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Analyzing bilingual advantage in metalinguistic awareness: the roles of executive functioning and vocabulary knowledge on metalinguistic tasks

A thesis submitted in partial satisfaction

of the requirements for the degree of Mater of Arts

in Education

By

Lichao Sun

2016

ABSTRACT OF THE THESIS

Analyzing bilingual advantage in metalinguistic awareness: the roles of executive functioning and vocabulary knowledge on metalinguistic tasks

by

Lichao Sun

Master of Arts in Education

University of California, Los Angeles, 2016

Professor Alison L. Bailey, Chair

Past research has found that bilingual children exhibit an advantage on metalinguistic awareness, the metacognitive ability to reflect on language. However, studies of executive functioning and bilingualism have yielded conflicting results. Given bilinguals need to concentrate on the relevant linguistic system and suppress interference from a second linguistic system simultaneously during processing, they have demonstrated better performance on nonverbal executive tasks involving the choice of two competing perceptual stimuli (interference suppression). However, bilinguals performed no differently on verbal executive tasks that required inhibition of habitual or prepotent responses (response inhibition) than monolinguals. Furthermore, bilinguals have shown weaker vocabulary knowledge in both languages than monolinguals. Thus, the current study hypothesizes that bilingual performance varies in metalinguistic tasks according to task demands on types of executive functioning (interference suppression or response inhibition) and the involvement of linguistic knowledge.

This research aims to analyze the roles of executive control and vocabulary knowledge in metalinguistic tasks in an effort to assess how these two components independently and jointly contribute to metalinguistic development in bilingual and monolingual children. Sixteen English-monolingual 2nd graders and sixteen English-Spanish emerging bilinguals were recruited from a university demonstration school. All students completed four subtests, including Expressive One-Word Picture Vocabulary Test, Color-Shape Task, Zoo Game, and Auditory-visual Selective Attention Task. As expected, this study found bilingual advantage appears differently according to the types of executive control engaged in the metalinguistic tasks. Specifically, emerging bilingual had significantly higher accuracy and less reaction time on the nonverbal metalinguistic tasks involved with response inhibition in relative to monolinguals; meanwhile, there was a bilingual advantage in the number of total responses in the nonverbal interference suppression task. However, emerging bilinguals performed the same as monolinguals did in the verbal interference suppression task. These findings provide new evidence for the diverse effects of bilingualism in the cognitive processing underlying metalinguistic competence.

The thesis of Lichao Sun is approved.

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Table of Contents

With the increasing bilingual population in the U.S., researchers are starting to pay more attention to analyzing the influence of daily language experiences on literacy development in bilingual children (e.g., Hinkel, 2011; August & Shanahan, 2006). According to Bialystok (2007), there are three prerequisite skills for literacy acquisition, which are competence with the oral language, understanding of symbolic concepts of print, and establishment of metalinguistic awareness. Specifically, metalinguistic awareness can be characterized as the metacognitive ability that consciously reflects on the structure of linguistic knowledge and the cognitive processes engaged in literacy learning. Research over the past 30 years has consistently found that bilingual children exhibit advantages on metalinguistic tasks relative to their monolingual peers (Adesope, Lavin, Thompson & Ungerleider, 2010). Bilingual children have demonstrated better performance on executive functioning tasks but weaker formal language knowledge when compared with their monolingual peers (e.g., Bialystok, Craik & Luk, 2008; Esposito et al., 2013; Carlson & Meltzoff, 2008). However, the relationship between executive functioning and linguistic knowledge on metalinguistic development and the contribution of each component are still unclear. The purpose of this study is to analyze the roles of executive functioning and vocabulary knowledge in metalinguistic tasks in an effort to assess how these two components independently and jointly contribute to bilingual advantage on metalinguistic development.

Literature Review

Metalinguistic Awareness and Its Components

Metalinguistic awareness refers to an individual's linguistic knowledge and consciousness of language structures and its functions. In a factor analysis, Ricciardelli (1993) confirmed executive functioning and linguistic knowledge are indeed separate components of performance on metalinguistic tasks. Bilingualism benefits the development of executive functioning, but does not show significant effect on the acquisition of language representations. From the perspective of executive functioning, a number of studies have demonstrated that bilinguals perform significantly better on nonverbal executive control tasks across the life span (Adesope, Lavin, Thompson, & Ungerleider, 2010). For instance, bilingual preschoolers produced shorter reaction times to both congruent and incongruent trials on the Simon task than monolingual did (Martin-Rhee & Bialystok, 2008). Young bilingual children had lower response times on the test of color-shape task switching (Barac & Bialystok, 2012) as well as less percentage of errors on the Dimensional Change Card Sort (Carlson & Meltzoff, 2008) than their monolingual peers. Bilingual adults also had less latency of time than monolinguals had on both the Simon Task (Bialystok et al., 2004) and the Stroop Color-naming task (Bialystok, Craik &Luk, 2008). Moreover, the size of the metalinguistic advantage increased with age, indicating a slower decline in performance with aging for bilinguals (Bialystok, Craik & Luk, 2008). The underlying mechanism of bilingual advantage on nonverbal executive control tasks is based on the involvement of the executive functioning system in bilingual language processing (Bialystok, 2011). Bilinguals need to manage two or more linguistic representations, and recruit the executive network to manage attention on the targeted language corresponding with the specific linguistic context. Thus, bilinguals experience extensive practice in selective attention and cognitive flexibility (Esposito et al., 2013). This substantial practice using the executive network for language selection enables bilinguals to have more efficient executive functioning skills.

From the perspective of linguistic knowledge, bilinguals show disadvantages on formal vocabulary tests. Many bilingual studies involve at least one test for English vocabulary before measuring executive functioning. Although bilinguals have demonstrated a total larger amount of vocabulary, they have less vocabulary knowledge in each of their language than their monolingual peers (Pearson et al., 1993). For example, bilingual children performed significantly worse than monolinguals at each age from 3 to 10-years old on the test of English receptive vocabulary (Bialystok, Luk, Peets & Yang, 2010). Young and older bilingual adults had significantly lower scores on the Verbal Task Battery including the Peabody Picture Vocabulary Test, Category Fluency Task, and Boston naming Task (Bialystok, Craik & Luk, 2008). These findings indicate that monolinguals have more experience in encoding and retrieving representations from a language system than bilingual individuals; meanwhile, bilingualism limits bilingual individual's exposure to each of their languages. In addition, since bilinguals need to pay more attention to resolve the conflicts between competing responses from various language systems, it is plausible that bilinguals pay limited attention to lexical retrieval in the monolingual environment, leading to their poor performance on vocabulary knowledge tasks.

Combining these findings above, Friesen & Bialystok (2012) claimed that bilingual advantages in metalinguistic awareness vary according to the degree to which metalinguistic tasks require vocabulary knowledge and executive control. Bilinguals should significantly outperform monolinguals on the metalinguistic tasks that involve high demands on executive functioning and limited vocabulary knowledge. For instance, bilingual adults completed both the congruent and incongruent trials on the Simon task in shorter reaction time than their monolingual peers (Bialystok, Craik & Luk, 2008). In contrast to the bilingual advantage on nonverbal executive control tasks, bilinguals have worse performance than monolinguals on vocabulary tasks that involve little executive functioning. For example, the Wug test requires children to apply their implicit linguistic morphology to sentences with some novel words. Barac & Bialystok (2012) found that both 6-years old Chinese-English children and French-English children who had lower scores than English-speaking peers in the receptive vocabulary also had worse performance on the Wug test when compared with monolingual students. Only the Spanish-English students who had comparable scores for English vocabulary and grammar knowledge to their English-speaking peers showed equivalent performance on the Wug Test as monolingual (Barac & Bialystok, 2012). These results suggest that bilinguals perform worse than monolinguals on a metalinguistic task only assessing vocabulary knowledge but not involved with any executive functioning demand. Only when bilinguals have a comparable amount of vocabulary knowledge as monolinguals have, does the bilingual advantage on a verbal metalinguistic task appear.

The previous studies separately investigated the role of executive functioning and vocabulary knowledge in influencing bilingual performance on tasks of metalinguistic awareness. However, there is limited research assessing the joint contribution of executive functioning and linguistic knowledge on metalinguistic development. When it is a metalinguistic task both related to executive functioning as well as vocabulary knowledge, bilinguals' superior executive control skills may compensate the disadvantage of limited vocabulary knowledge. For instance, the Stroop color-naming effect assesses participants' metalinguistic ability through naming the font color which conflicts with the color names

(Stroop, 1935). The Stroop color-naming task requires participant's executive control (e.g., participant needs to pay attention to the targeted color only) as well as vocabulary knowledge (e.g., the knowledge of color words). Bialystok, Craik, & Luk (2008) found that young bilinguals had significantly less latency of time and less error than the same-aged monolingual participants on the Stroop color-naming task. Moreover, the size of the metalinguistic advantage increased with age, indicating a slower decline in performance with aging for bilinguals (Bialystok, Craik, & Luk, 2008). Therefore, bilinguals may preserve their advantages on metalinguistic tasks when the characteristics of the task require both executive control and vocabulary knowledge. It also seems plausible that the outstanding competence of executive functioning may compensate for bilinguals' week vocabulary knowledge in each language when compared with monolinguals (Friesen & Bialystok, 2012).

Bilingualism and The Development of Executive Control

In addition to the engagement of vocabulary knowledge, the different types of executive control can also affect bilingual performance in diverse metalinguistic tasks. Executive functioning refers to a set of general-purpose control processes that regulate one's thoughts and behaviors. Miyake et al. (2000) claimed that executive network consists of three core components: inhibition (inhibitory control), shifting (cognitive flexibility), and updating (working memory). Previous studies investigating the effect of bilingualism on executive functioning primarily focused on the role of inhibition. Specifically, bilingual advantage varies according to two different types of inhibitory control: interference suppression and response inhibition (e.g., Bialystok et al., 2004; Martin-Rhee & Bialystok, 2008; Esposito et al., 2013)

The distinction between types of inhibitory control refers to the difference between bivalent displays which are comprised of two potentially conflicting dimensions, and univalent displays in which only a single feature is presented (Bunge et al., 2002). The two features of bivalent displays can either converge on a single response, creating congruent trials, or conflict by indicating different responses, creating incongruent trials. Bunge and her colleagues (2002) call the inhibition required in this case "interference suppression." For instance, the DCCS paradigm is a measure of executive function based on interference suppression that requires children to sort bivalent test cards depending on one dimension (e.g. shape) or the other (e.g. color) (Martin-Rhee & Bialystok, 2008). Since bilinguals have two or more semantic systems, which provide different, potentially competing response options to the same goal, bilinguals experience a lot of selective attention practices during their daily lives that require them to focus attention on the relevant language system and inhibit response from other lexical domains. Thus, bilingual preschoolers responded more rapidly than monolinguals to both the congruent and incongruent trials in the bivalent arrow task (Martin-Rhee & Bialystok, 2008). Also, Esposito et al. (2013) claimed that bilinguals had higher accuracy on the bivalent shape task, demonstrating bilingual advantage on the nonverbal metalinguistic tasks requiring interference suppression.

On the other hand, the advantage of two or more linguistic systems is not associated with univalent tasks requiring response inhibition (Martin-Rhee & Bialystok, 2008). In the univalent displays, the conflict is between two response options to the same stimulus feature, creating a conflict between the habitual response and a less familiar arbitrary response that must override and replace it. According to Bunge et al. (2002), these problems require a specific inhibitory control ability called “response inhibition”. For example, in the Stroop situation-naming task, children will be asked to say “night” in response to a picture of the sun and “day” in response to a picture of the moon (Esposito et al., 2013). Previous studies have demonstrated that there are no differences in either accuracy or response time between bilingual and monolingual preschoolers on the univalent direction task (Martin-Rhee &Bialystok, 2008) as well as the Sun/Moon task (Esposito et al., 2013). These previous findings suggest that executive control is not a unitary construct but rather comprises different control abilities that exhibit some commonalities as well as specialties (Stuss et al., 2005). Bilingual advantage varies according to the nature of metalinguistic tasks involved with different types of executive control. Therefore, it becomes essential to investigate how metalinguistic development in bilingual and monolingual children is a function of different types of executive control as well as diverse linguistic demands on metalinguistic tasks.

Conceptual Model and Hypotheses

Past research suggests executive functioning and vocabulary knowledge as two major characteristics of metalinguistic awareness. However, these studies rarely discussed the separable function of each component on metalinguistic tasks. Moreover, the impact of the interaction between types of executive control and vocabulary knowledge on metalinguistic ability is not well known. It is plausible that metalinguistic awareness and executive control share some common characteristics and functions, but they have different developmental trajectories and might be affected differently by the language learning environment.

Furthermore, previous research of bilingualism focuses on different bilingual population. For instance, bilingual studies in Canada often recruit participants from different language immersion programs. The majority of these bilingual children systemically learned one language (e.g., English) at school but used another language at home (e.g., French). Thus, the sample of bilingual studies included a large number of developing bilinguals. Different from Canadian bilinguals, bilingual or multilingual populations in the U.S. are comprised of a majority of non-English speaking immigrants (e.g. English language learners). In particular, bilingual children from low SES families do not have sufficient language-learning resources. Little is known about the metalinguistic development in emerging bilinguals in the U.S.. The current study recruited English-Spanish emerging bilinguals from an immersion program in the U.S., and investigates whether bilingual advantages appear in diverse metalinguistic tasks.

This study aims to analyze the roles of executive functioning and vocabulary knowledge on metalinguistic tasks in an effort to assess how these two components independently and jointly contribute to metalinguistic development in bilingual and monolingual children. This study includes two parts. Part I of the current study assesses whether a bilingual advantage appears on the vocabulary knowledge test as well as different types of nonverbal executive functioning tasks (shown in Appendix I). In particular, this study addresses the question of the effects of bilingualism in two specific skills of executive control, interference suppression and response inhibition.

- Question 1. Do bilingual children perform differently from monolingual children on a test of English vocabulary knowledge?
- Question 2. When controlling for linguistic effects (i.e., vocabulary knowledge), do bilingual children perform differently from monolingual children according to the

types of executive functioning on nonverbal metalinguistic tasks (interference suppression vs. response inhibition vs. working memory)?

Considering that bilingual children simultaneously use two languages in both the home and school environment, I hypothesize that bilingual children in this study will perform the same as their English monolingual peers on the English vocabulary test.

Given bilinguals need to concentrate on the relevant linguistic system and suppress interference from a second linguistic system simultaneously during language processing, I hypothesize that bilinguals should have better performance on nonverbal executive tasks involving the choice of two competing perceptual stimuli (interference suppression). At the same time, bilinguals do not benefit from their substantial experiences of switching between linguistic systems when inhibiting habitual responses. Thus, bilinguals should perform no differently on nonverbal executive tasks that required inhibition of habitual or prepotent response (response inhibition) than monolinguals.

In Part II, this study investigates the joint function of vocabulary knowledge and executive functioning in metalinguistic tasks (shown in Appendix II). This study designed a verbal metalinguistic task involving both vocabulary knowledge as well as a specific inhibitory control skill, interference suppression, to assess whether there is a bilingual advantage on the verbal interference suppression task.

- Question 1. Do bilingual children perform differently on the verbal interference suppression task relative to monolingual children?

Considering the consistent bilingual advantage on nonverbal interference suppression tasks, bilinguals may keep the same pattern of advantage on the metalinguistic task involving interference suppression and vocabulary knowledge. I hypothesize that bilingual children develop advanced abilities in inhibitory control of competing cues. Thus, bilingual children should have better scores than monolingual children's on the verbal metalinguistic tasks involved with interference suppression and vocabulary knowledge.

Method

Participants

Fifty-nine typically developing 2nd graders were recruited from a university demonstration school in Los Angeles area. Thirty-three students were part of the English-medium instructed classrooms (EMI), while twenty-six students were part of a 50:50 instructed time English-Spanish Dual-language Immersion Program (DLI). Both children whose dominant language is Spanish and English-speaking children who want to acquire Spanish-speaking skills can join the DLI classrooms.

Students were categorized into different language groups according to parental responses to questions regarding the child's language usage and proficiency in a school admission survey. Both English and Spanish language proficiency were measured by a 4-point Likert scale, including "never", "a little", "fairly well", and "fluent". A student was categorized as an English monolingual when she/he used English only. To be an English-Spanish emerging bilingual, students needed to use both languages "fairly well" or "fluently". An English-dominant bilingual used English "fairly well" or "fluently" and knew "a little" Spanish. A Spanish-dominant bilingual used Spanish only and did not use English at home before entering school. Additionally, a student who spoke any other language was categorized as another bilingual/multilingual. Finally students were categorized into eight groups: 1) English monolingual in EMI, 2) English-Spanish emerging bilingual in EMI, 3) English-dominant bilingual in EMI, 4) other bilingual/multilingual in EMI, 5) English-Spanish emerging bilingual in DLI, 6) English-dominant bilingual in DLI, 7) Spanish-dominant bilingual in DLI, and 8) other bilingual/multilingual in DLI. In summary, there were 16 English monolinguals, 5 English-Spanish emerging bilinguals, 9 English-dominant bilinguals, and 3 other bilinguals/multilinguals in EMI; and there were 16 English-Spanish emerging bilinguals, 2 English-dominant bilinguals, 6 Spanish-dominant bilinguals, and 2 other bilinguals/multilinguals in DLI.

To control for the potential effects of the classroom learning environment, ELL, and other language learning, this study only analyzed the behavioral differences between English monolinguals and their English-Spanish emerging bilingual peers who kept using dual language in and out of the classroom. Thus, the following analyses only focused on two language groups: 1) English monolinguals in EMI, and 2) English-Spanish emerging bilinguals in DLI. On the other hand, 27 students (5 English-Spanish emerging bilinguals, 9 English-dominant bilinguals, and 3 other bilinguals/multilinguals in EMI; and 2 English-dominant bilinguals, 6 Spanish-dominant bilinguals, and 2 other bilinguals/multilinguals in DLI) did not meet criteria for language group classification, and they were excluded in the analyses.

The final sample included 16 English monolinguals in EMI (8 female, 8 male; mean age=7.38 years, SD=.50 year) and 16 English-Spanish emerging bilinguals in DLI (8 female, 8 male; mean age=7.63 years, SD=.50 year). The final sample reflected an ethnic diversity: of these, 12 Caucasian, 3 Latino, 9 Latino and other, 1 African American, 1 Asian, 5 multi non-Latino, and 1 unspecified race. Annual household income was also diverse: 3 reported annual income lower than \$50,000; 4 between \$50,000 and \$100,000; 10 between \$100,000 and \$200,000; 11 between \$200,000 and \$350,000; 4 higher than \$350,000. There was a marginal ethnic difference between groups ($x^2(5)=10.89$, $p=.054$); groups did not differ significantly by age ($t(30)=-1.41$, $p=.17$), gender ($x^2(1)=.00$, $p=1.00$), or annual family income ($x^2(4)=5.218$, $p=.266$).

Materials

EOWPVT-4 (Expressive One-Word Picture Vocabulary Test, Fourth Edition; Brownell, 2010)

This test is an individually administered, norm-referenced assessment of individuals aged from 2 years 0 months to over 80 years. The examiner presented a series of full-color illustrations in the test plate, and asked the student to name each picture by one English word. Testing continued until the student reached the basal of eight consecutive correct responses and the ceiling of six consecutive errors. The number of correct responses up to the ceiling item determined the raw score, and converted to a standard score by means of age-related norms. The standard score was used for comparing English expressive vocabulary knowledge between the two language groups.

Corsi Blocks Task

This task was an adapted version of the classical Corsi Block-Tapping test, which is used for assessing nonverbal short-term working memory (Berch, Krikorian, & Huha, 1998). The task was instantiated on a Dell laptop computer and designed by E-prime 2.0 Program (Schneider, Eschmann, & Zuccolotto, 2002). Nine white squared “blocks” randomly arranged on the screen. A series of blocks were “tapped” and flashed in green color in an uneven consequence. The student was asked to point the same blocks in the same order by mouse. The task began with a series of two blocks and gradually increased in length until nine blocks. The student had three attempts at each pattern length, and continued the game until she/he responded incorrectly on two or more trials in a given pattern length. The longest pattern that the student correctly completed referred to the task score. For instance, the student who failed in the four-block pattern was scored three as the final score of the Corsi Blocks Task.

Color-Shape Task

The task was adapted based on the standard Stroop color-word paradigm (Stroop, 1935). In this task, it provides the student with two competing stimulus at the same time: color and novel shape. Because no linguistic knowledge involved in this task, it is used for assessing the ability of interference suppression alone. The student was instructed to match the shape of graphs only in five mixed blocks (each including 10 congruent trials and 10 incongruent trials), for a total of 100 trials. In the congruent condition, the student saw a colored novel shape on the screen, and she/he was asked to choose the picture with both the same color and shape from two options (e.g. match the red circle with the red circle). In the incongruent condition, the student needed to match the same shape but with different color (e.g. match yellow square with blue square). The incongruent condition requires the student focusing on the shape and not being distracted by the graph color.

The task was instantiated on a Dell laptop computer and designed by E-prime 2.0 Program (Schneider, Eschmann, & Zuccolotto, 2002). Each trials starts with a cross fixation for 500 ms, followed by the stimulus (a colored novel shape) for 1000 ms. The student could make response when the two options displayed for 2000 ms or at any point of the following buffering period for 1000 ms. Before the formal task, the student was given a series of instruction of how to use two active colored buttons in a keyboard for answering. Additionally, the student was asked to complete a practice block consisting of five congruent trials and five incongruent trials. The sample task did not account by time, but the student needed to achieve 80% accuracy, ensuring she/he understood the task procedures. Each trial values one point, and the maximum possible score for the task is 100, 50 for congruent trials and 50 for incongruent trials. Both accuracy and reaction time were recorded for further data analysis.

Zoo Game

This task was adapted from a child-friendly Go/No-go task based on the task developed by McDermott and colleagues (2014). Go/No-go task were generally used for assessing the ability of response inhibition. This task requires the student to quickly respond to the targeted stimulus as well as inhibit their habitual responses to “no-go” stimulus. For example, it is hard for individuals to stop themselves from making a habitual response when a “no-go” stimulus suddenly appears after a series of go stimuli. In this adapted task, the student was told that he/she was playing a game of catching lost zoo animals back. Experimenter showed the student three pictures of orangutans, which helped the zookeeper put other animals back into cage. The student was instructed to press the yellow button when seeing a zoo animal (Go trials), but not to press any button when seeing any one of three orangutans (No-go trials).

The task was instantiated on a Dell laptop computer and designed by E-prime 2.0

Program (Schneider, Eschmann, & Zuccolotto, 2002). A cross fixation displayed for 300 ms before each animal image showed in the middle of the screen. The stimuli were presented for 1000 ms, followed by a buffering period for 500 ms. The sudent could make response while the stimulus was on the screen or at any point during the buffering period. Before the formal task, the student was asked to preform a practice block consisting of 12 trials, 9 go trials and 3 no-go trials. Student needed to receive 85% accuracy in the sample block to continue the game. In the formal task, student needed to complete four mixed blocks, each with 28 trials (each including 21 novel zoo animal pictures, and 7 pictures of the orangutans), for a total of 112 trials. Each trial values 1 point. Thus, the maximum score of Go trial is 84, and the score of No-Go trial is 28. Both accuracy and reaction time were recorded for further data analysis.

Auditory-visual Selective Attention Task

This task is adapted from the Auditory Selective Attention Task for adults (Knight, Hillyard, Woods, & Neville, 1981). Instead of listening to paragraphs from different ears, this task adjusted sentence to single word and adds visual components into the selective attention task. This task requires verbal interference suppression that student needs to accurately respond to the visual conflicts corresponding to the auditory stimulus. The student was asked to wear a headphone and listen to a list of words while watching on the screen. Images on the screen may be the same word as the student heard (congruent trial) or not (incongruent trial). When stimuli disappeared (both the image of word and the sound), the student needed to make response as fast as possible from two images of word according to the word she/he heard from the headphone.

The task was instantiated on a Dell laptop computer and designed by E-prime 2.0

Program (Schneider, Eschmann, & Zuccolotto, 2002). Each stimulus began with a cross fixation for 500 ms, followed by the stimuli (both the sound from the headphone and the image on the screen) for 3000 ms. The student could make response during the following 2000 ms and at any point of the buffering period for 1000 ms. Before the formal task, the student was given an instruction and a practice block, which consists of 10 congruent trials and 10 incongruent trials. The sample task did not account by time, but the student needed to receive 80% accuracy in order to continue the formal task. The formal task is comprised of five mixed blocks (each including 10 congruent and 10 incongruent trials), in the total of 100 trials. Each trial values 1 point. Thus, the maximum total score of the task is 100, 50 for congruent trials and 50 for incongruent trials.

Procedure

Every student took part in one-on-one test sessions with experimenter in a quiet location at school. Considering to the required workload of sustained attention in the tasks, each test session took approximate 10-15 minutes. Every student completed three test sessions across a week period: In Session I, students took the Color-Shape Task and the Zoo Game in a counterbalanced order; In Session II, students completed the EOWPVT-4 test; In Session III, students took the Corsi Blocks Task and the Auditory-visual Selective Attention Task in a counterbalanced order. Before testing, students were given English instructions of how to play the computer games. They also had chances to practice the colored keys on the keyboard and completed a series of sample trials before formal testing. During testing, all responses were recorded by laptop and experimenter's notes. The laptop used to record the accuracy of each trial and collected response time for all tasks except the EOWPVT-4 test. All trials with a response time under 300 ms were considered too fast for students to consciously make responses, thus these trials were excluded from the data analysis. Part I of the current study applied an independent t-test for comparing English language proficiency between the two language groups in terms of the EOWPVT standard score. In addition, this study applied three 2 between-subject (language group: English monolingual in EMI or English-Spanish emerging bilingual in DLI) × 2 within-subject (trial type) mixed ANOVA models to compare mean differences in the number of total responses, mean response time and accuracy for the Color-Shape Task, Zoo Game, and Auditory-visual Selective Attention Task.

Results

English monolinguals in EMI classrooms obtained a mean score of 118.00 (SD=10.68) on the EOWPVT standard score and English-Spanish emerging bilinguals in DLI classrooms obtained a mean score of 112.50 (SD=12.85). There was no significant difference in the EOWPVT standard score between two language groups, $t(30)=1.316$, $p=.20 > .05$. Furthermore, there was no significant difference between two language groups in the scores of Corsi Block Task, $t(30)=.58$, $p=.57>.05$; the mean score was 3.75 (SD=.93) for English monolinguals in EMI and 3.56 (SD=.89) for English-Spanish emerging bilinguals in DLI.

Color-Shape Task

A 2 between-subject (language group: English monolingual in EMI or English-Spanish emerging bilingual in DLI) × 2 within-subject (trial type: congruent or incongruent condition) mixed ANOVA model was respectively analyzed in accuracy in terms of the numbers of correct, incorrect, and missing trials. Particularly, the numbers of correct and incorrect trials reflected the accuracy of the Color-Shape Task when students made responses within the recording period (3000 ms); meanwhile, the number of missing trials referred to the number of trials that students had no response within the recording period.

Accuracy and the number of total responses

The mixed ANOVA model revealed a main effect of language group for the number of missing trials, *F*(1, 30)=8.14, *p*=.008, η^2=.21. Specifically, English monolinguals in EMI (M=2.13, SD=.36) missed more trials across both trial types than English-Spanish emerging bilinguals in DLI did (M=.66, SD=.36). In terms of correct responses within the recording period, there was a main effect of trial type, *F*(1, 30)=107.33, *p*=.00, η^2=.78. The mixed model revealed a strong Stroop effect, where students in both language groups made significantly more errors in the incongruent condition (M=20.13, SD=1.61) than in the congruent condition (M=3.59, SD=.74), *F*(1, 30)=110.34, *p*=.000, η^2=.79. There was no effect of language group in the number of incorrect trials, F(1,30)=.83, *p*=.37, and no language group by trial type interaction, *F*(1,30)=.004, *p*=.95 (See Fig.1).

Mean response time

Similarly, there was a main effect of trial type in the mean reaction time of the Color-Shape Task, *F*(1, 30)=106.29, *p*=.000, η^2=.78. Students in both language groups had faster responses in the congruent condition (M=761.96, SD=21.65) than in the incongruent condition (M=906.29, SD=31.79). There was no effect of language group, *F*(1,30)=.59, *p*=.45, and no language group by trial type interaction, *F*(1,30)=.04, *p*=.84, though English-Spanish emerging bilinguals in DLI (M=813.97, SD=37.17) responded more rapidly across trial type than English monolinguals in EMI did (M=854.29, SD=37.17) (See Fig.2).

Zoo Game

Accuracy and the number of total responses

Accuracy was analyzed in another 2 between-subject (language group: English monolingual in EMI or English-Spanish emerging bilingual in DLI) × 2 within-subject (trial type: go or no-go condition) mixed ANOVA model in terms of the numbers of correct, incorrect, and missing trials in the Zoo Game. The mixed model revealed a main effect of language group, $F(1, 30)=5.53$, $p=.025$, $\eta^2=.16$, a main effect of trial type, $F(1, 30)=49.08$, $p=.00$, $\eta^2=.62$, and a marginal interaction effect in the number of missing trials, $F(1, 30)=3.54$, $p=.07$, $\eta^2=.11$. In other words, English monolinguals in EMI missed more go trials (M=9.13, SD=1.31) than English-Spanish emerging bilinguals in DLI did (M=4.94, SD=1.31); meanwhile, English monolinguals in EMI missed more no-go trials (M=2.19, SD=.49) than English-Spanish emerging bilinguals in DLI did (M=.94, SD=.49). In terms of correct trials within recording period (1500 ms), there was a main effect of trial type, $F(1, 30)=3385.61$, $p=.00$, $\eta^2=.99$, and an significant interaction with language group, $F(1, 30)=6.15$, $p=.02$, $\eta^2=.17$. Specifically, English-Spanish emerging bilinguals in DLI had more correct responses in go condition (M=76.63, SD=1.38) than English monolinguals in EMI did (M=72.56, SD=1.38); on the other hand, the number of correct trials in no-go condition for English-Spanish emerging bilinguals in DLI (M=21.56, SD=1.08) did not differ from English monolinguals in EMI (M=22.00, SD=1.08). In addition, there was a main effect of trial type in the number of incorrect trials, $F(1, 30)=83.27$, $p=.001$, $\eta^2=.36$. Students in both language groups had more incorrect responses in no-go condition (M=4.66, SD=.68) than in go condition (M=2.38, SD=.34). There was no effect of language group, $F(1,30)=1.00$, $p=.33$, and no language group by trial type interaction, $F(1,30)=1.77$, $p=.19$ (See Fig.3).

Mean response time

Moreover, the mixed ANOVA model revealed a main effect of trial types, *F*(1, 30)=27.09, *p*=.00, η^2=.47, as well as a main effect of language groups in the mean response time of the Zoo Game, *F*(1, 30)=4.25, *p*=.048, η^2=.12. Specifically, English-Spanish emerging bilinguals in DLI (M=611.28, SD=14.47) had significantly faster responses across both trial types than English monolinguals in EMI did (M=653.47, SD=14.47) (See Fig.4).

Auditory-visual Selective Attention Task

Accuracy and the number of total responses

Similarly, a third 2 between-subject (language group: English monolingual in EMI or English-Spanish emerging bilingual in DLI) × 2 within-subject (trial type: go or no-go condition) mixed ANOVA model was used for analyzing accuracy in terms of the numbers of correct, incorrect, and missing trials in the Auditory-visual Selective Attention Task. There were no difference between English-Spanish emerging bilinguals in DLI and English monolinguals in EMI in the number of missing trials for either trial type, *F*(1, 30)=.754, *p*=.39, and no language group by trial type interaction, *F*(1, 30)=.55, *p*=.47. The mixed model revealed a main effect of trial type in the number of correct trials within the recording period (3000 ms), *F*(1, 30)=52.00, *p*=.00, η^2=.63. As expected, there was a strong Stroop effect in the Auditory-visual Selective Attention Task, *F*(1, 30)=46.10, *p*=.00, η^2=.61. Specifically, students in both language groups made significantly more errors in the incongruent condition (M=5.59, SD=.57) than in the congruent condition (M=2.06, SD=.35). There was no effect of language group, *F*(1, 30)=.002, and no interaction with trial condition, *F*(1, 30)=.032, *p*=.86 (See Fig.5).

Mean response time

In contrast with the findings in the Color-Shape Task, English-Spanish emerging bilinguals (M=782.47, SD=24.75) had longer response time across trial type in relative to English monolinguals in EMI (M=773.19, SE=24.75). The difference in mean response time was no significant, *F*(1, 30)=.07, *p*=.79 (See Fig.6).

Discussion

In contrast with previous bilingual research, this study adopted a more precise and strict criteria of bilingualism when categorizing participants into different language groups. Bilingual students in the final sample were considered to be equally proficient in both English and Spanish language before enrolling into school according to the parental survey. These bilinguals have systematically been learning two languages in a 50:50 immersion program for at least two years. Thus, it is accurate to define these children as English-Spanish emerging bilinguals who have simultaneous contact with two languages in both the school and the home environment. Moreover, they have sufficient linguistic knowledge in each lexical domain. Therefore, it is not surprising that English-Spanish emerging bilinguals in DLI classrooms had comparable EOWPVT scores to the English monolingual students in EMI classrooms had. To be noted, students in both language groups obtained a mean standard score around 115, suggesting that both groups' performances are one standard deviation above the age-related median of a population distribution. In other words, all students in the final sample did better than 84% of the normative sample for the EOWPVT. Considering that 90% of participants in the final sample reflected annual household income higher than the median annual income of Los Angeles areas (U.S. Census Bureau, 2014), it is possible that bilinguals from higher SES background receive adequate language-learning resources, ensuring the establishment of dual language mastery in early childhood.

Corresponding with the characteristics of unity and diversity in the executive functioning network (Miyake et al., 2000; Teuber, 1972), Part I of the current study found that bilingual advantage appears differently according to the different components of executive control engaged in nonverbal metalinguistic tasks. Specifically, English-Spanish emerging bilinguals outperformed their English monolinguals peers in terms of accuracy, the number of total responses, and mean response time. In both the Color-Shape Task and the Zoo Game, English monolinguals in EMI had significantly more missing trials across both trial types relative to English-Spanish emerging bilinguals in DLI. In other words, emerging bilinguals completed significantly more trials within the recording time than their monolinguals peers did.

From the perspective of accuracy, students in both language groups had significantly more incorrect responses in the incongruent condition than the congruent condition in the Color-Shape Task. Similarly, all students made more errors in the no-go condition than the go condition in the Zoo Game. The above findings support the view of an individual's cognitive processing delays when dealing with conflicting information (Stroop, 1935). Moreover, the skills of interference suppression and response inhibition share some common underlying mechanism of inhibitory control. Moreover, the current study found that the accuracy of Color-Shape Task and Zoo Game were significantly correlated with each other (r=.44, p=.00), supporting the property of unity in the executive functioning network.

There were also some bilingual advantages in the accuracy of nonverbal metalinguistic tasks. Emerging bilinguals in the current study had significantly more correct responses in the go condition of Zoo game. Though the difference in the number of correct responses between two language groups was not significant in the Color-Shape Task, emerging bilinguals had more correct responses in the both conditions when compared with their monolingual peers. In turn, English monolinguals made more errors across trial types in both the Color-Shape Task as well as the Zoo Game. Although these bilingual advantages were not as strong as previous studies proved (e.g., Martin-Rhee &Bialystok, 2008; Hilchey & Klein, 2011), emerging bilinguals were more accurate across the two different nonverbal metalinguistic tasks. These findings reflect the effects of bilingualism on the development of executive control in general.

From the perspective of mean response time, there was no significant difference between two language groups in the both conditions of Color-Shape Task; however, emerging bilinguals performed significantly faster than their monolingual peers in the both conditions of Zoo Game. Unlike the hypothesis that was proposed for the study, bilingual advantages emerged in the nonverbal response inhibition task in terms of accuracy as well as response time. There are several possibilities that may explain these unexpected findings. Primarily, previous studies of response inhibition hardly account for the effect of linguistic knowledge on metalinguistic tasks. For instance, Esposito et al. (2013) compared bilingual and monolingual preschoolers' competence of response inhibition using the Sun/Moon Task, which required students to make oral responses during assessment. Linguistic knowledge engaged in the task may negatively affect the potential bilingual advantage in response inhibition. In addition, the difference in categorization criteria between previous research and the current study may also lead to different findings. The bilingual group of Martin-Rhee &

Bialystok's study (2008) included a lot of developing bilinguals who were exposed to English only in school but entirely used another language at home. Thus, it is possible that a bilingual advantage in response inhibition appears only when an individual develops equal mastery of dual language. Moreover, there might have an age effect in the bilingual advantage of different executive control skills. Because the components of executive control develop at different times (Carlson, 2003), bilingual advantage in response inhibition may not establish yet in the preschool period (Esposito et al., 2013). Schooling could also be a potential factor determining the facilitative effect of bilingualism on response inhibition. Further study should especially examine the relationship between the developmental trajectory of response inhibition and bilingualism.

Taken together, the results of these two nonverbal metalinguistic tasks support the theoretical model of executive functioning that interference suppression and response inhibition are separable components of executive control but are also highly correlated with each other (Miyake et al., 2000). Bilingual advantage appears on the nonverbal interference suppression task in terms of the number of total responses only; meanwhile, emerging bilinguals performed more efficiently than monolinguals on the nonverbal response inhibition task in the forms of the number of total responses, accuracy, and mean response time. From the perspective of unity, the effect of bilingualism influences the common foundation of executive processing, including all components of inhibitory control. From the perspective of diversity, bilingual advantages appear differently according to the demands of specific executive control skills on the nonverbal metalinguistic tasks. These findings are consistent with previous research and contribute to a better understanding of the source of bilingual advantage.

In contrast to the nonverbal metalinguistic tasks, this study did not find any bilingual advantage on the verbal metalinguistic task. Emerging bilinguals and monolinguals performed the same on the Auditory-visual Selective Attention Task in terms of accuracy, the number of total responses, and mean response time. There was only a strong Stroop effect. That is, all students made more errors and had slower responses in the incongruent condition than in the congruent condition. Consistent with the results of nonverbal task (e.g., Bialystok, Craik & Luk, 2008; Esposito et al., 2013; Carlson & Meltzoff, 2008), these findings emphasize that an individual takes overall larger cost in cognitive processing when resolving with perceptual competition. It also supports that both the Shape-Color Task and the Auditory-visual Selective Attention Task require the same ability to control attention to complex stimuli. The only difference between the two tasks was the linguistic knowledge engaged in the Auditory-visual Selective Attention Task. Notably, emerging bilinguals had slower responses in the both conditions of Auditory-visual Selective Attention Task than their monolingual peers did, though the difference was not significant. Compared with the slight bilingual advantage in mean response time in the Color-Shape Task, the involvement of linguistic knowledge in the metalinguistic task probably increases the demands on problem solving for emerging bilinguals only. More evidence is needed for investigating the contribution of bilingualism in the verbal metalinguistic tasks.

In addition, the current study did not find significant bilingual advantages on these two interference suppression tasks as previous research observed (e.g., Esposito et al., 2013; Martin-Rhee &Bialystok, 2008). There are several factors that can explain this disparity.

Primarily, the sample size of this study is very small. Only 32 of 59 participants fitted in the strict emerging bilingual/monolingual categorization criteria. In addition, all participants were recruited from Los Angeles area, where half of the population is bilingual/multilingual (U.S. Census Bureau, 2014). Although the current study criteria required that English monolinguals in the final sample not systematically learn other languages, it is possible that they were exposed to multiple languages in other ways, such as playing with bilingual students at school or interacting with their multilingual neighborhood. Thus, English monolinguals in the EMI classrooms might potentially benefit from the linguistic diverse environments of their school and home, thus diminishing the significant difference between the two language groups. Furthermore, all participants in this study were from higher SES background and received substantial educational resources. Previous research has suggested that socioeconomic status is also positively associated with executive functioning competence (Arriaga, Fenson, Cronan, & Pethick, 1998). These factors make the generalizability of the results to all groups of young bilinguals become limited. Moreover, the current study may have underestimated the difference in executive functioning by language group.

In conclusion, this study provides new evidence for the effect of bilingualism in the development of metalinguistic awareness through two key factors: vocabulary knowledge and executive control. When controlling for the linguistic effect, bilingual advantage appears in different forms according to the specific executive control engaged in the metalinguistic tasks. These findings also support the characterization of “unity and diversity” in the theoretical model of executive functioning. Moreover, the results of the Auditory-visual Selective Attention Task suggest that the involvement of linguistic knowledge may account for the disappeared bilingual advantage on a verbal metalinguistic task. In sum, further studies should more cautiously judge bilingual advantage in metalinguistic development based on the characteristics of executive control and linguistic involvement in a metalinguistic task.

List of Figures

Figure 1

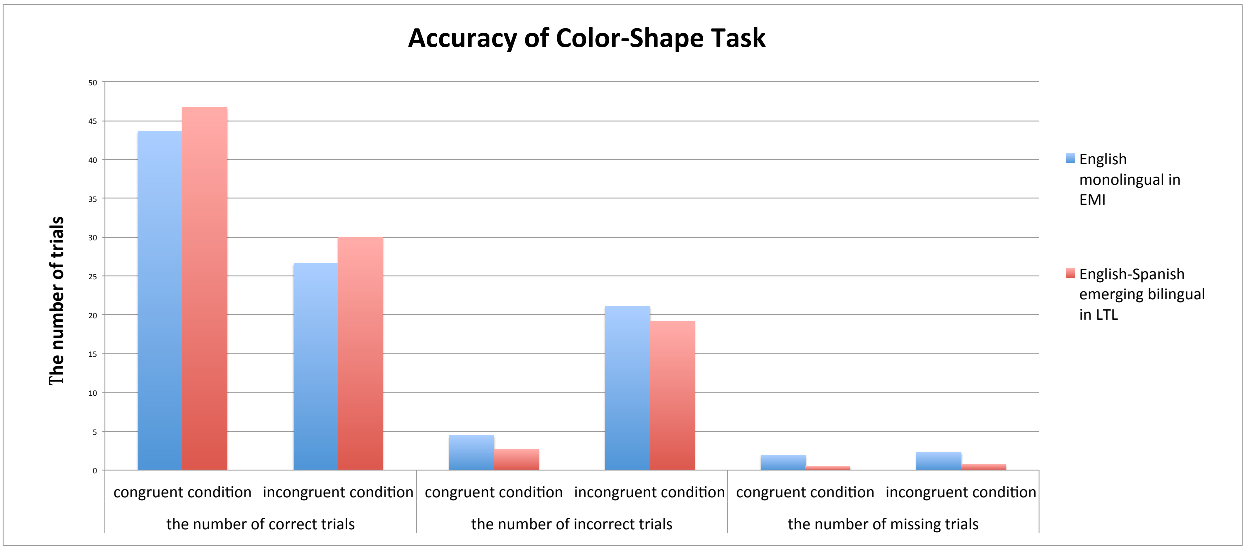


Figure 2

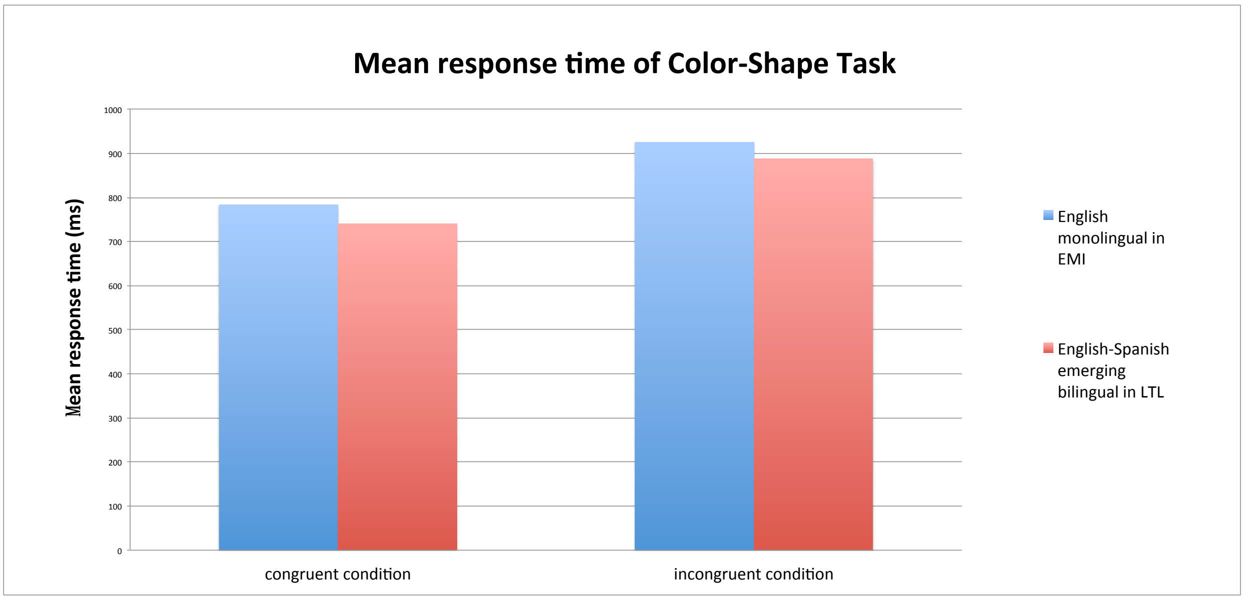


Figure 3

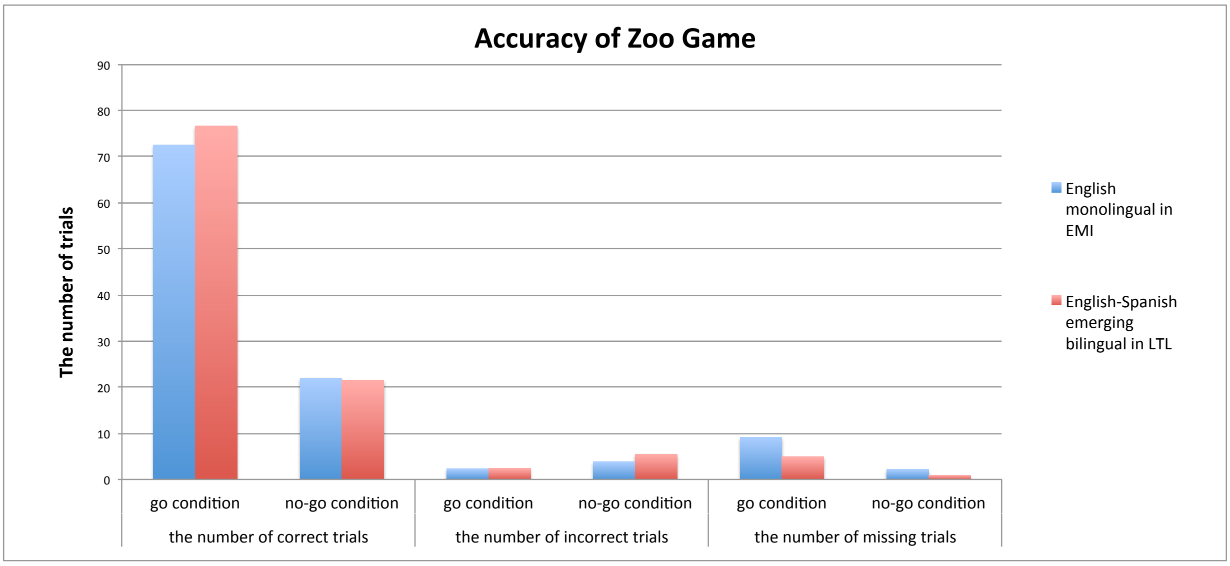


Figure 4

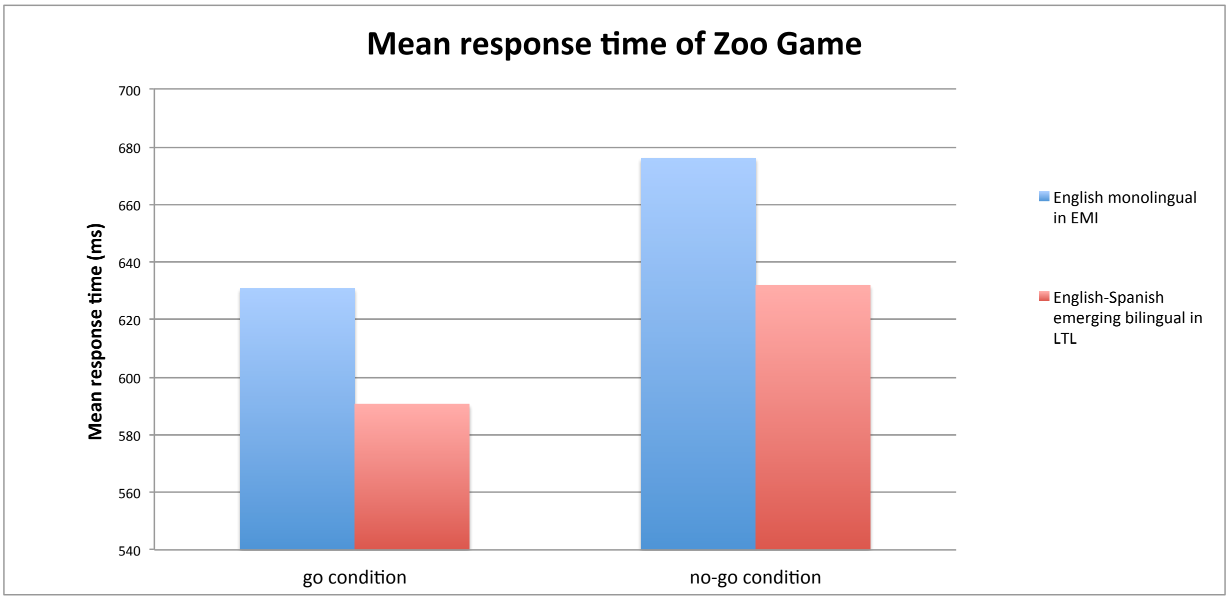


Figure 5

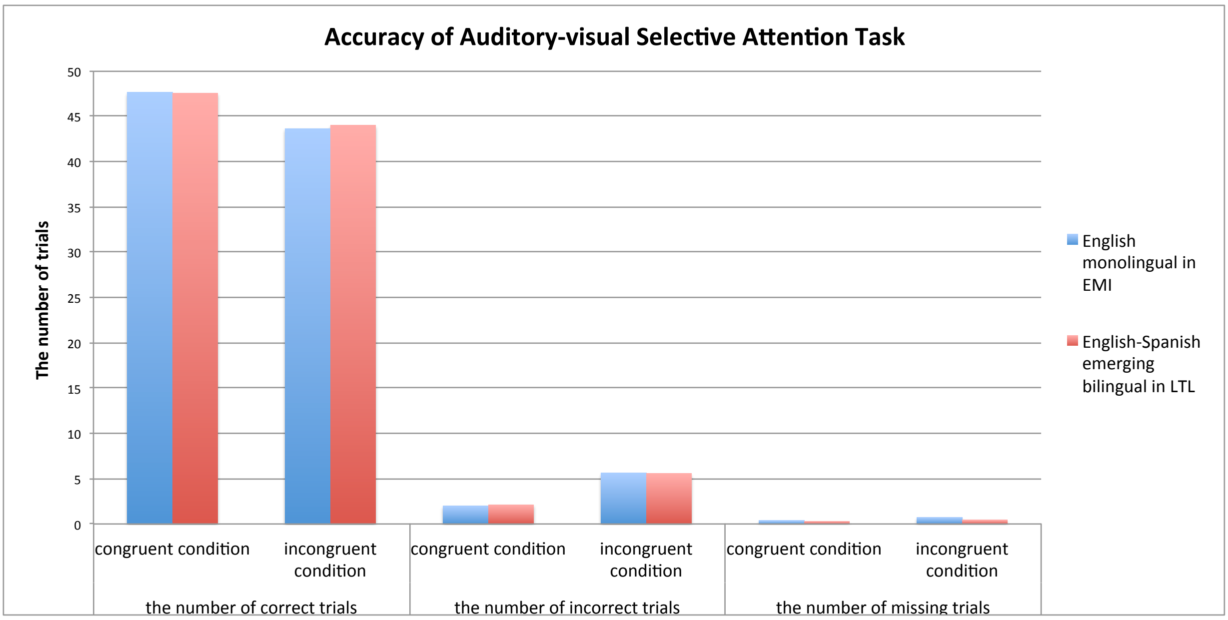
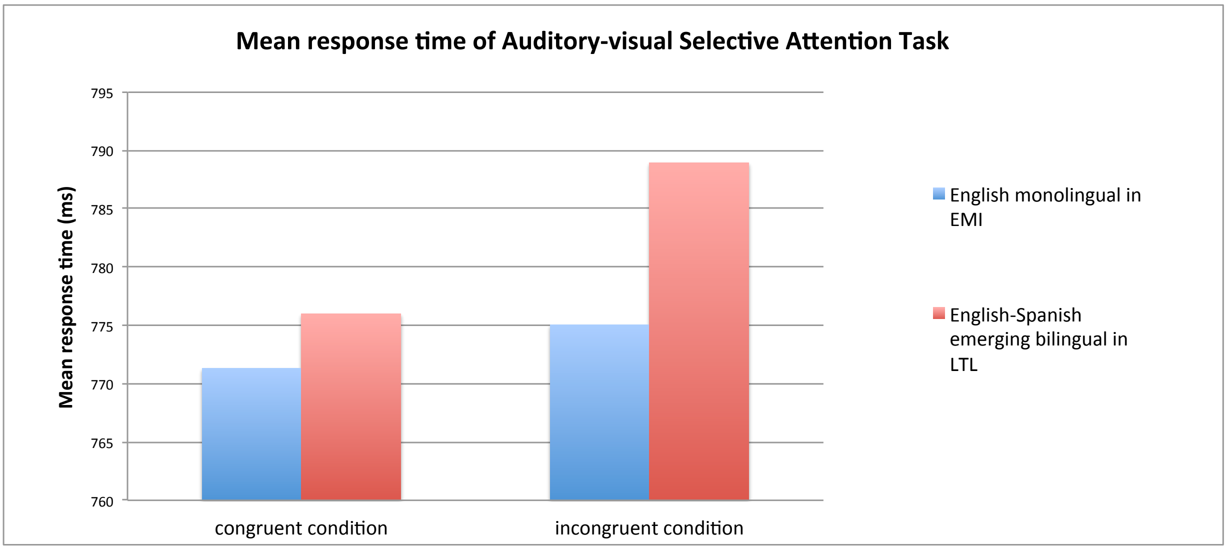
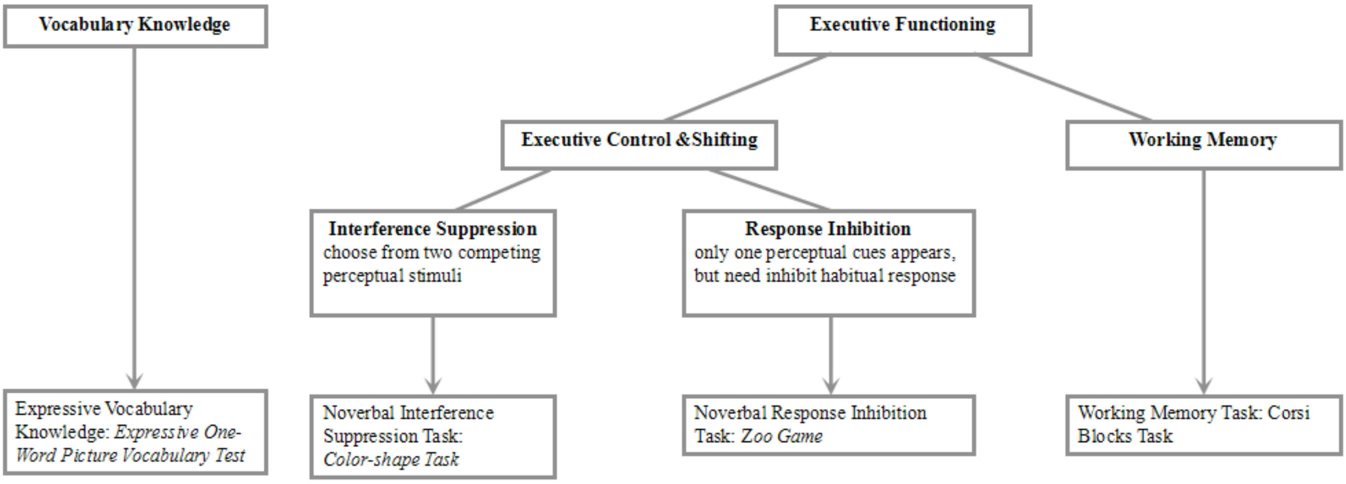


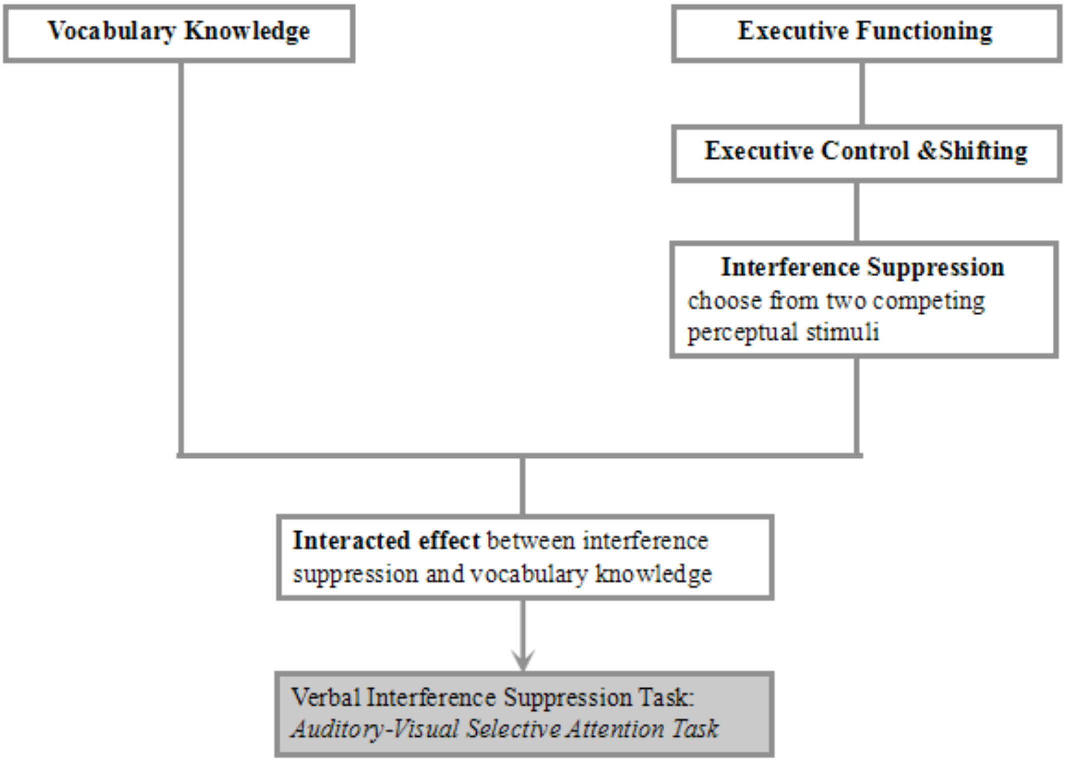
Figure 6



Appendix I


Vocabulary Knowledge
Executive Functioning
Executive Control &Shifting
Working Memory
Interference Suppression
choose from two competing perceptual stimuli
Response Inhibition
only one perceptual cues appears, but need inhibit habitual response
Expressive Vocabulary Knowledge: *Expressive One-Word Picture Vocabulary Test*
Noverbal Interference Suppression Task: *Color-shape Task*
Noverbal Response Inhibition Task: *Zoo Game*
Working Memory Task: Corsi Blocks Task

Appendix II


Vocabulary Knowledge
Executive Functioning
Executive Control &Shifting
Interference Suppression
choose from two competing perceptual stimuli
Interacted effect between interference suppression and vocabulary knowledge
Verbal Interference Suppression Task:
Auditory-Visual Selective Attention Task

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