Senior Honors Thesis:

Processing Speed in Typically-Developing Sequential Bilingual Children

Adrienne Jaida Propst
Department of Speech, Language, and Hearing Sciences
University of Colorado Boulder

Defense Date: April 3rd, 2023

Thesis Advisor:
Pui Fong Kan, Ph.D. CCC-SLP
Associate Professor
Speech, Language, and Hearing Sciences

Honors Council Representative:
Christine Brennan, Ph.D. CCC-SLP
Assistant Professor
Speech, Language, and Hearing Sciences

Outside Reader:
Lauren Collins, Ph.D.
Program Director and Teaching Assistant Professor
Asian Studies

Abstract

The purpose of this study was to investigate the response speed and speaking rate of Cantonese-English bilingual children during narrative contexts in both languages. Previous studies have primarily focused on monolingual school-age children, and there is a lack of research on younger bilingual preschool children's response speed and speaking rate. Understanding how bilingual children process language and respond to language stimuli is crucial for accurately identifying potential language delays and disorders. In this study, I analyzed the language samples of 36 typically-developing preschool children (3;1 to 5;3 M = 4;1; SD = 8.28) who learn Cantonese (L1) at home from birth and English (L2) in school. My focus was on whether age, existing language knowledge, and language (Cantonese vs. English) predicted children's response speed and speaking rate. Results indicated that on average, children produced more words per minute in Cantonese than in English, but there were no differences in the average time intervals between the two languages. Regression analyses were conducted to determine the predictors of participants' speaking rate and response speed. The results revealed that participants' syntactic skills (mean length of utterance; MLU) and lexical diversity (number of different words; NDW) were significant predictors of children's words per minute, but language was not significant. Moreover, older children responded faster to the examiner than younger children, but MLU and NDW failed to reach significance. In addition, there was no effect of language on speaking rates, suggesting that children's speaking rates in Cantonese and English were the same when age, MLU, and NDW were taken into consideration in the model. The investigation contributes to the understanding of the "normal" range of response speed and rate in typically-developing bilingual children through the process of story-retelling. This study provides a foundation for future research on the development of language processing and speech

production in bilingual children, which may have implications for the assessment and intervention of language disorders.

Keywords: Processing speed, sequential bilingual, Cantonese, English, story retell tasks, mean length of utterance (MLU), number of different words (NDW), Praat, SALT, and typically developing.

Introduction

The purpose of this study is to examine the speaking rate and the response speed to the examiner from bilingual children. Of interest in this study are preschool bilingual children who learn a minority language (L1) at home and English (L2) as a second language in school. In this study, children's response speed refers to the ability to efficiently perceive and act upon incoming speech. In a preschool classroom setting, children's response speed can play an essential role in their ability to engage with their teachers and peers and participate in various learning activities. For instance, during classroom discussions or storytime, children with a faster response speed can respond to questions or prompts and engage with the content. On the other hand, children with slower response speed may have difficulty engaging with the content. This can result in frustration or disengagement, leading to lower levels of participation and potential learning difficulties. In clinical settings, children's response speed can serve as an indicator of how efficiently information is processed, integrated, and retained within a specific timeframe for each child (Leonard et al., 2007). Children with DLD often exhibit slow processing speed, leading to the consideration of processing speed as a potential clinical marker for DLD (Leonard et al., 2007; Park et al., 2020). Previous research has shown that processing speed can effectively differentiate between bilingual children with DLD and their monolingual peers with DLD.

Previous studies evaluating children's processing speed were conducted in laboratory settings, where school-aged children were instructed to press buttons on a computer as quickly as possible for an extended period (e.g., Kohnert & Windsor, 2004). Such settings could be challenging for preschool children who do not have the advanced cognitive and motor skills to do so. Therefore, there is a need for more research that investigates processing speed in young children using alternative methods that are more developmentally appropriate and ecologically

valid. One way to measure preschool children's processing speed is to measure their respond speed in a natural setting (e.g., interacting an adult during narrative contexts). To our best knowledge, no previous studies have specifically measure children's processing speed in natural settings. In this study, I examined two measures, including children's response speed and the speaking rate of bilingual children. To understand what is normal response speed and speaking rate in bilingual children, this study examine typically-developing preschool children (age three-five years in age). I will examine the response speed of bilingual children in from the database of language sample collected by Dr. Kan. The language samples are from preschool children (three to five years in age) that learned Cantonese in their home (L1) and then taught English (L2) in a school setting. This comparison between the two languages is shown through the task of story retelling. This study will examine their processing speed by analyzing their speaking rate and how fast they respond (response speed) to the examiner in both Cantonese and English. This study will close that gap in research by examining the specific rate, length of utterances, and pause times between bilingual children through the process of story-retelling. The results will help us to understand typically developing bilingual children's processing speed.

Sequential Bilingual Children in the U.S.

According to ChildStats data (2019), 23% of school age children who speak a language other than English at home. Some examples of frequent home languages are, Spanish, Arabic, Chinese, English, Vietnamese, Hmong, Haitian Creole, Somali, Russian, and Korean (Mitchell, 2016). And these children learn their home languages within the unique socio-cultural contexts at home. In this study, I focus on children who learn a minority language (L1) with their family/caretakers and then later develop their second language (English; L2) in the school system. Within the past few years, there has been a growth and a larger community of bilingual

speakers (ChildStats, 2019). As seen through the percentage of 10-22% that shows that bilingualism is among English language skills (Hoff et al., 2012). This means that the average difference between monolinguals and bilinguals across the developmental period can be ranged from 10-21% (Hoff et al., 2012). The bilingual children in this study were more advanced English than Spanish thus the size of the effect of bilingualism shows in their English language skills. For monolingual children, Some examples of these milestones can be seen as rolling over, crawling, walking, and talking but will vary depending on the age (Medline Plus, N.D.). Monolingual children are able to crawl by 9 months, walk around 8 to 18 months, and able to produce their first word around 7 to 12 months (ASHA, N.D.). Bilingual children are expected to achieve major milestones similar to monolingual children (Hoff et al., 2012).

The importance of input environment for bilingual children can be seen through the results of Hoff et al. (2012) study of how language balance attenuated the effect of bilingualism. The results proposed two hypotheses of the effects of bilingualism which are that the cost of bilingual exposure is mitigated in the balance input and that there is a threshold of 20% of input that is required for language learning. The first hypothesis can be explained that if the child's language exposure is mainly in Spanish then their development of English will be delayed. While the child is developing two languages, the one language that has the most exposure is likely to develop faster than the language that is less exposed (Hoff et al., 2012). Due to the differing amount of exposure in the two languages, it will cause a differing amount of vocabulary development. It is seen in recent studies that young bilingual children will lag behind monolingual children (in the same age group) with their vocabulary and grammatical development (Hoff et al., 2012). Many external factors can contribute to language exposures and use in bilinguals. For example, in the study of Anderson et al (2018), bilingual children are

examined in three different ways, primary language used by adults at home, non-English use for media, and non-English use with siblings. This pattern of these three ways of examination shows that the child's language is shaped and reflected by the home environment. Bilingualism can be shown in three main ways, single language, dual language, and dense code switching (Hoff et al., 2012). Bilingual speakers will use their two languages very differently from one another due to the various number of contexts that surround them. Among the various uses and contexts bilingual speakers are placed into; their ages (children, young adult, and older adults) will emerge and sustain their two languages differently due to the contexts (or environments) they are placed into. The second hypothesis is socio-economic status (SES) is an important factor that affects bilingual children's development by the amount of interaction that is available from the caregivers or parents. In a study done by Bierman et al (2008), an early education program, Headstart, was made to reduce SES disparities in school readiness. A child's overall language skills will help support their socio-emotional adjustment and their ability to grow with the behavioral demands that are seen in the school system. There are increasing demands (physical, emotional, and mental) that are placed onto young students who are entering the school system. With bilingual children, the demands will increase so it can help them guide their emotions, thoughts, and understanding of two separate cultures (school and home). Many sequential bilingual children are from low SES background. Previous studies showed that SES affect bilingual children's language development (Hammer et al., 2010).

Bilingual children's development can occur under many different living circumstances such as growing up in an English-speaking middle-class family and learning another language later on. In comparison, to growing up in a family that is speaking Spanish, Chinese, or other languages (L1) and starting to learn English (L2) in the school setting. The language learning

environment matters for bilingual children's language development. The factors that play into the child's language learning environment can be seen as the amount of SES, neglect, and cultural-linguistic diversity (CLD). SES is an index measure of economic status in society. For bilingual children's language development is not determined by the amount of income that is present in the household. Instead, it is a combination of education, income, and occupation that helps to determine how bilingual children's language will develop. SES plays into a role of the amount or limit of interaction that caregivers or parents will be available to provide.

Language Development in Typically Developing Bilingual Children

Language development in typically developing bilingual children begins early in life, with infants showing sensitivity to speech sounds even before birth. After birth, children start to comprehend the world around them and learn to communicate their needs and wants through early vocalizations, such as crying, babbling, and cooing. Comprehension of the world around them is a crucial aspect of a child's cognitive and physical development. It encompasses the ability to make sense of sensory information, perceive and respond to environmental cues, and engage with people and objects in meaningful ways. Given the age of 8 to 15 months, it is often seen that typically developing sequential bilingual children produce their first words slightly later than monolingual children (Hoff et al., 2012). Bilingual children start to produce short sentences and develop grammar patterns in a similar way to monolingual children (Hoff et al., 2012). In bilingual children, both languages do not develop at the same rate due to the factors of different language learning environments and how language is used in each language. Instead, bilinguals' two languages develop at different rates due to their language learning environment and language use (Hoff et al., 2012). The different rates of development between bilinguals' two languages can lead to an asymmetrical language proficiency, where one language is more

dominant than the other. Moreover, bilingual children may also use each language differently in different contexts. For example, they may use one language more frequently at home and another language more often at school or in the community. The language use patterns and exposure can impact the rate at which each language develops. For instance, if a child speaks one language more frequently in social interactions, they may develop stronger proficiency in that language compared to the other. Bilingual children's uneven language development in L1 and L2 can have implications for their cognitive and academic development, as well as their communication with others who may not speak both languages. Therefore, understanding the factors that contribute to the different rates of development in bilingual children's two languages is important in supporting their language development and promoting their academic success.

Typically developing bilingual children's language development can be affected by various factors. Research showed that several significant external factors contribute to a bilingual child's language development, including home/household environments, language usage in both L1 and L2, and the differing amounts of exposure to both languages in varying environments (Hoff et al., 2012). In a study done by Cheung et al. (2018), home language-learning exposure was examined with how L1 (Cantonese) was affected while later learning L2 (English). Some examples of social contexts where children receive input can be seen in Cheung et al. (2018). The language input in L1 and/or L2 contains highly language-specific, phonological, lexical-semantic, and syntactic information. The patterns and regularities in the input are crucial for learning each language. For example, phonological patterns in the input in Cantonese (L1) contribute to children's skills to recognize and produce sounds in Cantonese, so as those in English (L2). When the number of children being raised in a bilingual home continues to keep growing, it is important that we recognize that they also achieve basic milestones like

monolingual children (Hoff et al., 2012). If a child is only exposed to two languages, the one that the child is exposed to the most will develop faster than the one that is less exposed. Children who are exposed to multiple different languages will develop at a slower pace than compared to monolingual individuals (Hoff et al., 2012). The overall amount of language exposure will cause a differing amount of vocabulary development and the language acquisition that takes place to develop the ability to learn new words.

Previous studies examined bilingual children's language developing through various linguistic tasks. For example, in the study done by Hoff et al. (2012), the amount of language exposure will cause a differing amount of vocabulary development. In this study, Hoff et al., (2012) used the data from 25 male and 22 female participants that were exposed to both Spanish and English from birth. The goal of this study was to investigate the effects of dual language exposure of occurs in a natural bilingual environment (Hoff et al., 2012). This study obtained the language skill measurements by using extensive interviews such as *MacArthur-Bates Communicative Development Inventory: Words and Sentences* and the Spanish version *El Inventario del Desarrollo de Habilidades Comunicativas.* These vocabulary inventories helped to establish reliability and validity for both monolingual and bilingual populations (Hoff et al., 2012). The score that will be obtained through these vocabulary inventories is through the breakdown of if the child is able to produce the three measures of grammatical development of word combinations, a grammatical complexity, and has a mean length that is based on 37 items of the utterances that are presented (Hoff et al., 2012). Language acquisition will take into account the ability to learn new words. In this study, it was seen that with the exposure to two languages (dual language exposure) the language that the child is exposed to the most will develop faster than the one they are exposed to less. If a child is only exposed to one language

(monolingual) they will develop that language more rapidly than those who are developing two or more languages (Hoff et al., 2012). The results that were found was that on average children that are acquiring two languages will often lag behind children that are only acquiring one language.

In another study, Bialystok et al., (2010) examined monolingual and bilingual school-age children's receptive vocabulary, using the Peabody Picture Vocabulary Test (PPVT). Results showed that bilingual children know fewer words in English than monolingual children. Bilingual children have to distribute their language-learning time across two different languages. Bilingual children are also compromised in their expressive ability due to their split language-learning time. Vocabulary size is a predictor of academic achievement and literacy acquisition. It can be expected that the gap between monolingual children and bilingual children will decrease over time and their ages, but there has been no study to show that change will the years passing. Another factor that can be seen is the vocabulary size difference due to different home lives (Bialystok, 2010). The school vocabulary is more comparable due to students learning and using the same language in the same way as their peers (Bialystok, 2010).

The uneven vocabulary development in bilingual's two languages can be described as the possibility of not responding to specific vocabulary words or their own names in either one of their developing languages (Hoff et al., 2012). Rather than being measured in one language, researchers have been examined bilingual children's vocabulary conceptual knowledge (Bedore et al., 2005). Conceptual vocabulary scores can be described as the total number of independent concepts, and those are distributed across the two different languages. Cheung et al. (2018) show that older siblings and the home/family environment are crucial to how (s) a bilingual child will learn vocabulary from both languages. As the family dynamic changes, the method and process

of learning will also change with it. Family language practices and cultural practices can be affected by the differing amounts of L1 and L2 used among family members (L1 tends to be more flexible). Along with older siblings having a significant influence, family dinners are crucial in family activities that show where language (usually L1) can thrive. Along with sitting down with your family and enjoying a meal, the characteristics of reading aloud, telling stories, and playing word games can all be seen through a family dinner.

Consistently in another study conducted by Garcia (2018), they found that there is a correlation between the child that has weaker English (L2) skills, they will be in a classroom where there is more Spanish (L1) being spoken. From this study, it is unclear whether the parents choose their child to attend the majority of Spanish (L1) classrooms because that language is the home language. Teachers used L1 or L2 in any response based on the child's preference. It is important to recognize the limitation of this study that only one aspect of language development was examined- receptive language. When reexamining the process of language development, it is crucial that language input and use at home and in school are thoroughly studied. Some of the parts that are studied are the language context in the classroom and the peer composition in the classroom. The language context in the classroom can be seen as how dual language learners (DLL) can benefit from experiencing the same high instructional environments that are similar to the language majority learners (Garcia, 2018). The peer composition in the classroom can be seen as how much language a classroom is able to hold. Peer language is one of the most important factors for DLLs, especially if they are learning English as their second language (Garcia, 2018).

Processing Speed in Typically-developing Bilingual Children

Processing speed has been described as the speed at which one can respond, complete, or understand information (Leonard et al., 2007). Previous studies showed that monolingual children with developmental language disorder (DLD) might take longer to process linguistic and non-linguistic information (Miller et al., 2001; Montgomery & Windsor, 2007). Slow processing speed can significantly affect children's daily lives, such as understanding instructions, participating in conversations, and completing academic tasks. There are several theoretical explanations for slow processing speed in monolingual children with DLD (Windsor, 2017). For example, the "limited processing capacity" hypothesis suggests that the slow processing speed in children with DLD is due to a reduced capacity for processing and storing information (Ellis Weismer & Evans, 2002). Leonard et al. (2007) suggest that processing limitations can be looked at through several different lenses, such as "spatial or space," "energy," or "time." In the lens of "spatial," the computational region of the memory is restricted. Thus, there will be little space to work with. In the lens of "energy," fuel is needed before a task is completed. Lastly, the lens of "time" means that if the information is not processed quickly enough, it will decay. In contrast, the "working memory" hypothesis proposes that children with DLD have reduced working memory capacity which limits their ability to hold and manipulate information in their brain. Some researchers proposed that the slow processing speed in children with DLD is due to the fact that they need more time to process and respond to language input (Mainela-Arnold & Evans, 2005).

Since monolingual children with DLD are consistently slow in responding linguistic and nonlinguistic tasks, processing speed measures have been proposed to be used included in the assessment protocol for identify children with DLD (Kohnert & Windsor, 2004). However,

processing speed in typically-developing bilingual children is not as straightforward as monolinguals because they have to manage and switch between two languages, which can affect their cognitive processing. For typically-developing bilingual children, they might have an advantage for processing speed in tasks that require executive control and attentional flexibility (Bialystok & Viswanathan, 2009). However, some studies find no advantage in typically-developing bilingual (Bonifacci et al., 2011; Kohnert & Windsor, 2004). Processing speed plays an important role when investigating bilingual children. Through processing speeds one is able to look into the factors of quantitative and qualitative data differences (Kohnert and Windsor, 2004). In a study done by Kohnert and Windsor (2004), 100 participants were between the ages of eight and thirteen years old. In this study there were three separate groups. The bilingual group (BI) spoke both Spanish and English, the monolingual group spoke English (EO) with intact language (meaning there is no presence of a language impairment), and the third group spoke English (LI) but there is a presence of a language impairment. In this study they used nonlinguistic tasks such as simple auditory detection, complex auditory detection, simple visual detection, and complex visual detection. Simple auditory and visual detections can be described as presenting only one stimulus for one response. For example, either a tone (auditory) or a colored light (visual) is presented, and the participant is only needed to respond once (usually by pushing a button). Whereas in complex auditory and visual detections there will be two stimuli (instead of one tone there will be a high and low tone) and the participant will be needed to make two responses by pressing two buttons. These nonlinguistic tasks will measure response time by the speed of the task completion which includes the time it takes to encode the stimulus, the time it takes to make a decision, and the motor response time. The results of this study are seen as the

response time being faster for the BI and EO (those with intact language) when being compared to LI.

Recent research showed that bilingual children with developmental language disorders (DLD) show a slower response time or processing speed when compared to typically developing (TD) bilingual children (Park et al., 2020). In this study, there are eighty-six participants that range from the ages of eight to twelve years old. All of the participants were required to have a nonverbal IQ of above a 75 which is measured by the Wechsler Abbreviated Scale of Intelligence-Second Edition (Park et al., 2020). The participant monolingual groups had to confirm that they had a minimum of three years of English exposure, used a home language with at least one member of the household, and used the home language at least 20% of the time (Park et al., 2020). All of these requirements were set in place, so both the bilingual and monolingual participants were on an even level with how much English they were exposed to. Both of the BI-TD and BI-DLD (bilingual typically developing and developmental language disorder) had various different language backgrounds in addition to English (Park et al., 2020). Some of these languages were Korean, Chinese, German, Bengali, French, and Spanish. One of the main tasks they used to measure response time was through the Visual Choice RT. The Visual Choice RT is where all of the participants were presented with a randomized image of either a red or blue circle in the center of the computer screen. The participants were then asked to press the corresponding buttons with the instructions of placing their index fingers on the buttons that were marked with blue and red stickers (Park et al., 2020). All of the instructions were given in English and allowed for feedback, so it was ensured that all of the children completely understood the task. The results showed that children with DLD showed a slower response time

(RT) when compared to TD children. There was no evidence showing children's processing speed is related to bilingual experience.

The methodology of these two studies on processing speed (Park et al., 2020 and Kohnert and Windsor, 2004) use tasks require children to press a button as fast as possible. These tasks are often too challenging for young preschool children to complete. I think that when looking and investigating response time, in order to gain accurate results, one must use tasks that are appropriate for preschool children. In this study, I examined the feasibility of using narrative context to measure response time such as having preschool children retell a story and not asking them to respond. Specifically, I manually measured the response times and speaking rates of typically-developing children who learn Cantonese as L1 and English as L2. The results would potentially provide valuable information about typically developing bilingual preschool children's processing speed. The information could serve as a baseline for examining bilingual children with DLD.

The Current Study

The purpose of this study is to examine Cantonese-English bilingual children's response speed to the examiner and speaking rate in both Cantonese and English narrative contexts. Response speed is operationally defined as the time interval (in seconds) between the end of the examiner's utterance and the beginning of the child's utterance. Speaking rate is operationally defined as words per minute. Specifically, I analyzed the language samples collected by Dr. Kan from 36 preschool bilingual children who learn a Cantonese (L1) at home and English (L2) as a second language in preschool school. At the time of testing, children had stronger skills in Cantonese than in English. In this investigation, I examined where age, exist language knowledge, and language (Cantonese vs. English were predictors of children's response speed and speaking rate. Specific research questions are:

1. Does age predict bilingual children's response speed and speaking rate in bilingual preschool children? That is, do older bilingual children speak faster and respond quicker than younger children? If so, in what language?
2. Does existing language knowledge predict bilingual children's response speed and speaking rate? This, do children who have stronger L1 skills speak faster and respond quicker than children have weaker L1 skills? do children who have stronger L2 skills speak faster and respond quicker than children have weaker L2 skills?

As stated earlier, no previous studies have specifically examined the response speed and the speaking rate of typically-developing bilingual children. There is reason to hypothesize that there is a developmental effect on the processing speed in bilingual children. Studies have shown that younger monolingual children tend to have slower processing speed than older children, and that this improves with age (Kail, 1992). If language experience plays a role in children's processing

speed and our participants had more experiences in L1, then it should be expected that children should be faster in L1 than in L2. The investigation could contribute our understanding of the "normal" range of response speed and rate in typically-developing bilingual children through the process of story-retelling.

Methods

Participants

Participants were 36 typically developing Cantonese-English children from 3;1 to 5;3 (M = 4;1; SD = 8.28). There were 18 boys and 18 girls. Fifty-five participants were randomly selected from a larger group of 224 preschool children who spoke Cantonese at home and were learning English in the preschool setting. The final sample included children (n =36) who speak both Cantonese and English at the time of testing. Children who did not yet speak English were not included in this analysis. All included participants were born in the United States but lived in homes in which the primary language was Cantonese. Participants attended a Head Start program, 5 days per week. The Head Start program serves low-income families in a large metropolitan area in San Francisco, CA. On average, children had attended preschool for 13 months (SD = 9.2). According to the parent and teachers' reports, participants were stronger in Cantonese than in English at the time of testing. In this study, a mid-split was performed on a sample of 36 preschool children, resulting in two distinct groups based on their age.

Methods

Story Retell Task

The picture Frog books by Mayer (1969) was used as the basis for story retells. Rather than requesting the children to narrate a story based on a set of pictures, the researchers began by telling the children a story that was linked to the pictures. To maintain uniformity in the testing process for all children across different cultures and developmental levels, the researchers developed appropriate scripts in Cantonese and English that were suitable for the children's developmental and cultural backgrounds. It is important to note that the Cantonese script was not a direct translation of the English script and vice versa. The development of these story scripts

involved the input of bilingual research assistants and preschool teachers. During the Cantonese session, the examiner told the story following the script in Cantonese while displaying the relevant pictures to the child. The same approach was adopted during the English session. The story retell samples were transcribed by trained research assistants who were native speakers of either Cantonese or English. The analysis of the English language data involved coding and entering the English transcriptions into the Systematic Analysis of Language Transcripts (SALT) Version 18 (Miller, 2017). For each child's story retell, the Mean Length of Utterance (MLU) and Number of Different Words (NDW) were determined and used in subsequent analyses. The calculation of MLU-M in morphemes was used as a conventional approach for assessing grammatical development in toddlers and preschool children. The SALT software was also adjusted for Cantonese language analysis, following a three-step process of transcribing the samples into Chinese characters, converting each syllable into pinyin (a Romanization system for Cantonese), and identifying and coding the compound words (Kan et al., 2020). For Cantonese, segmentation of utterances was established based on Cantonese rules and assessed by taking into account intonation contours and grammatical completeness. In the Cantonese sample, standard markers in SALT were used to code the transcript (e.g., " . " was used to signify the end of an utterance). The Mean Length of Utterance (MLU) was determined by counting the number of words in an utterance (MLU-W) because Cantonese is a non-inflected language that does not have bound morphemes. As such, there is no distinction between MLU-W and MLU-M counts. Compounding is a frequent feature in Cantonese, which was also considered in the adaptation of SALT for Cantonese analysis. Monosyllabic words were combined based on the semantic information of the words.

Participants' vocabulary and grammatical skills in Cantonese (L1) and English (L2) are summarized in Table 1. Participants had significantly stronger syntactic skills in Cantonese than in English, $F(1, 35) = 131.87$, $p < .001$. On average, their mean length of utterance in words (MLU-w) in Cantonese is 4.06 (SD =2.72) and their MLU-morphemes (MLU-m) is 2.49 (SD = 1.68). They also had significantly greater lexical diversity (number of different words), $F(1, 35) = 115.50$, $p < .001$. On average, they had 142.19 different words in the Cantonese samples and 84.75 different words in the English samples.

Table 1.

Participant Characteristics

	Cantonese (L1)		English (L2)	
	Mean	SD	Mean	SD
MLU in morpheme	--	--	2.49	1.74
MLU in words	4.06	2.72	2.34	1.68
Number of different words (NDW)	53.03	34.19	31.78	21.34
Number of Total words (NTW)	142.19	119.59	84.75	73.25

Coding Response Speed

The methods of obtaining our data were mainly from two different computer coding systems. I used the computer programs of Systematic Analysis of Language Transcripts (SALT) (Miller, 2017) and Praat (Boersma & Weenink, 2012). SALT is a computer program that helps standardize the process of eliciting, transcribing, and analyzing various language samples ranging from various languages. The program uses a coding system to identify various linguistic

features, such as grammatical structures, semantic content, and pragmatic functions. Praat is a computer software the helps show the visuals of speech analysis in phonetics.

The tasks that were involved with obtaining our data was through the process of listening to sound samples through Praat. As I listened to the samples, I took note of the beginning and end time of each utterance to then calculate the pause time in milliseconds in-between each utterance. To calculate the pause-times was through the process of subtracting the time of the end of the utterance and the beginning time of the utterance (see Appendix A).

After calculating the pause time using Praat, I took the time of each utterance (in milliseconds) and placed it on the corresponding utterance in SALT.

Once the beginning and ending times of each utterance were identified using Praat, I inserted the corresponding pause times into their appropriate locations. The time format in SALT refers to the time is entered on timing lines (which begin with a hyphen) or pause lines (which begin with a colon or a semicolon) or when entering pauses within utterances. The time formats I used in this study are:

minutes:seconds	1:00 or 5:13 or 05:13
:seconds	:05 or :5 or :75

I placed the pause times in between the ending of the utterance and the beginning of the next utterance. After inputting the correct utterance (beginning and ending) times and the pause times, I went back through the file and deleted the utterance lengths so only the beginning and ending language sample time was on the file. By deleting the rest of the file's utterance times it only showed the pause times in-between each utterance (see Appendix B). Once all of the data (utterance and pause times) was complete for each language or sound sample, the file was then run through the SALT program to calculate the pause rates and other various important

statistics. To measure the speaking rate of a child, SALT code the number of words produced by the child in a given amount of time. The program can automatically calculate the words per minute (WPM) based on the duration of the sample and the total number of words produced. In addition to measuring speaking rate, SALT can also code the pause time between utterances. The program calculates the average pause time based on the duration of the sample and the total number of pauses.

Results

Table 1 provides a summary of the speaking rate (words per minute) and the response time of the participants (the average time intervals it took for the participants to respond to the Examiner). On average, children produced 39.22 words per minute in Cantonese and 23.43 words per minute in English (see also Figure 1). The average time intervals were the average of all time intervals between the end of the examiner's utterance and the beginning of the child's utterance. Paired t tests were used to inspect the two within-subject language conditions. Results showed that children produced more words in Cantonese than in English [$t(35) = 2.75$, $p < .05$]. There were no differences between the two language conditions in terms of the average time intervals [$t(35) = .17$, $p > .5$].

Table 1.

Speaking rate and time intervals (in sec) participants responding to the examiner.

	Child			
	Cantonese		English	
	Mean	SD	Mean	SD
Words per minute	39.22	29.55	23.43	21.23
Average time interval (in sec) between utterance	2.72	3.31	2.88	2.16

Note.

Time interval = the interval between the end of the examiner's utterance and the onset of the child's utterance.

Table 2 provides a summary of the speaking rates and the response time of the examiner (see also Figures 1 and 2). On average, the examiner produced 64.81 words per minute in Cantonese and 42.6 words per minute in English. Paired t tests were used to inspect the two within-subject language conditions. Results showed that the examiner produced more words in Cantonese than in English [$t(35) = 3.21$, $p < .01$]. However, there were no differences between the two language conditions in terms of the average time intervals [$t(35) = .19$, $p > .5$].

Table 2.

Speaking rate and time intervals (in sec) the examiner responding to the participants.

	Examiner			
	Cantonese		English	
	Mean	SD	Mean	SD
Words per minute	64.81	34.23	42.60	24.39
Average time interval (in sec) between utterance	2.03	0.86	2.62	1.61

Note.

Time interval = the interval between the end of the child's utterance and the onset of the examiner's utterance.

Figure 1.

Speaking rate (Words per minute) of the participants and their examiners

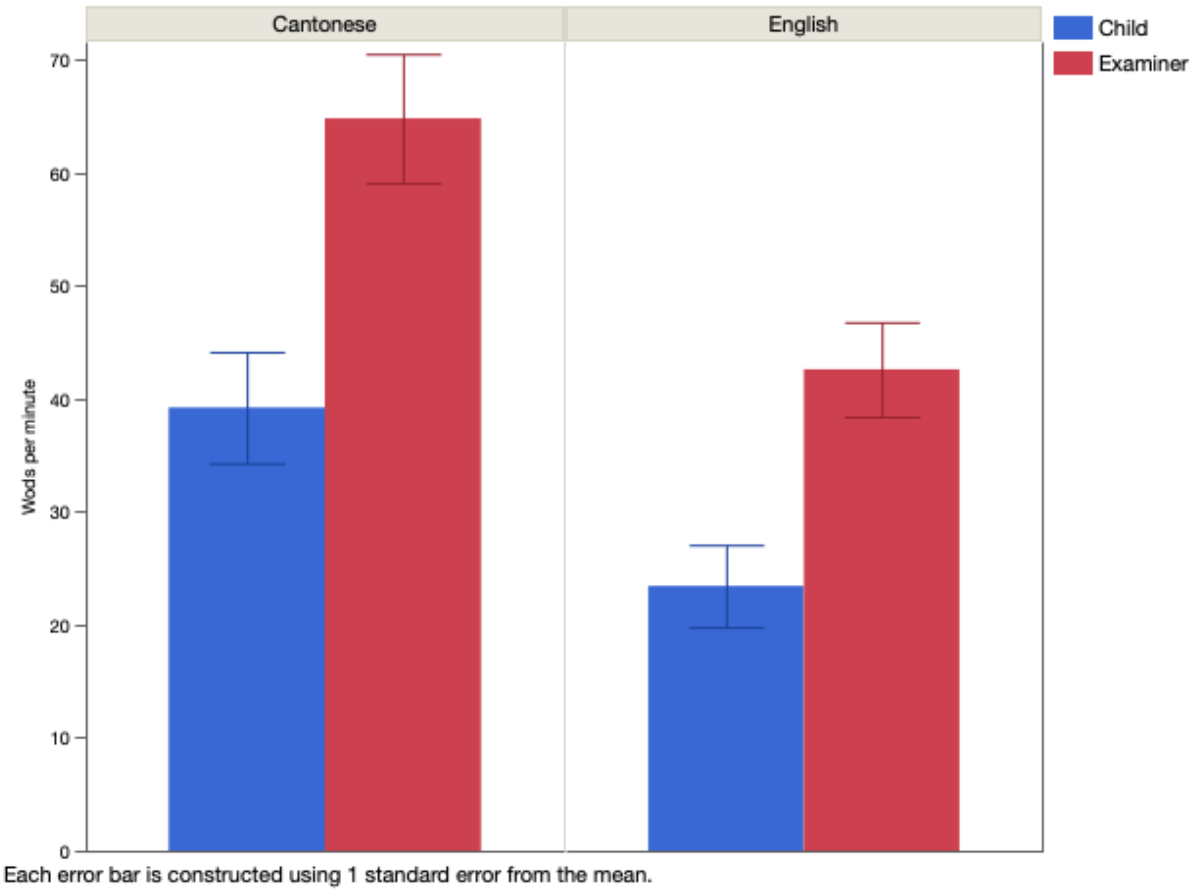
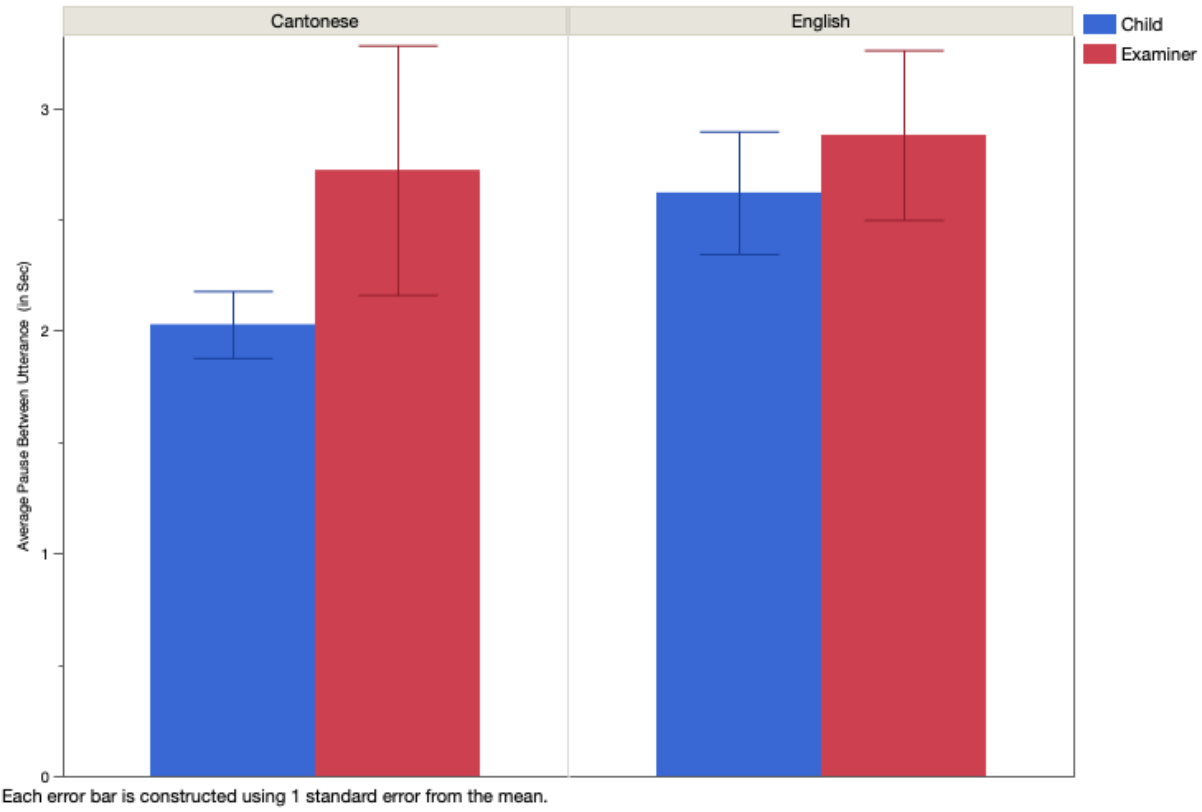


Figure 2.

Average pause between utterances (in seconds) of the participants and their examiners.



Regression analyses were done to examine participants' speaking rate and the response speed of the participants. The dependent variables were words per minute and the average child-to-examiner intervals (in seconds). The predictors were age in months, participants' mean length of utterance (MLU), number of different words (NDW), language (Cantonese vs. English). The results were summarized in Table 3. In terms of speaking rate, participants' MLU and NDW were significant predictors of children's words per minute, but language was not significant. The findings suggest that children who had longer MLU and greater vocabulary diversity had faster speaking rate in both languages. Children's age (age in month) was not significant, suggesting

that older children were not faster than young children. In addition, there was no effect of language (Cantonese vs. English), suggesting that children's speaking rates in Cantonese and English were the same when age, MLU and NDW were taken into consideration in the model. In terms of response speed, participants' age predicts the average child-to-examiner intervals, but MLU and NDW failed to reach significance. The results suggest that on average older children who took less time to respond to the examiner.

Table 3.

Regression Analysis Results: Children's Speaking Rate and Response Speed

Dependent variables	Predictors	Regression Coefficient (β*β*)	*SE*	*t*	*p*
Word per minute of the child	Child's MLU	5.69	1.02	5.6	<.001*
	Child's NDW	0.44	0.08	5.13	<.001*
	Child's age in month	0.15	0.18	0.84	0.40
	Language	-0.85	1.51	-0.56	0.58
Average child-to-examiner intervals	Child's MLU	0.21	0.27	0.78	0.44
	Child's NDW	-0.01	0.02	-0.33	0.74
	Child's age in month	-0.09	0.04	-2.07	<.05*
	Language	-0.18	0.37	-0.48	0.63

Discussion

The purpose of this study is to examine the processing speed to the examiner from bilingual children. Of interest in this study are preschool bilingual children who learn a minority language (L1) at home and English (L2) as a second language in school. In preschool classrooms, children's processing speed refers to how quickly they can understand and respond to spoken information. For example, if a teacher gives directions to a child to put away their toys, a child with fast processing speed will quickly understand and start putting their toys away. On the other hand, a child with slower processing speed may struggle to understand the directions and take longer to respond. Slow processing speed can lead to difficulties in following instructions, completing tasks, and engaging in classroom activities. While processing speed has been suggested as a substitute screening tool for identifying bilingual children who may have developmental language disorder (DLD; e.g. Kohnert & Windsor, 2004), the practical challenges of using it with bilingual preschoolers, such as requiring them to press a button as quickly as possible for an extended period of time, pose methodological limitations. To address this issue, one possible solution is to measure the response time of children with DLD to adults or their speaking rate and compare it to that of typically-developing children. However, before investigating this question, it is vital to establish a baseline of what is considered normal for bilingual children who are typically developing.

In this current study, I analyzed a dataset from the database of language sample collected by Dr. Kan. The language samples were selected from 36 preschool children (3;1 to 5;3; Mean age = 4;1; SD = 8.28) that learned Cantonese in their home (L1) and then taught English (L2) in a school setting. In this study, the language samples collected were derived from the interactions between a test examiner and a child during a story-retell task. The primary objective was to

investigate potential age and language effects on the typically-developing bilingual children's speaking rate and response time in L1 and L2 contexts. Speaking rate was measured in words per minute, while response time was defined operationally as the duration (in seconds) between the conclusion of the examiner's utterance and the commencement of the child's response. Specifically, I examined whether there was a difference between typically-developing bilingual children's L1 and L2 in their speaking rate and their response time. I also looked at if children's existing grammatical and lexical skills (MLU and NDW) predict their their speakiing rate and their response time in both Cantonese and English. In what follows, I discuss children's

Speaking Rate

On average, children produced 39.22 words per minute in Cantonese and 23.43 words per minute in English (see also Figure 1). The average time intervals were the average of all time intervals between the end of the examiner's utterance and the beginning of the child's utterance. Paired t tests results showed that children produced more words in Cantonese than in English [$t(35) = 2.75$, $p < .05$]. The regression analysis results suggest that children who had longer syntactic skills (MLU) and greater vocabulary diversity (NDW) had faster speaking rate in both Cantonese and English (see Table 3 and also Figure 1). Children's age in months did not predict their speaking rate, suggesting that older children were not necessarily faster compared to younger children. Furthermore, the analysis revealed that there was no significant effect of language (Cantonese vs. English) on the children's speaking rate, indicating that their rates of speech in both languages were similar when age, MLU, and NDW were controlled for in the model.

One explanation for the finding that children with longer mean length of utterance (MLU) and greater vocabulary diversity (NDW) had a faster speaking rate in both languages.

Children with a higher level of language proficiency may have a greater capacity to process words more quickly, leading to faster speaking rates. The stronger processing skills could enable children to retrieve and use linguistic information more quickly and efficiently, resulting in faster speaking rates. It is important to note that our participants were from age of 3 to 5. One possible explanation could be that speaking rate may not be strongly influenced by age, but instead by other factors such as language exposure or cognitive development. As for the absence of a significant effect of language on speaking rate, one possible explanation is that speaking rate is less influenced by language-specific factors and more related to general cognitive processing speed or motor coordination skills that are less language-dependent.

Response Speed

On average, the participants' average time interval (in seconds) between utterances was 2.72 in Cantonese. While the average time interval (in seconds) between utterances was 2.88 in English. (as seen on Table 1). In comparison, the examiner responded in 2.03 seconds between utterances in Cantonese and 2.62 seconds in English (as seen in Table 2). One of the main aspects of examination for speaking rate and response speed is regression analyses. With regression analyses, there is four main predictors that are used and can be seen as the participants' age in months, participants' MLU, NDW, and language (Cantonese or English).

In terms of response speed, the participants' chronological age (in months) predicted the average child-to-examiner intervals while MLU and NDW did not reach the same level of significance as they did in speaking rate. This use of age can be seen as a key finding of how the older the child/participant the less time it took for them to respond to the examiner. The results that age predicted response speed, but not MLU or NDW, suggests that there may be a developmental aspect to processing speed in preschool bilingual children. It could be that as

children age, they develop more efficient cognitive processing skills, such as attention, working memory, and processing speed, which enable them to respond more quickly to spoken information. On the other hand, vocabulary and grammatical skills may not be as closely linked to response speed, as the ability to process and comprehend language may be separate from the ability to produce a response quickly. In comparison to speaking rate, where MLU and NDW were found to be significant predictors, response speed seems to be more related to age than to language-specific or linguistic factors. This finding highlights the importance of considering both age and language when assessing language processing skills in bilingual children.

Limitations

Although the results of the study measuring children's response speed using child-examiner interactions in narrative samples appear to be promising, there are some limitations to consider. One limitation of a study that measures children's response speed using child-examiner interactions in narrative samples is that the results may not be generalizable to other contexts or communication partners. For example, the child's speaking rate may differ when interacting with peers or family members. Therefore, the findings from the study may not be fully representative of the child's speaking rate in everyday communication. Another limitation is that the study may not capture the full range of speaking rates that children are capable of producing. In the context of a narrative sample, children may speak more deliberately or at a slower pace to ensure they accurately convey the story. However, in other contexts, such as during play or conversation, they may speak more rapidly. As a result, the study may not reflect the full range of speaking rates that children can produce. In addition, attention bias and interpretation bias could affect children's speaking rate and response speed measures in this study. Attention bias in this study can be seen through the participant's current and present attention to the story retell task when being examined. For example, if the child was distracted by another child in the room while being examined there will now be attention bias that is present. Interpretation bias in this study can be seen through the tendency to interpret ambiguous information in a manner that is consistent. For example, if one of the utterances a participant makes goes uncoded then there will be current interpretation bias. Another limitation is that the study may be limited by the sample size, age range, or language background of the participants. For example, the study may not have included a diverse range of children from different cultural or linguistic backgrounds, which may limit the generalizability of the findings. Finally, the study may be subject to measurement

errors, such as inconsistent or inaccurate transcription of the narrative samples, or errors in determining the response time. These errors could impact the validity and reliability of the findings, and thus the study's overall conclusions.

Conclusion and Clinical Implications

In conclusion, this study provides valuable insights into the speaking rate and response speed of typically developing bilingual preschool children. Within this current study there were three main key findings that were established. The first key finding was that on average children took less time to respond to the examiner in the Cantonese condition than the English. The second key finding is that the children who had a longer MLU and more diverse vocabulary produced more words per minute. The third key finding is that older children responded to the examiner faster than young children.

These findings have important clinical implications for identifying and screening bilingual children with developmental language disorder (DLD). Since processing speed has been suggested as a screening tool for identifying bilingual children with DLD (e.g., Park et al. 2020), this study's baseline data on typically developing bilingual children's response speed and speaking rate could be used as a comparison point to identify potential language difficulties in bilingual children. In terms of speaking rate, the lack of a significant age effect on speaking rate suggests that clinicians should be cautious when using this measure alone to identify/screen bilingual children with DLD. While slower speaking rates may be indicative of DLD in younger children, this may not hold true for older children who have already reached a plateau in their speaking rate development. Therefore, clinicians should use multiple measures to assess language development, including measures of vocabulary, grammar, and processing speed, to make a more accurate diagnosis of DLD in bilingual children.

In terms of response speed, if a bilingual child's response speed interval falls significantly outside the range of the typically developing bilingual children, it may indicate the need for further language assessment to rule out DLD. It is important to note that response speed and

speaking rate are not the only measures that should be considered in identifying bilingual children with DLD. Overall, this study's findings suggest that processing speed measures, such as response speed and speaking rate, can be useful tools for identifying potential language difficulties in bilingual children, and should be used in conjunction with other language measures to provide a comprehensive assessment of a child's language development.

The results can be used to further development parent or teacher reports as clinical indicator for identifying and screening bilingual children with DLD. When assessing a bilingual child's language development, clinicians should use multiple measures to ensure an accurate diagnosis.

Future Directions

In future studies, it would be valuable to investigate the relationship between response speed and speaking rate and other measures of language development in bilingual children. For example, studies could examine how response speed and speaking rate relate to measures of syntax, semantics, and pragmatic language abilities. This could provide a more comprehensive understanding of how processing speed relates to overall language development in bilingual children.

Additionally, in this study, we examined only children's response in narrative contexts, future studies could further explore processing speed across various tasks in bilingual children. It would be useful to investigate whether age plays a role in the processing speed in bilingual children with and without DLD.

Furthermore, studies could examine the potential impact of language dominance on processing speed and language development in bilingual children. Many bilingual children do not have balance language proficiency in both languages. It is still unclear the role of language proficiency affect children processing incoming language information.

Acknowledgements

I would like to acknowledge and give my warmest thanks to Dr. Pui Fong Kan for guiding and assisting me through the process of writing this thesis. Dr. Kan not only made this work possible by allowing me to use and experiment with her language samples in her lab, but she also mentored me throughout the entire process. I would also like to thank my committee members, Dr. Christine Brennan and Dr. Lauren Collins for letting my defense be an enjoyable moment and for all of your brilliant comments and suggestions, thanks to you. In addition to my committee members, I would like to thank my fellow peers Abigail Matthews and Mei White. I truly appreciate their diligent work with the final steps of my coding process.

I would also like to thank my family members, specifically my parents, Kristin and Jake Propst, for their unwavering support. The constant encouragement from the both of them is what sustained me in the entire process.

Finally, I would like to thank my partner, Garret Jordan, for his continuous support and understanding for the amount of time and effort that went into this research and writing process.

I am forever grateful and appreciative for the unconditional patience and support throughout this entire thesis process. Thank you to all of you who were apart of this journey.

References

Abutalebi, J., & Clahsen, H. (2017). Bilingual language acquisition: The role of input and experience. *Bilingualism: Language and Cognition*, *20*(1), 1–2. https://doi.org/10.1017/S1366728916001164

Aguilar-Mediavilla, E., Buil-Legaz, L., López-Penadés, R., Sanchez-Azanza, V. A., & Adrover-Roig, D. (2019). Academic outcomes in bilingual children with developmental language disorder: A longitudinal study. *Frontiers in Psychology*, *10*, 531. https://doi.org/10.3389/fpsyg.2019.00531

Anderson, J. a. E., Hawrylewicz, K., & Bialystok, E. (2018). Who is bilingual? Snapshots across the lifespan. *Bilingualism: Language and Cognition*, 1–12. https://doi.org/10.1017/S1366728918000950

Anderson, R. T. (2012). First language loss in spanish-speaking children: Patterns of loss and implications for clinical practice. In B. Goldstein (Ed.), *Bilingual Language Development and Disorders in Spanish-English Speakers* (2nd Edition, p. 21). Brookes Publishing Company.

ASHA. (N.D.). Birth to one year. *American Speech-Language Association.* https://www.asha.org/public/speech/development/01/.

Bialystok, E. (2015). Bilingualism and the Development of Executive Function: The Role of Attention. *Child Development Perspectives*, *9*(2), 117–121. https://doi.org/10.1111/cdep.12116

Bialystok, E., Luk, G., Peets, K. F., & Yang, S. (2010). Receptive vocabulary differences in monolingual and bilingual children. *Bilingualism: Language and Cognition*, *13*(4), 525–531. https://doi.org/10.1017/S1366728909990423

Bierman, K. L., Domitrovich, C. E., Nix, R. L., Gest, S. D., Welsh, J. a., Greenberg, M. T., Blair, C., Nelson, K. E., & Gill, S. (2008). Promoting academic and social-emotional school readiness: The head start REDI program. *Child Development*, *79*(6), 1802–1817. https://doi.org/10.1111/j.1467-8624.2008.01227.x

Buac, M., Gross, M., & Kaushanskaya, M. (2016). Predictors of processing-based task performance in bilingual and monolingual children. *Journal of Communication Disorders*, *62*, 12–29. https://doi.org/10.1016/j.jcomdis.2016.04.001

Cheung, S., Kan, P. F., Winicour, E., & Yang, J. (2019). Effects of home language input on the vocabulary knowledge of sequential bilingual children. *Bilingualism: Language and Cognition*, *22*(5), 986–1004. https://doi.org/10.1017/S1366728918000810

Garcia, E. B. (2018). The classroom language context and English and Spanish vocabulary development among dual language learners attending Head Start. *Early Childhood Research Quarterly*, *42*, 148–157. https://doi.org/10.1016/j.ecresq.2017.09.005

Hoff, E., & Core, C. (2013). Input and language development in bilingually developing children. *Semin Speech Lang*, *34*(4), 215–226. https://doi.org/10.1055/s-0033-1353448

Hoff, E., Core, C., Place, S., Rumiche, R., Señor, M., & Parra, M. (2012). Dual language exposure and early bilingual development. *Journal of Child Language*, *39*(01), 1–27. https://doi.org/10.1017/S0305000910000759

Hurtado, N., Marchman, V. A., & Fernald, A. (2008). Does input influence uptake? Links between maternal talk, processing speed and vocabulary size in Spanish-learning children. *Dev Sci*, *11*(6), F31-9. https://doi.org/10.1111/j.1467-7687.2008.00768.x

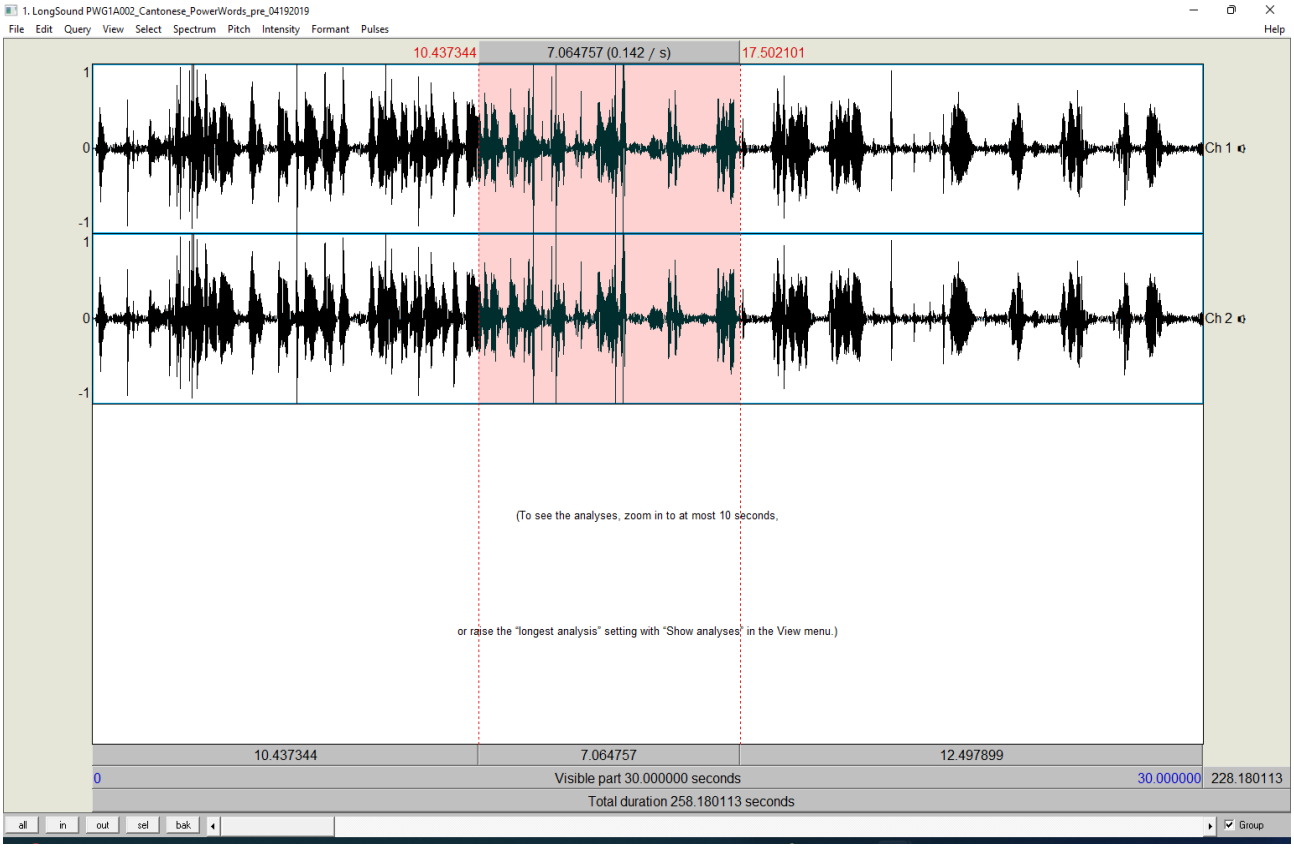
Kohnert, K., & Windsor, J. (2004). The search for common ground: Part II. Nonlinguistic performance by linguistically diverse learners. *Journal of Speech, Language, and Hearing Research*, *47*(4), 891–903. https://doi.org/10.1044/1092-4388(2004/066)

Leonard, L. B., Ellis Weismer, S., Miller, C. A., Francis, D. J., Tomblin, J. B., & Kail, R. V. (2007). Speed of processing, working memory, and language impairment in children. *Journal of Speech, Language, and Hearing Research*, *50*(2), 408–428. https://doi.org/10.1044/1092-4388(2007/029).

Medline Plus. (N.D.). Developmental Milestones Record. *Medline Plus.* https://medlineplus.gov/ency/article/002002.

J. S., Miller, C. A., Sanjeevan, T., van Hell, J. G., Weiss, D. J., & Mainela-Arnold, E. (2020). Bilingualism and processing speed in typically developing children and children with developmental language disorder. *Journal of Speech, Language, and Hearing Research*, *63*(5), 1479–1493. https://doi.org/10.1044/2020_JSLHR-19-00403

Appendix A:


1. LongSound PWG1A002_Cantonese_PowerWords_pre_04192019
File Edit Query View Select Spectrum Pitch Intensity Formant Pulses
Help
10.437344
7.064757 (0.142 / s)
17.502101
1
0
-1
Ch 1
Ch 2
(To see the analyses, zoom in to at most 10 seconds,
or raise the "longest analysis" setting with "Show analyses" in the View menu.)
10.437344
7.064757
12.497899
0
Visible part 30.000000 seconds
30.000000
228.180113
Total duration 258.180113 seconds
all
in
out
sel
bak
Group

Appendix B:

Child, Examiner SFA 101
+ Language: English
+ Context: Narratives
- 0:00
- 00:07:38
E Ok.
: :0:00:75
E Now we begin.
; :0:00:91
E The story?
; :0:00:16
E Frog where are you.
; :0:01:08
E So what happen/3s here?
; :0:05:00
E Can you try it?
E Explain what happen/3s.
; :0:00:48
E It/'s night time so>
; :0:00:46
C {Cantonese}.
: :0:01:03
E Uhuh And then can you (can you) try to say it English?
: :0:00:53
C {Cantonese}.
: :0:00:43
E Uh_huh.
: :0:00:49
C {Cantonese}.
: :0:00:70
E Uhuh and then what happen/3s to the.
: :0:00:59
C {Cantonese}
: :0:00:54
E Hmm?
: :0:02:16
C {Cantonese}.
: :0:00:76
E You can try:
: :0:00:27

Appendix C:

Additional regression analyses were done to examine the examiner's speaking rate and the response speed of the examiner. The dependent variables were words per minute and average examiner-to-child intervals (in seconds). The predictors were age in months, participants' mean length of utterance (MLU), number of different words (NDW), language (Cantonese vs. English). The results were summarized in Table 4. In terms of speaking rate, participants' MLU, age in month, and language were significant, but NDW was not significant. The findings suggest that examiner produced more words per minute for children who were older or had longer MLU. In addition, the examiner produced more words in Cantonese than in English. In terms of the average child-to-examiner intervals, none of the predictors reach significance. The results suggest that the examiner did not respond faster for older children or children who had stronger skills in either language.

Regression Analysis Results: Examiner's Speaking Rate and Response Time

Dependent variables	Predictors	Regression Coefficient (β)	SE	t	p
Word per minute of the examiner	Child's MLU	-7.89	2.38	-3.32	<.001*
	Child's NDW	0.28	0.20	1.42	0.16
	Child's age in month	0.93	0.42	2.22	<.05*
	Language	14.00	3.55	3.94	<.001*
Average Examiner-to-child intervals	Child's MLU	0.07	0.11	0.62	0.53
	Child's NDW	-0.01	0.01	-0.59	0.56

	Child's age in month	-0.02	0.02	-1.04	0.30
	Language	-0.28	0.18	-1.64	0.11