	C1	Since K.1	USA	2023	3 months
28	21	Thailand		Thai	English	C1	Since K.1			
29	21	Thailand		Thai	English	C2	Since K.1	Singapore	2018	<1 week
30	19	Thailand		Thai	English	C1	Since K.1			

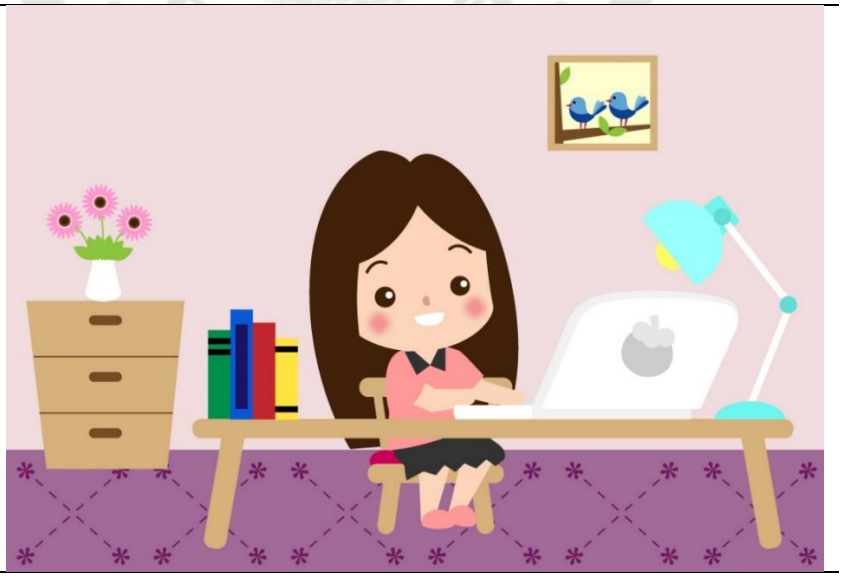
Appendix C Pictures Used in the Attention Test

A practice picture for participants prior to the actual test

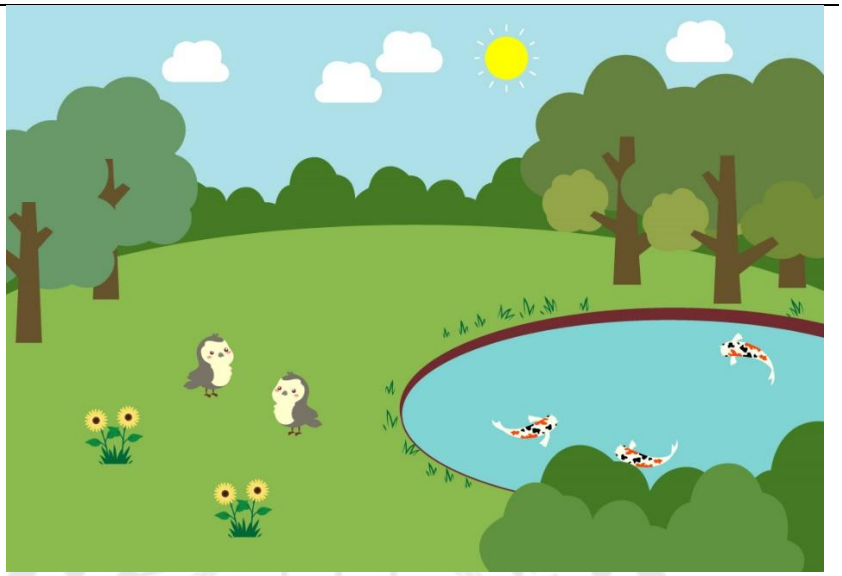
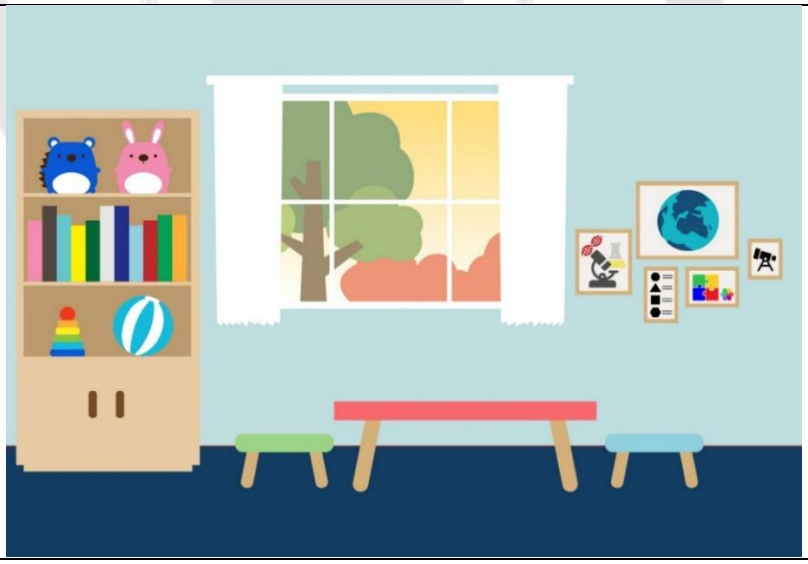
A practice picture

Question : What is a boy doing? Answer: He is reading a book.

Test Pictures

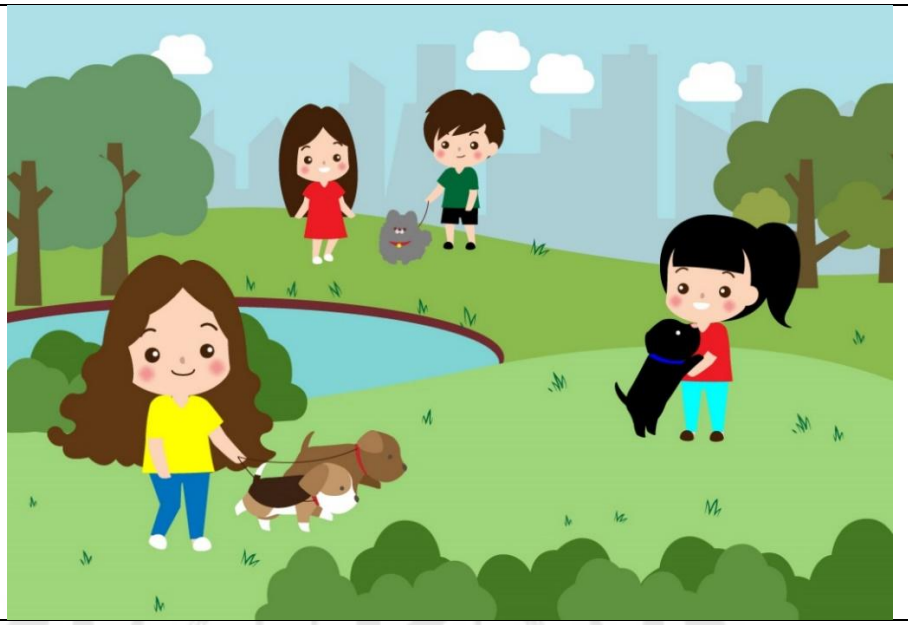
No.	The test pictures
1	
	Question 1: how many birds are there in the picture frame? Answer: Two

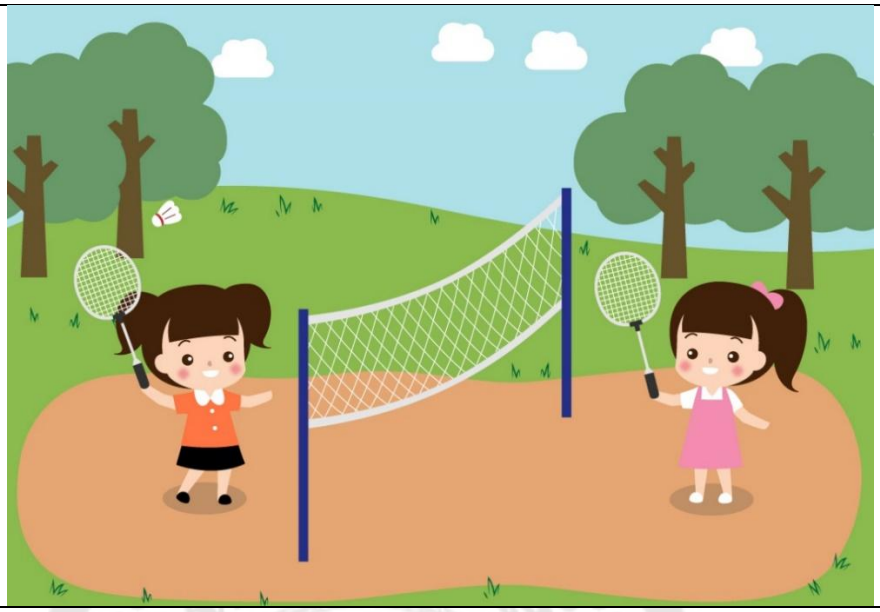
Test Pictures

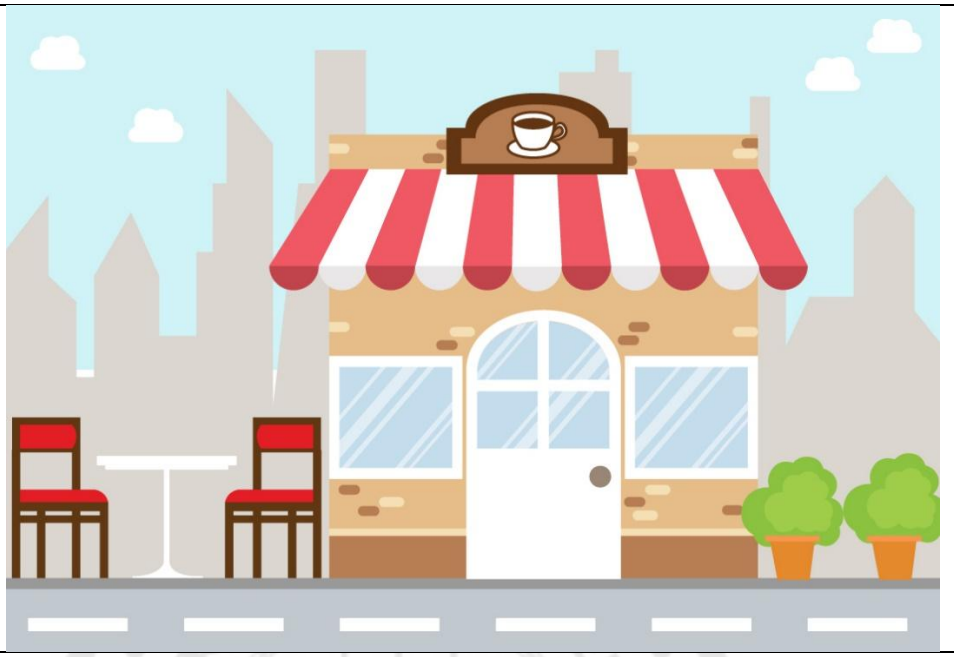
No.	The test pictures
2	
	Question 2: How many flowers are there in this picture? Answer: Four
3	
	Question 3: How many dolls are there in the shelf? Answer: Two

No.	The test pictures
4	
	Question 4: How many crabs are there in this picture? Answer: Two
5	
	Question 5: How many clouds are there in this picture? Answer: Four

Non-Test Pictures

No.	The non-test pictures
6	
	Question 6: What are the colors of the dogs in this picture? Answer: Brown, black and grey.
7	
	Question 7: What kind of party is shown in this picture? Answer: A birthday party.

No.	The non-test pictures
8	
	Question 8: What are two girls doing? Answer: They are playing badminton.
9	
	Question 9: What are the rabbit and the bear holding? Answer: The rabbit is holding a carrot, while the bear is holding a honey jar.

No.	The non-test pictures
10	
	Question 10: What is the color of the chairs? Answer: Red and brown.

Appendix D Pictures Used in the Memory Test Using Photo Hunt

A practice picture set for participants prior to the actual test

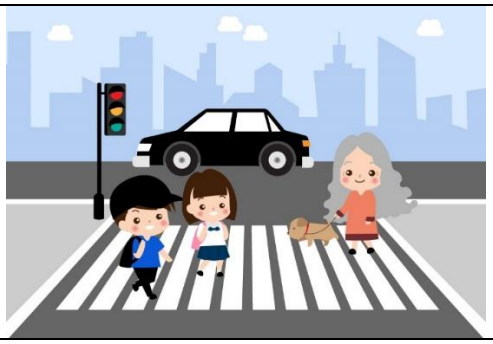
A practice picture set	
	
Prototype picture	
	
Alternate picture 1	Alternate picture 2

Prototype picture and alternate picture 1 = Different colors of dresses

Prototype picture and alternate picture 2 = An ice cream changes into a gift

Test Picture Sets

No.	The test picture sets	
1		
	Prototype picture	
		
	Alternate picture 1	Alternate picture 2
	Prototype picture and alternate picture 1 = Different colors of doors Prototype picture and alternate picture 2 = Different number of trees	

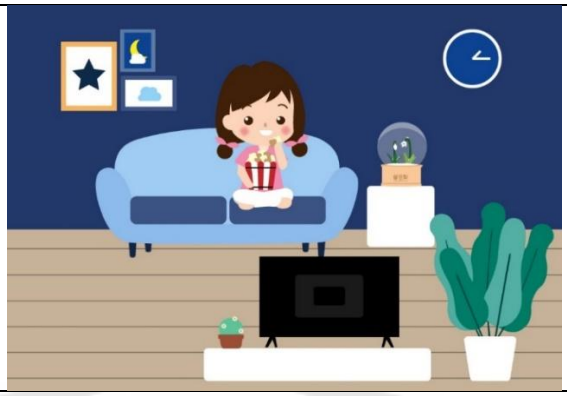
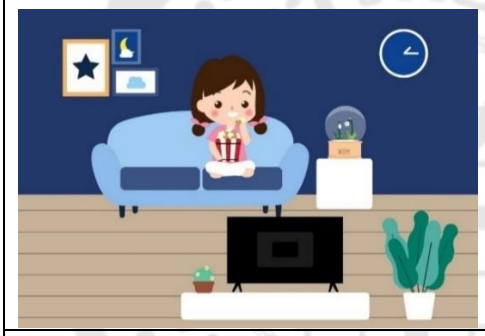
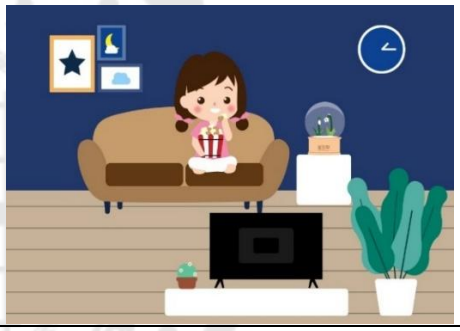
No.	The test picture sets	
2		
	Prototype picture	
		
	Alternate picture 1	Alternate picture 2
	Prototype picture and Alternate picture 1 = Different colors of cars Prototype picture and Alternate picture 2 = Different number of dogs	

<table>
<tr><th>No.</th><th colspan="2">The test picture sets</th></tr>
<tr><td rowspan="5">3</td><td colspan="2">  </td></tr>
<tr><td colspan="2">Prototype picture</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>Alternate picture 1</td><td>Alternate picture 2</td></tr>
<tr><td colspan="2">Prototype picture and alternate picture 1 = A tree changes into a flower.
Prototype picture and alternate picture 2 = Different number of plant spoons</td></tr>
</table>

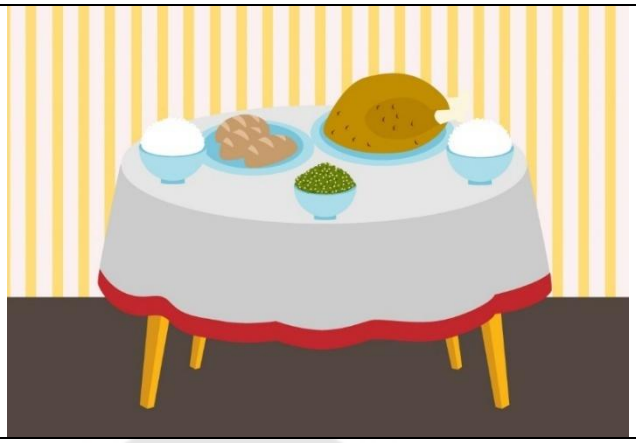
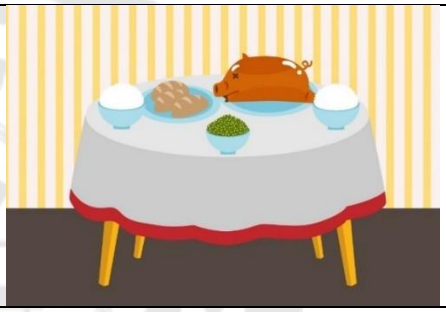
No.	The test picture sets	
4		
	Prototype picture	
		
	Alternate picture 1	Alternate picture 2
	Prototype picture and alternate picture 1 = The boy is holding an orange instead of an apple. Prototype picture and alternate picture 2 = Different number of eggs	

<table>
<tr><th>No.</th><th>The test picture sets</th></tr>
<tr><td rowspan="5">5</td><td>  </td></tr>
<tr><td>Prototype picture</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>Alternate picture 1</td><td>Alternate picture 2</td></tr>
<tr><td colspan="2">Prototype picture and alternate picture 1 = Different color of cars
Prototype picture and alternate picture 2 = Different number of people</td></tr>
</table>

Non-Test Picture Sets

<table>
<tr><th>No.</th><th>The non-test picture sets</th></tr>
<tr><td>6</td><td>  </td></tr>
<tr><td></td><td>Prototype picture</td></tr>
<tr><td></td><td>   </td></tr>
<tr><td></td><td>Alternate picture 1 | Alternate picture 2</td></tr>
<tr><td></td><td>Prototype picture and alternate picture 1 = Different color of sofa beds
Prototype picture and alternate picture 2 = Different sizes of trees</td></tr>
</table>

No.	The non-test picture sets
7	
	Prototype picture
	 
	Alternate picture 1 Alternate picture 2
	Prototype picture and alternate picture 1 = Different color of a girl's dress Prototype picture and alternate picture 2 = Different shape of toys

No.	The non-test picture sets
8	
	Prototype picture
	 
	Alternate picture 1 / Alternate picture 2
	Prototype picture and alternate picture 1 = Different colors of bread Prototype picture and alternate picture 2 = The roast chicken changes into the roast pork

<table>
<tr><th>No.</th><th>The non-test picture sets</th></tr>
<tr><td>9</td><td>


Prototype picture


Alternate picture 1 | Alternate picture 2

Prototype picture and alternate picture 1 = A girl is holding a trophy instead of a paint brush.

Prototype picture and alternate picture 2 = Different colors in two buckets.
</td></tr>
</table>

No.	The non-test picture sets	
10		
	Prototype picture	
		
	Alternate picture 1	Alternate picture 2
	Prototype picture and alternate picture 1 = Different color in the bucket. Prototype picture and alternate picture 2 = Different sizes of cats	

Appendix E Pictures Used in the Memory Test Using Short-Answer Questions

A practice picture for participants prior to the actual test

A practice picture

Question 1: Where is this place?

Answer: At a playground

Question 2: What is the color of the cat?

Answer: Orange

Question 3: What are these boys doing?

Answer: They are playing football.

Question 4: What is the color of the flowers?

Answer: Yellow.

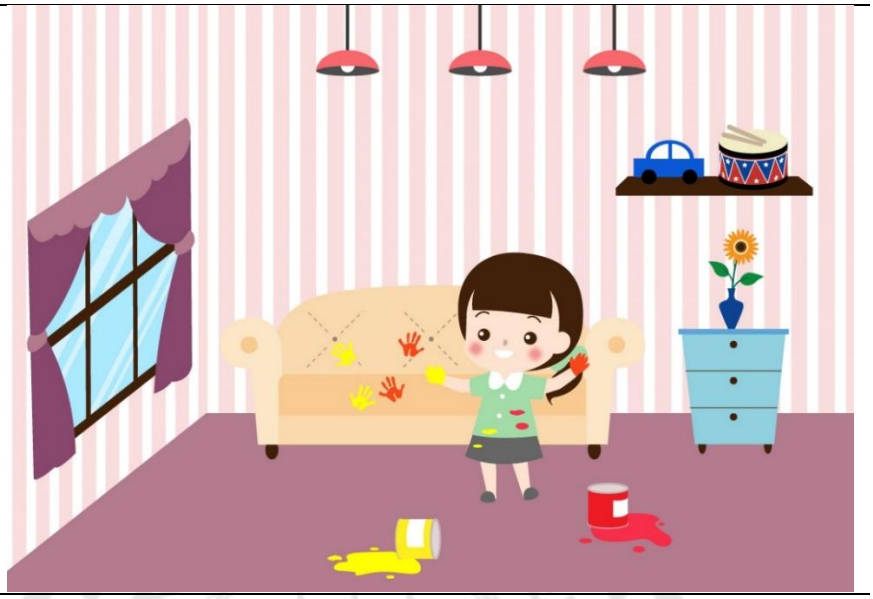
Question 5: How many footballs are there in this picture?

Answer: Two.

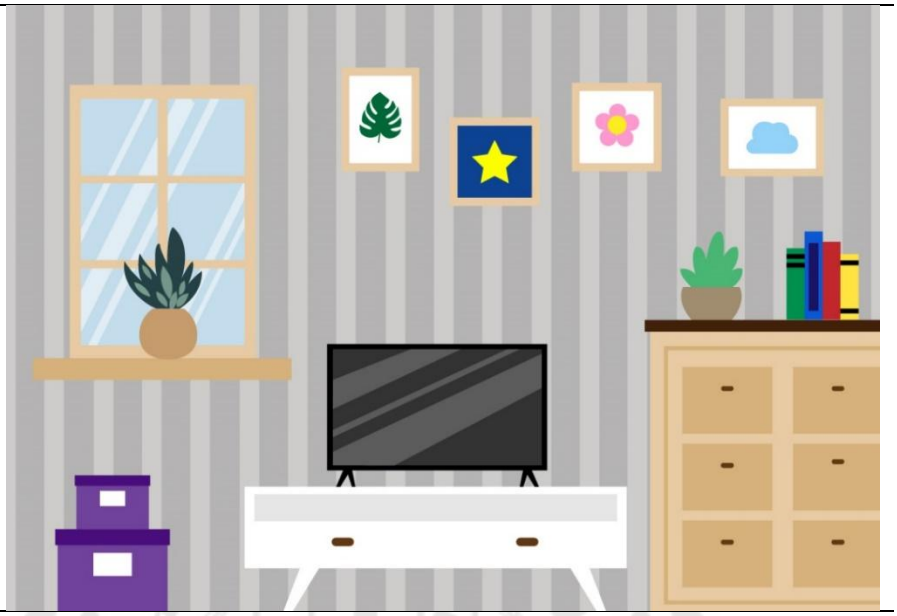
Test Pictures

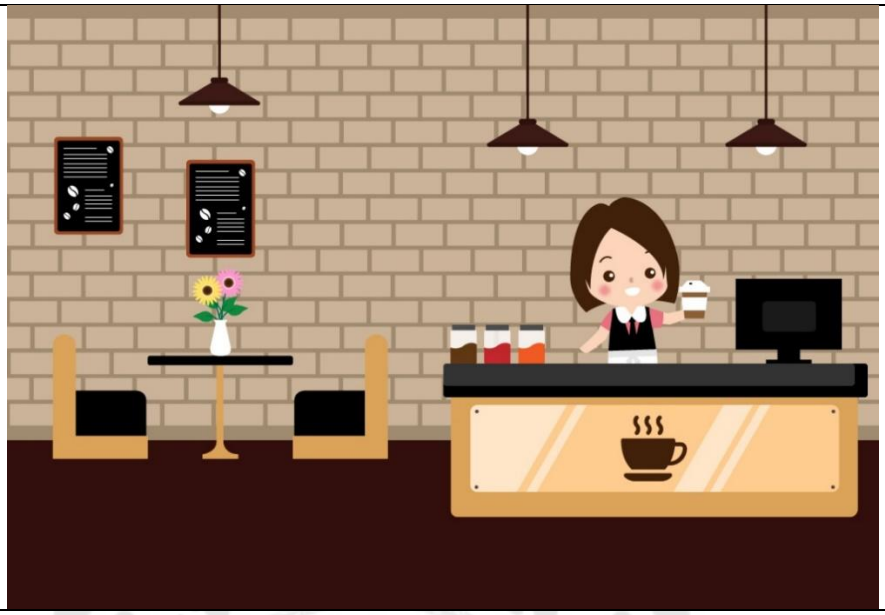
No.	The test pictures
1	 Question 1: How many toys are there on the cabinet? Answer: Two Question 2: How many balls are there in this picture? Answer: Four Question 3: How many picture frames are there in this picture? Answer: Two Question 4: Why is this child crying? Answer: It depends on participants' vision. Question 5: What is the color of the bed? Answer: Yellow, blue, and white.

No.	The test pictures
2	 Question 1: How many rats are there in this picture? Answer: Three Question 2: How many ducks are there in this picture? Answer: Four Question 3: How many shampoo bottles are there on the sink? Answer: Two Question 4: What is the color of T-shirts? Answer: Read and blue Question 5: Where is a rat on your left hand standing? Answer: A box

No.	The test pictures
3	
	Question 1: How many handprints are there in this picture? Answer: Four Question 2: How many lamps are there in this picture? Answer: Three Question 3: How many toys are there on the shelf? Answer: Two Question 4: What is this child doing? Answer: It depends on participants' vision. Question 5: What are the colors of handprints? Answer: Yellow and red.

Non-test pictures

No.	The non-test pictures
4	
	Question 1: What pictures do picture frames hold? Answer: A leaf, a star, a flower and a cloud. Question 2: What kind of room should it be? Answer: A living room. Question 3: What is on the right hand of the tree pot? Answer: Books Question 4: What is the color of the television? Answer: Black Question 5: Where are boxes? Answer: They are on the left hand of the television.

No.	The non-test pictures
5	
	Question 1: What kind of drinks does this woman making? Answer: It depends on participants' vision. Question 2: What is the color of chairs? Answer: Brown and black Question 3: Where is the menu? Answer: On the wall. Question 4: What is the color of jars? Answer: Brown, red and orange. Question 5: What color of clothes is this woman wearing? Answer: Black and pink

Appendix F Questionnaire for English Speakers

Part 1: General information and language experience

1. Age …….. years old

2. Years of birth ……..

3. Country of origin ……..

4. If you have learned more than one foreign language, please list the languages in which you are most fluent (1) to less fluent (5)

1) ……

☐ Advanced ☐Intermediate ☐Beginner

Please specify the duration of studying: Year …… to Year ……

2) ……

☐ Advanced ☐Intermediate ☐Beginner

Please specify the duration of studying: Year …… to Year ……

3) ……

☐ Advanced ☐Intermediate ☐Beginner

Please specify the duration of studying: Year …… to Year ……

4) ……

☐ Advanced ☐Intermediate ☐Beginner

Please specify the duration of studying: Year …… to Year ……

5) ……

☐ Advanced ☐Intermediate ☐Beginner

Please specify the duration of studying: Year …… to Year ……

5. Within the last 6 years, have you been in a foreign country? If yes, please give information as follows:

1) Country …….

Year of arrival ……..

How long did you stay?

☐ 1-3 months ☐ 4-6 months

☐ 7-9 months ☐ 10-12 months

2) Country …….

Year of arrival ……..

How long did you stay?

☐ 1-3 months ☐ 4-6 months

☐ 7-9 months ☐ 10-12 months

3) Country …….

Year of arrival ……..

How long did you stay?

☐ 1-3 months ☐ 4-6 months

☐ 7-9 months ☐ 10-12 months

4) Country …….

Year of arrival ……..

How long did you stay?

☐ 1-3 months ☐ 4-6 months

☐ 7-9 months ☐ 10-12 months

5) Country …….

Year of arrival ……..

How long did you stay?

☐ 1-3 months ☐ 4-6 months

☐ 7-9 months ☐ 10-12 months

Part 2: Where are they? (Easy mode)

Please answer the questions.

**** Questions are embedded in the actual test. ****

Question 1: *What are two girls doing?*

Answer:

Question 2: *How many birds are there in the picture frame?*

Answer:

Question 3: *What kind of party is shown in this picture?*

Answer:

Question 4: *What are the colors of dogs in this picture?*

Answer:

Question 5: *How many crabs are there in this picture?*

Answer:

Question 6: *How many dolls are there in the shelf?*

Answer:

Question 7: *What are the rabbit and the bear holding?*

Answer:

Question 8: *How many flowers are there in this picture?*

Answer:

Question 9: *What is the color of the chairs?*

Answer:

Question 10: *How many clouds are there in this picture?*

Answer:

Part 3: "Which one is different from the other two?"

Please select one of two alternate pictures that differ from the first one within 5 seconds.

If you do not know the answers, please select "uncertain" or leave blank.

1. ☐ the first alternate picture ☐ the second alternate picture ☐ uncertain

2. ☐ the first alternate picture ☐ the second alternate picture ☐ uncertain

3. ☐ the first alternate picture ☐ the second alternate picture ☐ uncertain

4. ☐ the first alternate picture ☐ the second alternate picture ☐ uncertain

5. ☐ the first alternate picture ☐ the second alternate picture ☐ uncertain

6. ☐ the first alternate picture ☐ the second alternate picture ☐ uncertain

7. ☐ the first alternate picture ☐ the second alternate picture ☐ uncertain

8. ☐ the first alternate picture ☐ the second alternate picture ☐ uncertain

9. ☐ the first alternate picture ☐ the second alternate picture ☐ uncertain

10. ☐ the first alternate picture ☐ the second alternate picture ☐ uncertain

Part 4: Where are they? (Difficult mode)

Please answer the questions.

***** Questions are not be revealed in the actual test.*****

Situation 1: A café'

Question 1: *What kind of drinks does this woman making?*

Answer:

Question 2: *What is the color of chairs?*

Answer:

Question 3: *Where is the menu?*

Answer:

Question 4: *What is the color of jars?*

Answer:

Question 5: *What color of clothes is this woman wearing?*

Answer:

Situation 2: A dirty bathroom

Question 1: *What is the color of T-shirts?*

Answer:

Question 2: *How many ducks are there in this picture?*

Answer:

Question 3: *How many shampoo bottles are there on the sink?*

Answer:

Question 4: *Where is a rat on your left hand standing?*

Answer:

Question 5: *How many rats are there in this picture?*

Answer:

Situation 3: A dirty living room

Question 1: *What is this child doing?*

Answer:

Question 2: *How many lamps are there in this picture?*

Answer:

Question 3: *What are the colors of handprints?*

Answer:

Question 4: *How many handprints are there in this picture?*

Answer:

Question 5: *How many toys are there on the shelf?*

Answer:

Situation 4: A living room

Question 1: *What pictures do picture frames hold?*

Answer:

Question 2: *What kind of room should it be?*

Answer:

Question 3: *What is on the right hand of the tree pot?*

Answer:

Question 4: *What is the color of the television?*

Answer:

Question 5: *Where are boxes?*

Answer:

Situation 5: A bedroom

Question 1: *What is the color of the bed?*

Answer:

Question 2: *Why is this child crying?*

Answer:

Question 3: *How many picture frames are there in this picture?*

Answer:

Question 4: *How many balls are there in this picture?*

Answer:

Question 5: *How many toys are there on the cabinet?*

Answer:

Appendix G Questionnaire for Thai Speakers

<u>ส่วนที่ 1: ข้อมูลทั่วไปและประสบการณ์ทางภาษา</u>

1. อายุ …….. ปี

2. ปี พ.ศ.ที่เกิด …….

3. คุณเกิดที่ประเทศอะไร…….

4. ถ้าคุณเคยเรียนภาษาต่างประเทศ กรุณาเรียงลำดับภาษาที่คุณเชี่ยวชาญมากที่สุดจนถึงน้อยที่สุด เชี่ยวชาญมากที่สุด (1) ---------- > เชี่ยวชาญน้อยที่สุด (5)

1) ……

ระดับความเชี่ยวชาญ

☐ ระดับสูง ☐ ระดับปานกลาง ☐ ระดับต้น

กรุณาระบุช่วงเวลาที่เรียน: พ.ศ. …… – พ.ศ. …….

2) ……

ระดับความเชี่ยวชาญ

☐ ระดับสูง ☐ ระดับปานกลาง ☐ ระดับต้น

กรุณาระบุช่วงเวลาที่เรียน: พ.ศ. …… – พ.ศ. …….

3) ……

ระดับความเชี่ยวชาญ

☐ ระดับสูง ☐ ระดับปานกลาง ☐ ระดับต้น

กรุณาระบุช่วงเวลาที่เรียน: พ.ศ. …… – พ.ศ. …….

4) ……

ระดับความเชี่ยวชาญ

☐ ระดับสูง ☐ ระดับปานกลาง ☐ ระดับต้น

กรุณาระบุช่วงเวลาที่เรียน: พ.ศ. …… – พ.ศ. …….

5) ……

ระดับความเชี่ยวชาญ

☐ ระดับสูง ☐ ระดับปานกลาง ☐ ระดับต้น

กรุณาระบุช่วงเวลาที่เรียน: พ.ศ. …… – พ.ศ. ……

5. ภายในระยะเวลา 6 ปี คุณเคยไปต่างประเทศหรือไม่ ถ้าเคยไป กรุณากรอกข้อมูลดังนี้

1) ประเทศที่ไป ……

คุณเดินทางไปในปีใด ……..

คุณอยู่ที่ประเทศดังกล่าวนานแค่ไหน

☐ 1-3 เดือน ☐ 4-6 เดือน

☐ 7-9 เดือน ☐ 10-12 เดือน

2) ประเทศที่ไป ……

คุณเดินทางไปในปีใด ……..

คุณอยู่ที่ประเทศดังกล่าวนานแค่ไหน

☐ 1-3 เดือน ☐ 4-6 เดือน

☐ 7-9 เดือน ☐ 10-12 เดือน

3) ประเทศที่ไป ……

คุณเดินทางไปในปีใด ……..

คุณอยู่ที่ประเทศดังกล่าวนานแค่ไหน

☐ 1-3 เดือน ☐ 4-6 เดือน

☐ 7-9 เดือน ☐ 10-12 เดือน

4) ประเทศที่ไป ……

คุณเดินทางไปในปีใด ……..

คุณอยู่ที่ประเทศดังกล่าวนานแค่ไหน

☐ 1-3 เดือน ☐ 4-6 เดือน

☐ 7-9 เดือน ☐ 10-12 เดือน

5) ประเทศที่ไป .....

คุณเดินทางไปในปีใด .....

คุณอยู่ที่ประเทศดังกล่าวนานแค่ไหน

☐ 1-3 เดือน ☐ 4-6 เดือน

☐ 7-9 เดือน ☐ 10-12 เดือน

<u>ส่วนที่ 2 เกมส์พวกเขาอยู่ที่ไหน (แบบง่าย)</u>

*****คำถามไม่ปรากฏในกระดาษคำตอบในการทดสอบจริง*****

<u>กรุณาตอบคำถาม</u>

คำถาม 1 : *เด็กสองคนกำลังทำอะไร*

ตอบ :

คำถาม 2 : *นกในกรอบรูปมีจำนวนกี่ตัว*

ตอบ :

คำถาม 3 : *จากสภาพในรูปนี้ควรเป็นงานอะไร*

ตอบ :

คำถาม 4 : *สีของสุนัขในรูปคือสีอะไร*

ตอบ :

คำถาม 5 : *มีปูกี่ตัว*

ตอบ :

คำถาม 6 : *ตุ๊กตาในตู้มีกี่ตัว*

ตอบ :

คำถาม 7 : *กระต่ายกับหมีถืออะไรอยู่*

ตอบ :

คำถาม 8: *ดอกไม้กี่ดอก*

ตอบ :

คำถาม 9*: เก้าอี้สีอะไร*

ตอบ :

คำถาม 10: *มีก้อนเมฆกี่ก้อน*

ตอบ :

<u>ส่วนที่ 3 เกมส์ “อะไรต่างจากพวก”</u>

<u>กรุณาเลือกรูปภาพที่ต่างจากรูปภาพแรก ภายในเวลา 5 วินาที หากไม่แน่ใจ ให้เลือก “ไม่แน่ใจ” หรือ ไม่ระบุ</u>

1. ☐ รูปตัวเลือกที่ 1 ☐รูปตัวเลือกที่ 2 ☐ ไม่แน่ใจ
2. ☐ รูปตัวเลือกที่ 1 ☐รูปตัวเลือกที่ 2 ☐ ไม่แน่ใจ
3. ☐ รูปตัวเลือกที่ 1 ☐รูปตัวเลือกที่ 2 ☐ ไม่แน่ใจ
4. ☐ รูปตัวเลือกที่ 1 ☐รูปตัวเลือกที่ 2 ☐ ไม่แน่ใจ
5. ☐ รูปตัวเลือกที่ 1 ☐รูปตัวเลือกที่ 2 ☐ ไม่แน่ใจ
6. ☐ รูปตัวเลือกที่ 1 ☐รูปตัวเลือกที่ 2 ☐ ไม่แน่ใจ
7. ☐ รูปตัวเลือกที่ 1 ☐รูปตัวเลือกที่ 2 ☐ ไม่แน่ใจ
8. ☐ รูปตัวเลือกที่ 1 ☐รูปตัวเลือกที่ 2 ☐ ไม่แน่ใจ
9. ☐ รูปตัวเลือกที่ 1 ☐รูปตัวเลือกที่ 2 ☐ ไม่แน่ใจ
10. ☐ รูปตัวเลือกที่ 1 ☐รูปตัวเลือกที่ 2 ☐ ไม่แน่ใจ

<u>ส่วนที่ 3 เกมส์พวกเขาอยู่ที่ไหน (แบบยาก)</u>

*****คำถามไม่ปรากฏในกระดาษคำตอบในการทดสอบจริง*****

<u>กรุณาตอบคำถาม</u>

สถานการณ์ที่ 1 คาเฟ่

คำถาม 1: *ผู้หญิงกำลังชงอะไร*

ตอบ :

คำถาม 2: *เก้าอี้สีอะไร*

ตอบ :

คำถาม 3: *เมนูอยู่ที่ไหน*

ตอบ :

คำถาม 4: *ขวดโหลเป็นสีอะไร*

ตอบ :

คำถาม 5: *ผู้หญิงใส่เสื้อสีอะไร*

ตอบ :

สถานการณ์ที่ 2 ห้องน้ำสกปรก

คำถาม 1: *เสื้อสีอะไร*

ตอบ :

คำถาม 2: *มีเป็ดกี่ตัว*

ตอบ :

คำถาม 3: *มีขวดบนอ่างล่างหน้ากี่ขวด*

ตอบ :

คำถาม 4: *หนูตัวซ้ายมือยืนอยู่บนอะไร*

ตอบ :

คำถาม 5: *มีหนูกี่ตัว*

ตอบ :

สถานการณ์ที่ 3 ห้องนั่งเล่นสกปรก

คำถาม 1: *เด็กกำลังทำอะไร*

ตอบ :

คำถาม 2: *มีโคมไฟกี่อัน*

ตอบ :

คำถาม 3: *รอยมือสีอะไรบ้าง*

ตอบ :

คำถาม 4: *มีรอยมือที่โซฟากี่รอย*

ตอบ :

คำถาม 5: *มีของเล่นบนชั้นกี่อัน*

ตอบ :

สถานการณ์ที่ 4 ห้องนั่งเล่นสะอาด

คำถาม 1: *มีรูปอะไรในกรอบรูป*

ตอบ :

คำถาม 2: *ห้องในรูปนี้น่าจะเป็นห้องอะไร*

ตอบ :

คำถาม 3: *อะไรอยู่ทางขวาของต้นไม้บนตู้เก็บของ*

ตอบ :

คำถาม 4: *โทรทัศน์สีอะไร*

ตอบ :

คำถาม 5: *กล่องอยู่ที่ไหน*

ตอบ :

สถานการณ์ที่ 5 ห้องนอน

คำถาม 1: *เตียงนอนสีอะไร*

ตอบ :

คำถาม 2: *ทำไมเด็กถึงร้องไห้*

ตอบ :

คำถาม 3: *มีกรอบรูปกี่อัน*

ตอบ :

คำถาม 4: *มีลูกบอลกี่ลูก*

ตอบ :

คำถาม 5: *ของเล่นบนชั้นมีกี่อัน*

ตอบ :

Appendix H Questionnaire for Thai-English Bilinguals

<u>ส่วนที่ 1: ข้อมูลทั่วไปและประสบการณ์ทางภาษา (Part 1: General information and language experience)</u>

1. อายุ …….. ปี

2. ปี พ.ศ.ที่เกิด …….

3. คุณเกิดที่ประเทศอะไร…….

4. ถ้าคุณเคยเรียนภาษาต่างประเทศ กรุณาเรียงลำดับภาษาที่คุณเชี่ยวชาญมากที่สุดจนถึงน้อยที่สุด เชี่ยวชาญมากที่สุด (1) ---------- > เชี่ยวชาญน้อยที่สุด (5) (If you have learned more than one foreign language, please list the languages in which you are most fluent (1) to less fluent (5))

   1) ……

   ระดับความเชี่ยวชาญ (Levels of fluency)

   ☐ ระดับสูง (Advanced) ☐ ระดับปานกลาง (Intermediate) ☐ ระดับต้น (Beginner)

   กรุณาระบุช่วงเวลาที่เรียน (Please specify the duration of studying)

   พ.ศ. (Year)……. – พ.ศ. (Year) …….

   2) ……

   ระดับความเชี่ยวชาญ (Levels of fluency)

   ☐ ระดับสูง (Advanced) ☐ ระดับปานกลาง (Intermediate) ☐ ระดับต้น (Beginner)

   กรุณาระบุช่วงเวลาที่เรียน (Please specify the duration of studying)

   พ.ศ. (Year)……. – พ.ศ. (Year) …….

   3) ……

   ระดับความเชี่ยวชาญ (Levels of fluency)

   ☐ ระดับสูง (Advanced) ☐ ระดับปานกลาง (Intermediate) ☐ ระดับต้น (Beginner)

   กรุณาระบุช่วงเวลาที่เรียน (Please specify the duration of studying)

   พ.ศ. (Year)……. – พ.ศ. (Year) …….

4) ……

ระดับความเชี่ยวชาญ (Levels of fluency)

☐ ระดับสูง (Advanced) ☐ ระดับปานกลาง (Intermediate) ☐ ระดับต้น (Beginner)

กรุณาระบุช่วงเวลาที่เรียน (Please specify the duration of studying)

พ.ศ. (Year)…… – พ.ศ. (Year) …….

5) ……

ระดับความเชี่ยวชาญ (Levels of fluency)

☐ ระดับสูง (Advanced) ☐ ระดับปานกลาง (Intermediate) ☐ ระดับต้น (Beginner)

กรุณาระบุช่วงเวลาที่เรียน (Please specify the duration of studying)

พ.ศ. (Year)…… – พ.ศ. (Year) …….

5. ภายในระยะเวลา 6 ปี คุณเคยไปต่างประเทศหรือไม่ ถ้าเคยไป กรุณากรอกข้อมูลดังนี้ (Within the last 6 years, have you been in a foreign country? If yes, please give information as follows.)

1) ประเทศที่ไป (Country) ……

คุณเดินทางไปในปีใด (Year of arrival) ……..

คุณอยู่ที่ประเทศดังกล่าวนานแค่ไหน (How long did you stay?)

☐ 1-3 เดือน (1-3 months) ☐ 4-6 เดือน (4-6 months)

☐ 7-9 เดือน (7-9 months) ☐ 10-12 เดือน (10-12 months)

2) ประเทศที่ไป (Country) ……

คุณเดินทางไปในปีใด (Year of arrival) ……..

คุณอยู่ที่ประเทศดังกล่าวนานแค่ไหน (How long did you stay?)

☐ 1-3 เดือน (1-3 months) ☐ 4-6 เดือน (4-6 months)

☐ 7-9 เดือน (7-9 months) ☐ 10-12 เดือน (10-12 months)

3) ประเทศที่ไป (Country) …….

คุณเดินทางไปในปีใด (Year of arrival) ……..

คุณอยู่ที่ประเทศดังกล่าวนานแค่ไหน (How long did you stay?)

☐ 1-3 เดือน (1-3 months) ☐ 4-6 เดือน (4-6 months)

☐ 7-9 เดือน (7-9 months) ☐ 10-12 เดือน (10-12 months)

4) ประเทศที่ไป (Country) …….

คุณเดินทางไปในปีใด (Year of arrival) ……..

คุณอยู่ที่ประเทศดังกล่าวนานแค่ไหน (How long did you stay?)

☐ 1-3 เดือน (1-3 months) ☐ 4-6 เดือน (4-6 months)

☐ 7-9 เดือน (7-9 months) ☐ 10-12 เดือน (10-12 months)

5) ประเทศที่ไป (Country) …….

คุณเดินทางไปในปีใด (Year of arrival) ……..

คุณอยู่ที่ประเทศดังกล่าวนานแค่ไหน (How long did you stay?)

☐ 1-3 เดือน (1-3 months) ☐ 4-6 เดือน (4-6 months)

☐ 7-9 เดือน (7-9 months) ☐ 10-12 เดือน (10-12 months)

ส่วนที่ 2 เกมส์พวกเขาอยู่ที่ไหน (แบบง่าย) (Part 2: Game "Where are they? (Easy mode))"

คำถามไม่ปรากฏในกระดาษคำตอบในการทดสอบจริง*

*** Questions are embedded in the actual test. ***

กรุณาตอบคำถาม (Please answer the question.)

คำถาม 1 : *เด็กสองคนกำลังทำอะไร (What are two girls doing?)*

ตอบ (Answer)

คำถาม 2 : *นกในกรอบรูปมีจำนวนกี่ตัว (how many birds are there in the picture frame?)*

ตอบ (Answer)

คำถาม 3 : *จากสภาพในรูปนี้ควรเป็นงานอะไร (What kind of party is shown in this picture?)*

ตอบ (Answer)

คำถาม 4 : *สีของสุนัขในรูปคือสีอะไร (What are the colors of dogs in this picture?)*

ตอบ (Answer)

คำถาม 5 : *มีปูกี่ตัว (How many crabs are there in this picture?)*

ตอบ (Answer)

คำถาม 6 : *ตุ๊กตาในตู้มีกี่ตัว (How many dolls are there in the shelf?)*

ตอบ (Answer)

คำถาม 7 : *กระต่ายกับหมีถืออะไรอยู่ (What are the rabbit and the bear holding?)*

ตอบ (Answer)

คำถาม 8: *ดอกไม้กี่ดอก (How many flowers are there in this picture?)*

ตอบ (Answer)

คำถาม 9: *เก้าอี้สีอะไร (What is the color of the chairs?)*

ตอบ (Answer)

คำถาม 10: *มีก้อนเมฆกี่ก้อน (How many clouds are there in this picture?)*

ตอบ (Answer)

ส่วนที่ 3 เกมส์ "อะไรต่างจากพวก" (Part 3: Game "Which one is different from the other two?")

กรุณาเลือกรูปภาพที่ต่างจากรูปภาพแรก ภายในเวลา 5 วินาที หากไม่แน่ใจ ให้เลือก "ไม่แน่ใจ" หรือ ไม่ระบุ

Please select one of two alternate pictures that differ from the first one within 5 seconds. If you do not know the answers, please select "uncertain" or leave blank.

1. ☐ รูปตัวเลือกที่ 1 (the first alternate picture)
   ☐ รูปตัวเลือกที่ 2 (the second alternate picture)
   ☐ ไม่แน่ใจ
2. ☐ รูปตัวเลือกที่ 1 (the first alternate picture)
   ☐ รูปตัวเลือกที่ 2 (the second alternate picture)
   ☐ ไม่แน่ใจ
3. ☐ รูปตัวเลือกที่ 1 (the first alternate picture)
   ☐ รูปตัวเลือกที่ 2 (the second alternate picture)
   ☐ ไม่แน่ใจ
4. ☐ รูปตัวเลือกที่ 1 (the first alternate picture)
   ☐ รูปตัวเลือกที่ 2 (the second alternate picture)
   ☐ ไม่แน่ใจ
5. ☐ รูปตัวเลือกที่ 1 (the first alternate picture)
   ☐ รูปตัวเลือกที่ 2 (the second alternate picture)
   ☐ ไม่แน่ใจ

6. ☐ รูปตัวเลือกที่ 1 (the first alternate picture)
   ☐รูปตัวเลือกที่ 2 (the second alternate picture)
   ☐ ไม่แน่ใจ
7. ☐ รูปตัวเลือกที่ 1 (the first alternate picture)
   ☐รูปตัวเลือกที่ 2 (the second alternate picture)
   ☐ ไม่แน่ใจ
8. ☐ รูปตัวเลือกที่ 1 (the first alternate picture)
   ☐รูปตัวเลือกที่ 2 (the second alternate picture)
   ☐ ไม่แน่ใจ
9. ☐ รูปตัวเลือกที่ 1 (the first alternate picture)
   ☐รูปตัวเลือกที่ 2 (the second alternate picture)
   ☐ ไม่แน่ใจ
10. ☐ รูปตัวเลือกที่ 1 (the first alternate picture)
   ☐รูปตัวเลือกที่ 2 (the second alternate picture)
   ☐ ไม่แน่ใจ

ส่วนที่ 4 เกมส์พวกเขาอยู่ที่ไหน (แบบยาก) (Part 4: Game "Where are they? (Difficult **

คำถามไม่ปรากฏในกระดาษคำตอบในการทดสอบจริง*

*** Questions are embedded in the actual test. ****

สถานการณ์ที่ 1 คาเฟ่ (Situation 1: A café')

คำถาม 1: *ผู้หญิงกำลังชงอะไร (What kind of drinks does this woman making?)*

ตอบ (Answer)

คำถาม 2: *เก้าอี้สีอะไร (What is the color of chairs?)*

ตอบ (Answer)

คำถาม 3: *เมนูอยู่ที่ไหน (Where is the menu?)*

ตอบ (Answer)

คำถาม 4: *ขวดโหลเป็นสีอะไร (What is the color of jars?)*

ตอบ (Answer)

คำถาม 5: *ผู้หญิงใส่เสื้อสีอะไร (What color of clothes is this woman wearing?)*

ตอบ (Answer)

สถานการณ์ที่ 2 ห้องน้ำสกปรก (Situation 2: A dirty bathroom)

คำถาม 1: *เสื้อสีอะไร (What is the color of T-shirts?)*

ตอบ (Answer)

คำถาม 2: *มีเป็ดกี่ตัว (How many ducks are there in this picture?)*

ตอบ (Answer)

คำถาม 3: *มีขวดบนชั้นวางของกี่ขวด (How many shampoo bottles are there on the vanity?)*

ตอบ (Answer)

คำถาม 4: *หนูตัวซ้ายมือยืนอยู่บนอะไร (Where is a rat on your left hand standing at?)*

ตอบ (Answer)

คำถาม 5: *มีหนูกี่ตัว (How many rats are there in this picture?)*

ตอบ (Answer)

สถานการณ์ที่ 3 ห้องนั่งเล่นสกปรก (Situation 3: A dirty living room)

คำถาม 1: *เด็กกำลังทำอะไร (What is this child doing?*

ตอบ (Answer)

คำถาม 2*: มีโคมไฟกี่อัน (How many lamps are there in this picture?)*

ตอบ (Answer)

คำถาม 3: *รอยมือสีอะไรบ้าง (What are the colors of handprints?)*

ตอบ (Answer)

คำถาม 4: *มีรอยมือที่โซฟากี่รอย (How many handprints are there in this picture?)*

ตอบ (Answer)

คำถาม 5: *มีของเล่นบนชั้นกี่อัน (How many toys are there in the shelf?)*

ตอบ (Answer)

สถานการณ์ที่ 4 ห้องนั่งเล่นสะอาด (Situation 4: A clean living room)

คำถาม 1: *มีรูปอะไรในกรอบรูป (What pictures do picture frames hold?*

ตอบ (Answer)

คำถาม 2: *ห้องในรูปนี้น่าจะเป็นห้องอะไร (What kind of room should it be?)*

ตอบ (Answer)

คำถาม 3: อะ*ไรอยู่ทางขวาของต้นไม้บนตู้เก็บของ (What is on the right hand of the tree pot?)*

ตอบ (Answer)

คำถาม 4: *โทรทัศน์สีอะไร (What is the color of the television?)*

ตอบ (Answer)

คำถาม 5: *กล่องอยู่ที่ไหน (Where are boxes?)*

ตอบ (Answer)

สถานการณ์ที่ 5 ห้องนอน (Situation 5: A bedroom)

คำถาม 1: *เตียงนอนสีอะไร (What is the color of the bed?)*

ตอบ (Answer)

คำถาม 2: *ทำไมเด็กถึงร้องไห้ (Why is this child crying?)*

ตอบ (Answer)

คำถาม 3: *มีกรอบรูปกี่อัน (How many picture frames are there in this picture?)*

ตอบ (Answer)

คำถาม 4: *มีลูกบอลกี่ลูก (How many balls are there in this picture?)*

ตอบ (Answer)

คำถาม 5: *ของเล่นบนชั้นมีกี่อัน (How many toys are there on the cabinet?)*

ตอบ (Answer)

Appendix I The Results of Non-Test Pictures across Cognitive Tasks

This appendix presents the average scores for non-test pictures across three cognitive tasks—Attention test, memory test using photo hunt, and memory test using short-answer questions. Non-test pictures were intentionally incorporated to divert participants' awareness from the actual focus of the test. Each group comprises 30 participants, categorized by language background and English proficiency levels. The scores, measured on a scale of 0 to 5, provide insights into participants' cognitive performance when engaging with these non-test pictures, focusing on their ability to process features such as the size, color, and situational context of objects depicted in the pictures. Detailed results are summarized in the table below.

Groups of Participants	The Average Scores of Non-test Pictures across Cognitive Tasks (out of 5 scores)		
	Attention Test	Memory Test Using Photo Hunt	Memory Test Using Short-Answer Questions
English speakers (N=30)	3.50	3.24	3.25
Thai speakers (N=30)	4.00	3.50	3.97
Thai-English bilinguals who have English proficiency at the basic level (N=30)	3.90	3.40	3.54
Thai-English bilinguals who have English proficiency at the intermediate level (N=30)	4.00	3.35	3.32
Thai-English bilinguals who have English proficiency at the advanced level (N=30)	3.80	3.15	3.25

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