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What Do We Know about the Bilingual Advantage When the Executive Functioning Performance Is Tested Using Auditory Stimuli? A Systematic Review

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WHAT DO WE KNOW ABOUT THE BILINGUAL ADVANTAGE WHEN THE EXECUTIVE FUNCTIONING PERFORMANCE IS TESTED USING AUDITORY STIMULI? A SYSTEMATIC REVIEW

By

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This manuscript has been read and accepted for the Graduate Faculty in Audiology in satisfaction of the capstone project requirements for the degree of Au.D.

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ABSTRACT

WHAT DO WE KNOW ABOUT THE BILINGUAL ADVANTAGE WHEN THE EXECUTIVE FUNCTIONING PERFORMANCE IS TESTED USING AUDITORY STIMULI? A SYSTEMATIC REVIEW

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Introduction: On a daily basis, people are required to selectively attend, perceive, process and respond to the stimuli around them as they conduct different tasks. Many of these tasks may require auditory perception and processing and involve verbal communication. For many of us, our verbal environment involves more than one language. Some researchers argue that those who speak more than one language experience enhanced abilities in cognitive and attention control However, there may be processing costs that come with bilingual exposure and proficiency the present review aims to examine studies that assess executive function skills in both monolinguals and bilinguals to better understand how stimuli modality may affect performance and the possible demonstration of a bilingual advantage.

Methods: A total of nine studies that investigated the presence of a bilingual advantage in executive function (EF) tasks using visual and auditory stimuli modalities in monolingual and bilingual individuals were selected for this review.

Results: Executive function tasks which relied on an auditory (verbal or nonverbal) stimuli and a combination of visual and auditory (verbal) stimuli showed no advantages between monolinguals and bilinguals, with both groups performing similarly. For tasks where the stimuli modality was primarily visual with some nonverbal auditory information, a monolingual advantage was mainly present. However, when the stimuli modality was visual only a majority of the results indicated a bilingual advantage. These results imply that there may be an effect of stimuli modality on EF performance which differs between bilingual and monolingual participants. In addition, the current literature examining EF is limited and the methods used were found to be inconsistent. Thus, future research is required in order to further examine the effect stimuli modality may have on EF and how it may interact with linguistic experience.

Key Words: “bilingual advantage,” “monolingual vs. bilingual,” “executive function in bilinguals,” “executive function modality”

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INTRODUCTION

Speech perception is a multisensory process that involves both visual and sound cues. Both auditory peripheral and central centers are used to define the incoming acoustic cues for speech perception and verbal communication. In everyday life, individuals commonly rely on auditory perception and processing to complete simple tasks and for many of us, our environment often involves more than one language. Through language we communicate thoughts, feelings, create connections and identification by gathering and interpreting sounds continuously without conscious effort. Individuals that are fluent in more than one language are considered bilinguals. This group of people are presented with greater challenge in processing verbal language because they have to monitor and control their languages constantly. Bilinguals have to inhibit and manipulate verbal competitors from their non-target languages for efficient communication.

Bilingualism is present in most countries throughout the world in diverse classes of society and all age groups. In Europe, people who live in countries like Switzerland and Belgium have more than one official language. For some border areas between two language groups, there are economic and social factors that lead people to use more than one language on a regular basis. In some countries, bilingualism is more widespread throughout the population, such as in Paraguay, where most people speak both Spanish and Guarani. Today, Americans are more bilingual than ever before. According to the U.S. Census Bureau, there has been a constant rise in bilingualism since 1980, and the percentage of bilingual individuals in the United States has nearly doubled during that time. Moreover, the number of those who speak a foreign language at home has nearly grown seven times faster than the number who speak only English at home since 1980. Based on the U.S. Census Bureau, the states with the largest share of bilingualism at linguistic home in 2018 were California (45 percent), Texas (36 percent), New Mexico (34 percent), New Jersey (32 percent) New York and Nevada (each 31 percent), Florida (30 percent), Arizona and Hawaii (each 28 percent) and Massachusetts (24 percent). There are many possible explanations for this rise such as the arrival of new immigrants, language(s) being passed down from generation to generation and an increase in recent globalization.

Bilinguals and Executive Function

Communicating in more than one language on a daily basis allows for more opportunities to exercise certain functions, such as switching attention and inhibition when focusing on one language at a time and suppressing activation of the other. There is evidence suggesting that bilingualism enhances specific aspects of executive function (EF) tasks, particularly those that require ignoring relevant information, task switching and resolving conflict (Barac, Bialystok, Castro & Sanchez, 2014; Bialystok, Craik & Luk, 2012; Costa, Hernandez, Costa-Faidella & Sebastian-Galles, 2009). Executive function is a multidimensional construct that is used to guide behavior toward a specific goal (Banich, 2009). The EF network represents a complex set of cognitive processes such as organization, planning, working memory, inhibition and flexibility. All of these aspects are involved in the control of thought, action and emotion (Gioia, Isquith & Guy, 2001). Executive functioning skills help with behaviors that are required to plan and achieve specific goals (Kluwe, Viola & Grassi-Oliveira, 2012). Some of these skills include time management, organization, working memory, flexible thinking, and self-control, which are all considered essential everyday skills to continue learning, working, and managing daily life activities. Executive function skills are closely linked to academic performance (Blair & Razza, 2007; Gathercole & Pickering, 2001). There are some experiences that appear to encourage early and greater EF skills, which include environmental factors such as cultural and parenting practices (Bernier, Carlson, Deschenes & Matte-Gagne, 2012; Lee, Baker & Whitebread, 2018) as well as early school experiences (Simanowski & Krajewski, 2019). There is an agreement among scientists that various aspects of EF play crucial roles in verbal processing and production via top-down feedback and control of processing activities in a wide range of behavioral tasks (Pisoni, Conway, Kronenberger, Henning & Anaya, 2010). One of the most researched and well-documented variables that was found to be correlated with EF performance is bilingualism (Bialystok & Miller, 1999; Bialystok and Craik, 2010; Soveri, Rodriguiez-Fornells & Laine, 2011; Chung-Fat-Yim, Himel & Bialystok, 2019).

The role of bilingualism has been primarily studied through three executive processes which include inhibitory control, monitoring and shifting. Inhibition is one of the most studied EF domains that is studied in bilingualism. Bilinguals require a continuous need to inhibit the nontarget language, since both languages are always cognitively active, even in a situation where one of the languages is not present (Thierry & Wu, 2007). Bilingual speakers must compartmentalize two languages in everyday listening situations, and focus on the language they want to use, while inhibiting the nonrelevant language. The training of bilinguals in inhibiting irrelevant information has been used to study the bilingual advantage in EF. The role of inhibitory control has revealed controversial results with some studies revealing evidence for competition for selection between languages (Hermans, Bongaerts, De Bot & Schreuder, 1998) and others showing evidence against it (Costa and Carmazza, 1999). Some research suggests that bilinguals' enhanced training in inhibiting irrelevant information provides them with better inhibitory control when compared to monolinguals (Bialystok & Martin, 2004; Green, 1998; Kroll et al., 2008). One of the most popular and most widely studied tasks that has been used to measure inhibitory control is the Stroop task (Stroop, 1935). The Stroop task is a processing task that requires participants to name the color in which the displayed words are printed in, without paying attention to the actual written words themselves. Words could be congruent with the color they were printed in (e.g., the word “red” printed in red ink) or incongruent (e.g., the word “blue” printed in green ink). The visual Stroop test is commonly used to measure EF skills in bilingual individuals (Dunabeita et al., 2014; Bialystok, Craik & Luk, 2008; Anton, Carreiras, Dunabeitia, 2019; Esposito, Baker-Ward, Mueller, 2013; Kousaie & Phillips, 2012).

Monitoring, also known as coordination or mental flexibility, can be described as the ability to monitor for goal-relevant information and/or detect conflict from competing information that may become the target for inhibition (Paap & Sawi, 2014). The Simon task (Simon & Ruddell, 1967) is primarily a visual EF task that is used to examine how conflicting information is managed in individuals. The Simon task requires participants to respond accordingly to one dimension or feature of a stimuli (e.g., the shape or color) by providing responses with the right and left hands, while ignoring some other dimensions of the same stimuli (e.g., their position on the screen) that represent either a congruency or conflict with respect to the hand with which they should respond with. A visual Simon task is commonly used to evaluate EF skills in bilinguals (Morton & Harper, 2007; Woumans, Ceuleers, Van der Linden, Szmalec & Duyckek, 2015; Bialystok, Martin & Viswanathan, 2005; Paap & Greenberg, 2013; Poarch, 2018).

Shifting involves movement between tasks and higher and lower levels of mental processing (Daucourt, Schatscheider, Connor, Al Qtaiba & Hart, 2018). The EF skill of shifting allows us to adapt to changing task demands and context (Poljac et al., 2010; Miyake, Emerson, Padilla & Ahn, 2004). In the case of bilingual individuals, this could indicate the mental movement that is required to shift between different languages, known and unknown words or even between different sound environments such as noisy and quiet backgrounds. A commonly used EF task that assess shifting ability in bilinguals is the dimensional change card sort task (DCCS) which requires individuals to shift from sorting based on one dimension (color) to sorting based on a second dimension (shape). Other studies have also used tasks such as color shape task (Miyake et al., 2004), category-switch task (Mayr & Kliegl, 2000), number-letter task (Rogers & Monsell, 1995) and the local-global task (Miyake et al., 2000) to measure EF skills in bilinguals. There is an abundant amount of evidence that bilinguals and monolinguals perform differently when it comes to EF tasks. This variance between the two groups could be due to the different cognitive skills that arise from diverse linguistic knowledge and experience, which in turn, lead to disadvantages and advantages.

Bilingual Advantage

The act of communicating in more than one language on a daily basis provides additional opportunities to exercise certain EFs and some studies have supported EF advantages in bilinguals. Previous research findings have demonstrated that individuals who are considered bilingual often outperform monolinguals on tasks that tap into EF. A study conducted by Bialystok (1999) studied cognitive control in two age groups of monolingual and bilingual children and found that the bilingual group demonstrated a better ability to inhibit disrupting information than the monolingual group. In another study by Bialystok and Viswanathan (2009), researchers compared monolinguals and bilinguals in Canada, and bilinguals in India and found that all bilingual children were better than monolingual children in inhibition and switching between tasks, but no differences were observed between the two groups in response suppression or on a control condition that did not involve executive control. Some research suggests that bilinguals' enhanced training in inhibiting irrelevant information provides them with better inhibitory control when compared to monolinguals (Bialystok & Martin., 2004; Green, 1998; Kroll et al, 2008).

Bilingualism has also been associated with improved cognitive function (Bialystok, 2015), increased attentional control (Soveri et al., 2011), increased auditory capacity (Motlagh, Jalilvand & Silbert, 2018), lower auditory thresholds for nonspeech stimuli (Krizman, Bradlow, Lam & Kraus 2017) and delayed symptoms of dementia (Guzman-Velez and Tranel, 2015). In a study by Kovacs and Mehler (2009), researchers investigated how bilingualism affects early speech recognition and development. Monolingual and bilingual 7-month year old children were matched and learned to respond to a speech or visual cue to anticipate a reward. The results suggested that bilinguals exhibited an enhancement of cognitive control before the onset of speech. There have been positive effects shown in children who are raised in bilingual environments even before they begin to speak, suggesting that exposure to two languages may be adequate to elicit EF advantages (Kovacs and Mehler, 2009). Overall, the bilingual advantage has been described in the literature as the ability of bilinguals to outperform monolinguals in diverse cognitive tasks when performance is assessed by measures of reaction time and precision. However, exposure to multiple languages rather than one might also result in disadvantages due to several possible reasons, which will be further discussed next.

Bilingual Disadvantages

The idea of a bilingual advantage has been challenged by many researchers in the last several years, where literature has shown that there are some disadvantages to being a bilingual. On a daily basis, there is a need to perform tasks that require EF control, speech perception and verbal processing. For those who are bilingual there are some processing costs that come with the cognitive benefits. Previous evidence implies that bilinguals may be at a disadvantage as they experience activation of lexical representations in both languages when listening to speech, and this dual coactivation leads to greater competition at the level of mental lexicon in bilinguals when compared with monolinguals (Green, 1998; Kroll et al., 2008). Being bilingual may reduce speech recognition due to many lexical items in memory which can lead to more lexical competition during recognition, ultimately creating competition between the target language and nontarget language (Hermans, et al., 1998). Other negative consequences include low vocabulary size (Oller, Pearson & Cobo-Lewis, 2007; Bialystok & Craik 2010; Bialystok & Luk, 2012) and poor lexical retrieval (Gollan et al., 2005; Roberts, Garcia, Desrochers & Hernandez, 2002; Bialystok, Craik & Luk 2008). A study completed by Kroll and colleagues (2008) explains that bilinguals could be at a disadvantage due to the interference of competing languages. Studies have shown that bilinguals have poorer receptive vocabulary scores compared to monolinguals on standardized tests such as the Peabody Picture Vocabulary Test (PPVT; Bialystok, Craik & Luk 2008b), and overall reduced verbal fluency (Gollan, Montoya, Fennema-Notestine, Morris, 2005). For individuals who are bilingual, there is a greater level of mental lexicon which lead to a less reliable lexical access (Bialystok, Craik & Luk, 2008). Bilinguals have also been shown to have more difficulties in nonword repetition (Gibson et al., 2014; Summers, Bohman, Gillam, Pena & Bedore, 2010), and in repeating both word and nonword tongue twisters (Gollan & Goldrick 2012). Although bilinguals have the ability to utilize multiple languages at high proficiency levels, they have been shown to be at a disadvantage in verbal tasks that demand lexical access (Michael & Gollan, 2005) and tasks that require them to produce noun phrases (Gollan, Montoya, Cera & Sandoval, 2008; Gollan & Goldrick, 2012).

Auditory verbal processing is generally a complex process that requires encoding an acoustic signal, matching it to the correct phonological representation and retrieving the semantic information associated with the phonological information to be integrated with the preceding information (Scmidtke, 2016). In addition, verbal processing requires auditory perception, at which bilinguals have been found to experience greater difficulties when compared with monolinguals (Gollan et al, 2008). Other potential disadvantages that bilingual individuals may experience include recognizing speech in noisy environments. Noise makes speech perception difficult for many, however the degree of difficulty increases for individuals who are bilingual (Bradlow & Alexander, 2007; May, Florentine & Buus, 1997; Shi, 2010). Bilinguals require a greater signal to noise ratio or an increase in clarity and predictability of the speech signal than monolinguals (Bradlow & Alexander, 2007). This disadvantage that is presented in bilinguals manifests as contextual cues are degraded (Cooke, Lecumberri & Barker, 2008), and because speech-in-noise perception is a multistep process, it is unclear why bilinguals are poorer in utilizing contextual clues.

Executive Function Modality

During common daily activities, individuals are required to perform executive functions in environments that offer auditory and visual input. For example, to ensure proper communication, it is imperative to acknowledge various sounds and messages and simultaneously process the competing inputs. In order to do this efficiently, the listener must rely on cognitive abilities and linguistic knowledge for further processing. However, despite the importance of such activities that heavily relay on auditory input, such as speech perception in the presence of competing sound sources, most of thereported cognitive benefits of bilingualisms are based on studies that tested EF skills performance using tasks that are heavily dependent on visual or nonverbal information only. There are only a few studies that have investigated the role of bilingualism in EF performance usingh tasks that mainly require manipulating auditory stimuli.

There is evidence in the literature implying that EF performance may differ depending on the modality of the stimuli used. For example, a study conducted by Knight & Heinrich (2017) compared results from several different scoring systems for visual and auditory Stroop tasks. The results suggested that the two types of Stroop tasks may be measuring different aspects of cognition, rather than tapping into a single modality cognitive ability. In an alternative study by D'Ascenzo and colleagues (2018), researchers looked at whether visual and auditory Simon effects could be accounted for by the same mechanism. Their results confirmed that the mechanisms underlying the visual and auditory Simon effects are essentially equivalent in terms of the interaction between unconditional and conditional response processes, however they differ with respect to the strength of their activation and inhibition. These findings should highlight the importance of considering hearing and/or central auditory processing abilities by incorporating EF tasks that manipulate auditory input when investigating the effects of bilingualism.

For this review we want to further examine EF task outcomes in studies that incorporate EF tasks that manipulate visual and auditory stimuli. We expect to find that for EF tasks that involve some level of auditory/verbal processing, the demonstration of any bilingual advantages will be reduced. Due to the evidence available of a bilingual disadvantage in noise and low receptive vocabulary scores, we expect that tasks that are heavily reliant on auditory/verbal processing, will yield outcomes that generally support a monolingual advantage. We do not expect to see a monolingual advantage on tasks that are purely visual, and for EF tasks that mainly involve visual processing we expect to find a bilingual advantage.

METHODS

The following description explains the methods used to select the studies included in this review. The search words used were chosen to maximize the number of articles found that included both monolingual and bilingual participants and tested EF using tasks that included auditory stimuli. Search phrases in the City University of New York (CUNY) Library database and Google Scholar included “bilingual advantage”, “bilingual disadvantage”, “bilingual advantage auditory and visual”,” bilingual auditory”, “bilingual executive processing”, “bilingual vs. monolingual”, “bilingual auditory linguistic status”, and “bilingual auditory visual”. The studies identified in the initial search were screened to determine if they met the inclusion criteria. Inclusion criteria for studies included in this review required that the study assessed EF with visual and auditory tasks in both language groups (monolinguals and bilinguals). It was also a requirement for the bilingual individuals’ L1 or L2 to be English. There were no specific limitations as to what languages were considered for the non-English language. The studies used in this review were not limited to a specific age group or a testing paradigm. Furthermore, existing literature reviews, graduate study dissertations and articles published in journal with a low impact score (<0.8) were also excluded from the study. The application of these criteria resulted in nine studies reviewed in this paper.

A method for categorizing the tasks presented in these studies was developed to distinguish the modality of each task. This resulted in a total of five types of task, with each type reflecting how the task was perceived and executed. In each study, the tasks were divided into one of the following categories:

1. **Visual Only** – The stimuli of the task were only presented visually, and the response required no auditory or verbal processing

2. **Visual + Auditory, nonverbal** – The stimuli of the task were presented mainly visually with some auditory, nonverbal component (e.g., tone).

3. **Visual + Auditory, verbal** – The stimuli of the task were presented mainly visually with some auditory, verbal component (e.g., verbal recall, speech perception).

4. **Auditory, nonverbal** – The stimuli of the task were presented auditorily and required no verbal/speech processing.

5. **Auditory, verbal** – The stimuli of the task were presented auditorily and required some verbal/speech processing.

RESULTS

All the studies in this review included two or more tasks that assessed EF using auditory and visual stimuli in monolingual and bilingual individuals. The study characteristics and demographics, including the total number of participants in each language group (monolingual, bilingual) or subgroup (early, late bilingual), mean age and standard deviation, assessment/definition of bilingualism, and age of L2 acquisition are displayed in Table 1. Of the nine studies, four evaluated children between four to seven years old and five studies evaluated adults between 18 to 31 years old. Gender was not taken into account in this review due to insufficient reports on gender distribution. Moreover, there is little support for significant gender differences in EF (Grissom & Reyes, 2018).

Definition/Assessment of Bilingualism

All nine studies in this review included two or more participant groups that differ in their linguistic status, with at least one being defined as a bilingual group by the authors. Three of the studies included three or more groups of participants which were divided based on language spoken (Desjardins, Bangert & Gomez, 2020; Bialystok, 1999; Kousaie, Sheppard, Lemieux, Monetta & Taler, 2014) and one study which included two groups of monolinguals (English monolinguals and English musician monolinguals) and one group of bilinguals (see Table 1).

Of the nine studies, two assessed bilinguals through the Language Experience and Proficiency Questionnaire (LEAP-Q) (Desjardins & Fernandez, 2017; Desjardins, Bangret & Gomez, 2020), one study administered the Clinical Evaluation of Language Fundamentals -4th Ed (CELF-4) in English and in Spanish, a vocabulary assessment and a parental report (Arizmendi et al., 2018), one study administered a language questionnaire (Warmington, Kandru-Pothineni & Hitch, 2018), one study administered a Language Background questionnaire, a language dominance survey and a parental report (Foy & Mann, 2014), one study used only a parental or self-report (Bialystok, 1999; Bialystok & DePape, 2009), one study administered a Language Background questionnaire and a parental report (Bialystok, 2010), one study administered a self-report and a Animacy Judgement task (Kousaie et al., 2014) (see Table 1).

Table 1

Study Characteristics and Demographics

Author	Number of Participants (n) MONO:BI	Mean Age (SD) in years MONO:BI	How Bilingualism was defined/assessed in the study
Arizmendi et al., 2018	167:80	7;7 (0.4): 7;9 (0.5)	Parents had to report that their child could carry on a conversation in English and Spanish through a detailed questionnaire. All bilingual children had to complete the **Clinical Evaluation of Language Fundamentals -4th Ed in English** CELF-4; Semel, Wiig, & Secord, 2003) **and Spanish** Semel, Wiig, & Secord, 2006). To confirm

			that the child had sufficient proficiency in each language to form complete sentences, children had to earn a standard score of 6 or greater on both the English and Spanish Sentence subtest of the CELF-4. Vocabulary assessments were also collected from the Expressive Vocabulary Test 2nd Ed, reading comprehension was assessed from the Woodcock Reading Mastery Test, Paragraph Comprehension Subtest and a parent rating scale on attention & behavior. Additionally, information was collected on Spanish Vocabulary using the Expressive One Word Picture Vocab Test-Bilingual version.
Foy & Mann, 2014	30:30	5.25 (NR)	Administered a **Language Background Questionnaire** to parents. Parents had to report child has been exposed to Spanish since at least 12 months of age. The parents were then screened using the Language Dominance Survey (in Spanish). Each bilingual child was then matched with an English-speaking monolingual child on age, gender, maternal education, short-term and working memory, and early reading skills.
Desjardins & Fernandez, 2017	20:19	18-31 (3.84): 18-31 (5.94)	All bilingual participants completed the **Language Experience and Proficiency Questionnaire** (LEAP-Q). Bilingual participants in this study reported that they had been exposed to Spanish at birth and to English before the age of 7 years and were equally proficient in both English and Spanish.
Warmington, Kandru-Pothineni & Hitch, 2018	23:23	23;4 (NR): 23;7 (NR)	Bilinguals completed a **Language Questionnaire** (adapted from Bialystok et al., 2014) in which they rated their proficiency in both languages and use of each language at home, work/school and with friends. They reported using English significantly more than Hindi on average but rated their

			proficiency in Hindi and English as comparable. The degree of bilingualism was estimated by dividing the reported English proficiency by the reported Hindi proficiency (L2/L1 ratio). The mean ratio was .98 which did not differ significantly from a value that might be taken to indicate perfect bilingual balance.
Desjardins, Bangret & Gomez, 2020	15 YOUNG ENGLISH MONO 16 YOUNG SPANISH-ENGLISH BI 15 OLDER ENGLISH MONO 15 OLDER SPANISH-ENGLISH BI	YOUNG ENGLISH MONO: 21 (1.9) YOUNG SPANISH-ENGLISH BI: 21 (1.9) OLDER ENGLISH MONO: 56 (5) OLDER SPANISH-ENGLISH BI: 55 (4)	A linguistic profile was obtained for each participant in this study using the **Language Experience and Proficiency Questionnaire** (LEAP-Q).The LEAP-Q is a self-report questionnaire that assesses a number of linguistic variables related to individuals' language use, language history, and self-rated proficiency in reading, writing, speaking, and understanding. Participants' responses on the LEAP-Q indicated that the two English monolingual groups had learned English from birth and had no other language.
Bialystok, 1999	30 MONO 30 BI	YOUNG MONO: 4,3 (NR) OLDER MONO: 5,5 (NR) YOUNG BI: 4,1 (NR) OLDER BI: 5,5 (NR)	Bilingual children spoke Cantonese or Mandarin at home but English in the community and at school. Hence, they were fluent in Chinese but differed in their mastery of English. All children were recruited from childcare centers in middle-class urban area. The monolingual and bilingual children often attended the same centers. Parents and childcare supervisors confirmed the children's status as monolingual English or bilingual Chinese-English.
Bialystok, 2010 STUDY 1	25 MONO 26 BI	6.1 (NR): 6.0 (NR)	Children's language background was reported through a **Language Background Questionnaire** completed by the parents

			with the consent form. The questions included the other languages the child was exposed to, the nature and extent of the exposure, and the child's competence in that language. In addition, parents rated statements about language use on a scale of 1-5, in which 1 represented "mostly in the other language" and 5 "mostly in English". Thus, a perfect balance between the two languages was indicated by a score of 3.
Bialystok, 2010 STUDY 2	25 MONO 25 BI	6.0 (NR): 6.1 (NR)	As in Study 1, parents completed the **Language Background Questionnaire**, and the results indicate an environment that is fully bilingual.
Bialystok, 2010 STUDY 3	26 MONO 25 BI	6.0 (NR): 6.1 (NR)	As in Study 1 and 2, the questionnaires confirmed that the bilingual children lived in bilingual environments.
Kousaie et al., 2014	131 MONO 87 BI	ENGLISH MONO: 21.48 (1.5) FRENCH MONO: 21.8 (2.47) BI: 21.49 (2.26)	Bilingual subjects were relatively equally proficient in French and English, having self-reported high proficiency in their L2 before the age of 13. Proficiency in each language was determined using both self-report measures and an **animacy judgement task.** Thirty-nine percent of young and 72 percent of older bilingual adults reported French as their native language, and the remainder reported English as their native language.
Bialystok & DePape, 2009	24 MONO 24 BI 47 MONO Musicians	23.8 (4.1)	The bilinguals reported using English about 56% of the time each day and the other language in about 44% of daily activities. Bilinguals rated themselves on a 5-point scale as being highly fluent in English and moderately fluent in their other language. The musician groups consisted of 22 instrumentalists who played at least 1 of 13 instruments and 25 vocalists who were classically trained. All the musicians were monolingual speakers of English.

Table 1. Participant characteristics and how bilingualism was assessed in each corresponding study. The first column (from the left) indicates the study by author/s and year of publication. The second column lists the total number of participants included in each of the study groups (monolingual (MONO): bilingual (BI) participants). Column number three indicates the mean age and SD of the participants, two studies grouped all participants together and the others reported by group. The last column describes how bilinguals were assessed or defined in each study.

Age of Acquisition

The age of acquisition (AoA) for L2 was reported only in five of the nine studies. Age of acquisition was reported differently across the studies and the AoA ranged from 0 to 13 years of age across all five studies. Of the five studies, one study (Warmington et al., 2018) reported AoA as a definitive range of 3 to 4 years old with an average of 3 years and five months, and the remaining four studies (Kousaie et al., 2014; Desjardins et al., 2020; Desjardins & Fernandez, 2018; Foy & Mann, 2014) reported AoA as a range with only an upper boundary (e.g., AoA of L2 was reported in Desjardins & Fernandez, 2018 to occur before the age of 7). See Figure 1 for the AoA as reported in the different studies.

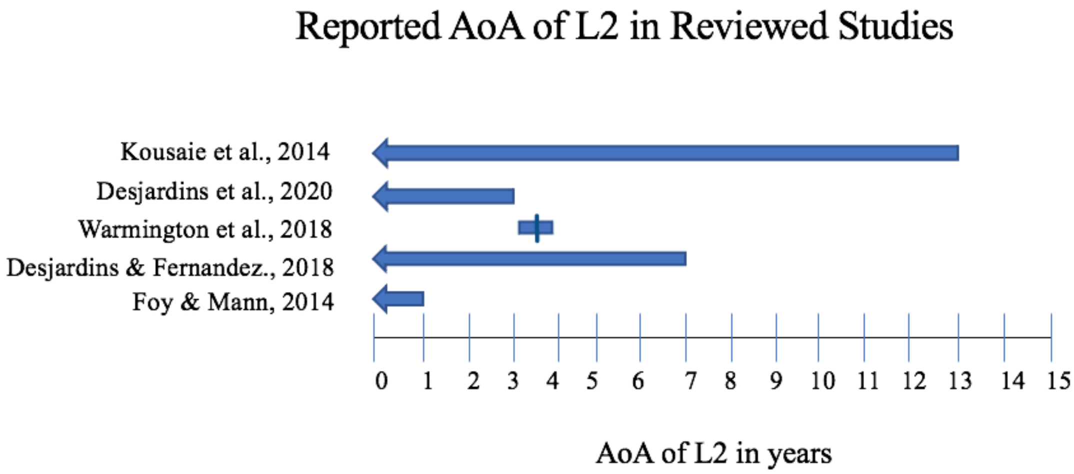

Figure 1. The X-axis represents the AoA of L2 in years that was reported in the reviewed studies, and the Y-axis represents the studies that reported AoA of L2. The arrows indicate the corresponding study reported AoA of L2 in years as a varying range with an upper boundary, whereas the bar without the arrows indicated the study reported the definitive range. The bar tick indicates the average of the reported range.

Executive Function Tasks Used

The nine studies assessed EF through a variety of tasks that involved visual and auditory stimuli. There was a total of 33 EF tasks used across all nine studies. Of the 33 tasks; the Simon task was used four times, trail making task and global local task were used three times (in the same study), a version of the Stroop task was used three times, the N-back task and forced dichotic consonant-vowel listening task were used two times. The following tasks were used once: number updating, SART, pirate sorting, Go/No-go auditory tasks (verbal and nonverbal), verbal & nonverbal auditory, stop signal reaction time, verbal executive, visuo-spatial executive, visually cued recall, moving word task, dimensional change card sort, backward digit span, digit span, and selective attention. The different tasks used as well as their description, are presented in Table 2.

Table 2

Study Executive Function Tasks Used in Each Study

Study	Executive Function Task Assessed	Description of Tasks
Arizmendi et al, 2018	Inhibition Shifting Updating	**Pirate Sorting task:** Subjects saw four different boats on the screen. Children were instructed to put the sea monster in the correct boat according to the instructions provided. **Number Updating task:** Subjects were presented with two numbers superimposed on images of a yo-yo and teddy bear. Subjects were expected to remember the numbers. The numbers disappeared, then children saw a 1 pop up under one of the toys. That number disappeared and subjects were instructed to add 1 to the appropriate toy and say the new number of yo-yos or teddy bears out loud. The number to be added could appear on either toy and children were expected to update the new numbers accordingly. **N-Back Auditory task:** Subjects listened to a tone and, 1000 ms later, heard another tone. They were instructed to decide whether it was the same or different as the one heard directly before it. **N-Back Visual task:** Subjects were presented with an image of a square with white dots inside of it for 1000 ms. The organization of the dots in the squares varied with each presentation.
Foy & Mann, 2014	Attention Switching	**Nonverbal EF task:** Subjects were asked to respond to a target (barking dog) and to ignore a distractor (ringing bell) in two blocks where the target was infrequent relative to distractors and subsequently, where the target was frequent relative to distractors (first block). The second block targets and distractors were reversed in order to study the children's ability to switch responses from block to block. **Verbal EF task:** Approximately one month after completion of the nonverbal task, the children completed

		the verbal version of the modified ACPT-P task. The verbal test consisted of two randomized blocks with interchanged target and distractor verbal stimuli (/ba/ and /pa/).
Desjardins & Fernandez, 2017	Inhibition	**Forced-attention dichotic consonant-vowel listening task:** The task included four lists of 30 CV stimuli consisting of six different syllables of a consonant (i.e., /b, p, t, d, g, k/) followed by the /a/ vowel sound recited by a male talker with constant intonation and intensity. The CVs were presented dichotically in three different attention conditions: (a) FR, (b) FL, and (c) NF. In the FR and FL conditions, partici- pants were instructed to listen to the CVs and report the CV that was presented in either the right or the left ear, respectively. In the NF condition, participants were instructed to listen to the CVs presented to both ears and report the CV they heard "best" or "most clearly." **Simon task:** Trials began with a fixation cross in the center of the screen At the end of the interval, a red or blue square appeared on the left or the right side of the screen and remained on the screen for 1,000 ms or until the participant chose a response. Participants were instructed to press as quickly and as accurately as possible the left shift key (marked with a blue dot) when they saw a blue square and the right shift key (marked with a red dot) when they saw a red square. On congruent trials, the color of the stimulus matched the side of the response (e.g., a red square was presented on the right); on incongruent trials, they mismatched (e.g., a red square was presented on the left).
Warmington, Kandru-Pothineni & Hitch, 2018	Working memory Attention	**Visuo-spatial short term memory task**: (Dot Matrix and Block Recall) Subjects were required to remember location and order of dots displayed on grid. **Verbal executive task:** (Listening Recall and Backward Digit Recall) Subjects were presented with a series of spoken sentences, and they had to determine the veracity of the sentence and recall final word for each sentence. In backward digit recall, they were required to recall a sequence of spoken digits in reverse order V**isuo-Spatial executive task: (**Odd One Out and Spatial Recall) For Odd One out task, subjects viewed three

		shapes, each in a box presented in a row and had to identify the odd one out and at the end they have to recall the location of each odd one out shape in the correct order. In spatial recall the subjects viewed a picture of 2 shapes and had to identify whether the shape on the right is the same or opposite to the shape on the left. **Selective attention task:** Flanker task which required to identify the direction of target while disregarding distractors **Stop signal reaction time task:** This task had a frequent visual 'go' signal set up to prepotent response tendency and a less frequent visual 'stop' signal for participants to withhold their response.
Desjardins, Bangret & Gomez, 2020	Inhibition	**Forced-attention dichotic listening task**: Subjects were presented with a prime syllable binaurally, followed by a 500-ms silent interval and then a dichotic target CV pair. Following the auditory presentation of the stimuli, a response screen with six possible CV syllable choices appeared on the computer monitor and subjects were instructed to use computer mouse to choose a CV syllable response. **Simon task:** Subjects were instructed to press left shift key when they saw blue square and right shift key when they saw red square.
Bialystok, 1999	Attention Working memory Updating	**Moving word task:** Two toy bunnies were introduced. The experimenter then showed the child two pictures of common objects and named them. A card with the name of one of the pictured objects printed on it was brought out and the experimenter told the child what the card said. The experimenter placed the card under the picture of the named object and asked the child what the card said. The child's attention was then distracted by the bunnies who began a scuffle and "accidently" kicked the card so that it was under the wrong picture. The child was asked for the second time what the card said, but this time the card was under the wrong picture. Finally, the experimenter drew the child's attention to the mess that the bunnies had made and said it must be tided up. The card was moved back under the original picture and the child was asked for the third time what the card said. **Dimensional change card sort task:** Children were required to sort a set of laminated cards into two groups on

		the basis of perceptual feature of the items and then to resort the same cards on the basis of different feature. **Visually cued recall task:** A series of posters were shown to each child. Each poster contained 12 different pictures of familiar objects. A toy cat was introduced, and the experimenter told the child that the car liked certain things on the poster. The cat then pointed to specific pictures and the experimenter named each selected object. When the cat finished, the child was asked to point to the things the cat liked.

Bialystok, 2010 STUDY 1	Working memory	**Global local task:** Each trial began with a fixation cross in the center of the screen. This was followed by a stimulus in the center of the screen, which remained until a response was made. There were two tasks, each based on a different type of stimulus. The letter task, the stimuli were the letters H or S (or X for neutral). In global trials, the instruction was to identify the large letter and for local trials, to respond to the small letters. In the shape task, the stimuli were circles or squares (or Xs for neutral). There were 4 types of experimental blocks: global letters, local letters, global shapes, and local shapes **Trail making task**: Consists of two parts, Trails A and Trails B. In Trails A, numbers from 1 to 25 are distributed across the page and children are asked to draw lines connecting the numbers in order beginning with 1, without lifting the pencil from the page. In Trails B, the page contains the numbers from 1 to 12 and letters from A to L and children must connect the symbols by alternating the sequence between numbers and letters.
Bialystok, 2010 STUDY 2	Working memory	**Global local task:** see above description **Trail making task:** see above description
Bialystok, 2010 STUDY 3	Working memory	**Global local task:** see above description **Trail making task:** see above description **Backward digit span task:** The experimenter read a list of single digit numbers in English at the rate of one digit per second, and the child was asked to repeat the digits in the same order.
Kousaie et al., 2014	Interference suppression Response inhibition	**Simon task:** Included three conditions, color naming, word reading, and interference/incongruent color naming.

	Working memory Shifting	**Stroop task**: Compromised three conditions: control, reverse and conflict. In each condition, an arrow was presented on the monitor and participants were instructed to indicate with keys on the keyboard, the direction of the arrow. **SART:** Subjects were presented with the digits 1-9 on computer screen and were required to press the space bar in response to every number except the number 3. **WCST:** Subjects were asked to sort a series of 64 cards based on color, shape/form and number.
Bialystok & DePape, 2009	Interference suppression Inhibition	**Simon Task:** Participants sat with the index finger of each hand resting on one of the mouse keys. There were four conditions: direction control, position control, opposite, and conflict (consisting of congruent and incongruent trials). The stimuli were black arrows shown on a white background. **Auditory Stroop task:** This measure was a modified version of the original task created by Hamers and Lambert (1972). Response keys were positioned on each side of the monitor. There were four conditions: pitch control, word control, pitch conflict, and word conflict. Each condition was preceded by 10 practice trials.

Table 2. First column from the left indicates the authors of the studies chosen. The second column indicates the EF control that was assessed in each study. The third column describes how the task was conducted in the corresponding study.

Stimuli Modality of EF Tasks and Outcome

Categories were created to describe the stimuli modality of the EF tasks used in each of the nine studies. A categorization method was created to sort the EF tasks by stimulus modalities. The five main modalities in which EF was assessed in included visual only stimuli, visual and some auditory verbal stimuli, visual and some auditory nonverbal stimuli, auditory verbal stimuli and auditory nonverbal stimuli. As shown in Figure 2, there was a total of 33 EF tasks used across the reviewed studies that were used for analysis. Four EF tasks were excluded from analysis from study by Arizmendi and colleagues due to inconclusive data. A majority, 19 out of 35, of the task stimuli used visual stimuli only, nine used stimuli that were presented visually with some auditory/verbal processing, four tasks presented the stimuli in the auditory modality with some verbal processing, two tasks were mainly visual with some auditory nonverbal processing, and one task included stimuli that was presented the stimuli in the auditory modality with no verbal processing required.

The outcome of each EF task conducted was assessed and grouped into one of the following categories: monolingual advantage, bilingual advantage and no advantage. The outcomes arranged according to the stimuli modality are presented in Figure 3. In EF tasks in which the stimuli were presented visually only, 12 out of the 33 tasks reported a bilingual advantage, five reported no advantage and two reported a monolingual advantage. In the tasks where the stimuli modality was mainly visual with some auditory/verbal processing, four outcomes indicated no advantage and two indicated no advantage. For tasks in which the stimuli modality was presented visually with some auditory nonverbal processing, one task resulted in a monolingual advantage and another in a bilingual advantage. There was only one task in which the stimulus was presented in the auditory modality with some nonverbal processing, which resulted in no advantage to either linguistic group. For the tasks that were presented in the auditory modality with some verbal processing, one resulted in a bilingual advantage and four resulted in no advantage to either group outcome.

Figure 2

Number of EF Task Modalities Used in Each Study

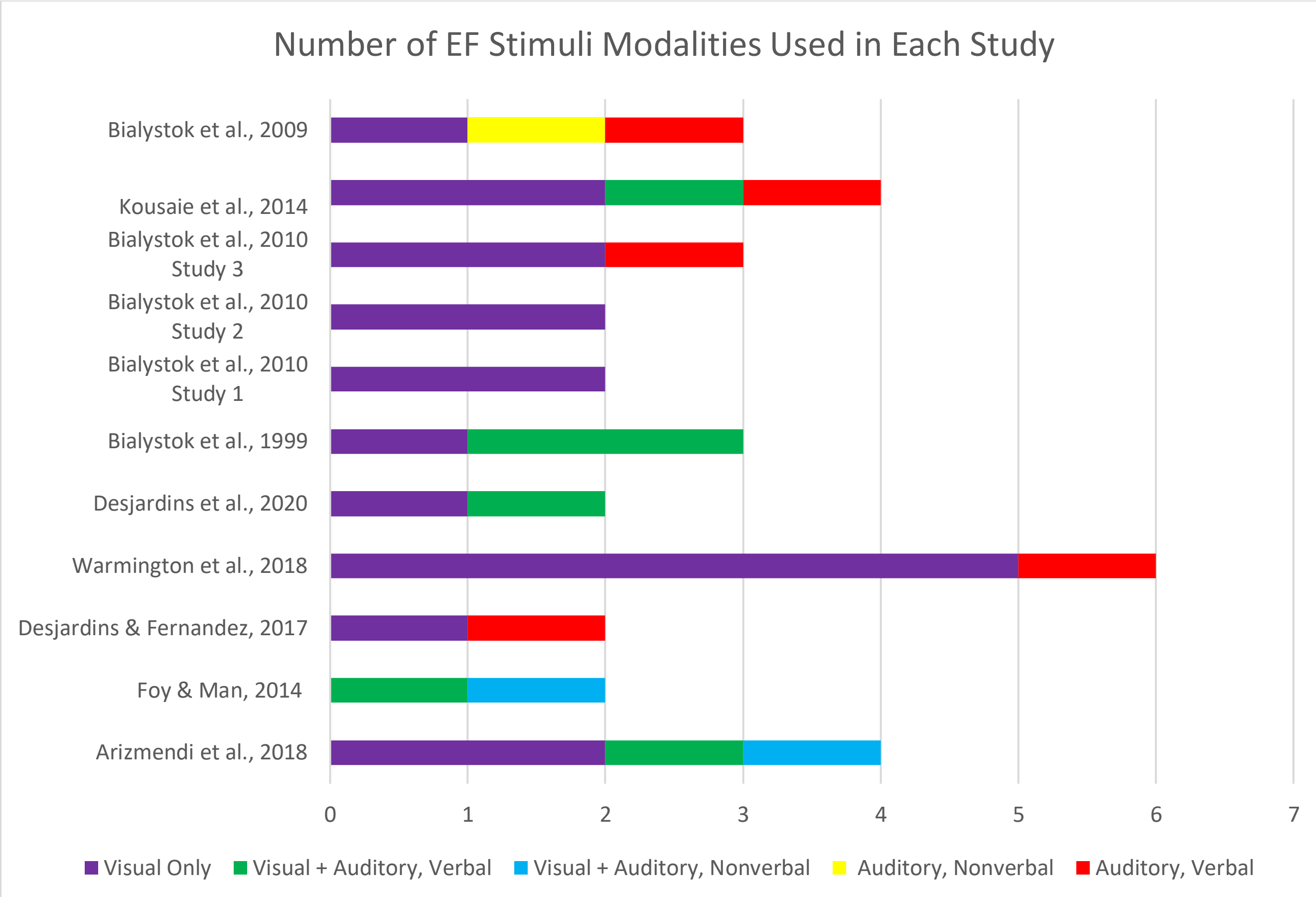

Figure 2. The X-axis represents the number of EF tasks used in each study, and the colors represent the different types of modalities. The Y-axis represents the 9 different studies used in this review.

Figure 3

Outcome of EF Task Comparisons Between Groups Based on Stimuli Modality

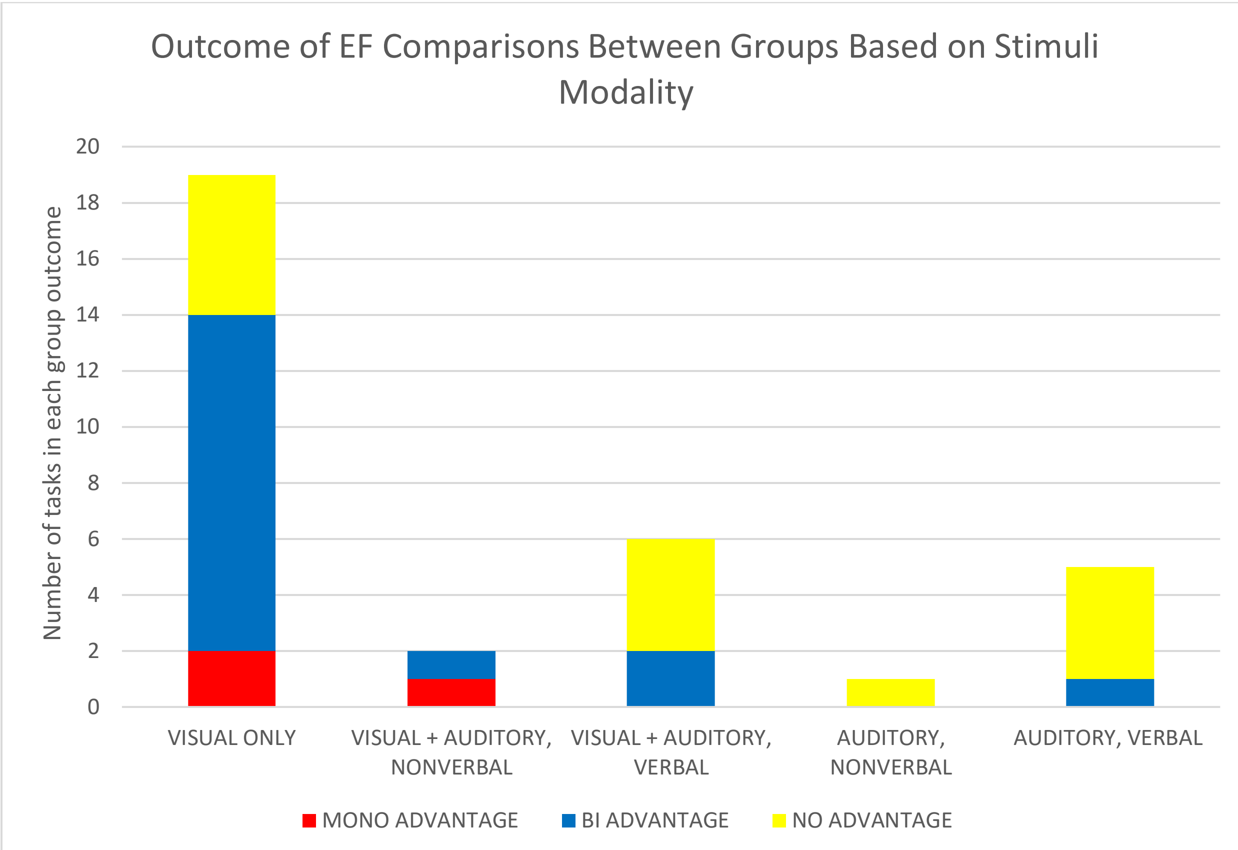

Figure 3. The X-axis represents the EF task modality. The Y-axis represents the number of EF tasks in each group outcome (monolingual advantage, bilingual advantage and no advantage).

DISCUSSION

In this review, we examined whether the outcome of EF tasks that incorporate auditory (verbal and nonverbal) stimuli modality differ from those that primarily use visual stimuli in bilinguals and monolinguals. We hypothesized the when the EF task involves some auditory nonverbal processing or visual processing only, bilingual individuals will be able to demonstrate a bilingual advantage. However, when the EF tasks involves auditory/verbal processing, a bilingual advantage might not be demonstrated due to the greater speech perception difficulties bilingual listeners experience compared with monolinguals. After reviewing selected studies, we revealed the following; tasks in which the stimuli modality was auditory only (verbal or nonverbal) and a combination of visual and auditory (verbal), indicated no advantage between monolinguals and bilinguals, for tasks where the stimuli modality was visual with some nonverbal auditory information, there was some degree of a monolingual advantage present, and the tasks in which the stimuli modality was visual only, a majority of the results indicated a bilingual advantage. Thus, our review did not fully support our hypothesis as the outcomes of the review were somewhat different than what we expected the outcomes to be. Furthermore, we identified several issues that require further examination, mainly that the stimuli modality of tasks previously used to assess EF in bilinguals are mainly presented visually and only very few studies assessed EF in bilinguals using auditory stimuli. In addition, the inclusion criteria of bilinguals and the tasks used for assessment were very diverse and inconsistent across studies. As a result, what we know about the ability of bilinguals to perform tasks which require EF and involve auditory verbal processing is very limited. These issues and concerns will be further discussed.

Inconsistent AoA requirements and linguistic status criteria

Of the nine studies that compared monolingual versus bilingual EF using tasks in the visual and auditory modality (Arizmendi et al., 2018; Foy & Mann, 2014; Desjardins & Fernandez, 2017; Warmington, Kandru-Pothineni & Hitch, 2018; Desjardins, Bangret & Gomez, 2020; Bialystok, 1999; Bialystok, 2010; Kousaie et al., 2014; Bialystok & DePape, 2009), four studies did not report L2 AoA at all neither in the text nor in the tables or supplement material (Arizmendi et al., 2018; Bialystok, 1999; Bialystok, 2010; Bialystok & DePape, 2009). Of the remaining five studies, two studies only reported the upper limit of the AoA age and did not provide average, median or interquartile information. More specifically, Desjardins and Fernandez (2017) reported that L2 was acquired before the age of seven, while Kousaie et al. (2014) reported that L2 was acquired before the age of 13. Of the remaining three studies, two studies indicated AoA was by three years of age (Warmington, Kandru-Pothineni & Hitch, 2018; Desjardins, Bangret & Gomez, 2020and one reported AoA before 12 months of age (Foy & Mann, 2014).

Why is AoA important when studying bilingualism?

Bilingualism is the knowledge of two languages. Given that there are multiple definitions for this term, it is possible that many individuals who differ significantly in their proficiency level and linguistic experience might be all grouped as "bilinguals" without taking factors that are known to influence the degree of bilingualism (AoA, socioeconomic status, experimental tasks) into consideration (see review by Paap, Johnson & Sawi., 2015). There is a vast amount of evidence that support the correlates of AoA and L2 performance levels. (Bialystok & Miller 1999; Mayo & Florentine, 1997; Flege, Yeni-Komshian & Lui, 1999). It has been shown that children whose L2 AoA is around age four or later acquire their L2 similarly to L2 adults, which is fundamentally different from the way children whose age onset is before four (Kroffke & Rothweiler, 2006; Meisel, 2008; Sopata, 2010). Age of acquisition is an essential macro-variable which is known to correlate with other factors such as L1 proficiency, language dominance, frequency of second language use, and the kind of input used such as native vs. non-native language (Flege, 2009). In the past decade there has been controversial debate on the identification of the L2 AoA intended cut off that qualifies an individual as a bilingual rather than a second language learner. Some authors set it around puberty, which is a time period during which language skills fully develop (Lenneberg, 1967; Long, 1990; Locke & Bogin, 2006), and others have suggested the period around six to seven years old be crucial because, after this age, learning some linguistic skills becomes challenging (Johnson & Newport, 1989). These learning effects can be attributed to critical development periods (for an overview see Birdsong, 2006 review) as well as other cognitive factors (Thomas-Sunesson, Hakuta & Bialystok, 2016).

There have been numerous studies that have looked at speech perception that support the idea that auditory exposure to a language at infancy may have a significant effect on one's perception, knowledge, and skills. Previous studies found that infants show auditory preference for their native language and focus on speakers with whom they share the same language with (Mehler et al., 1998; Nazzi, Bertoncini & Mehler., 1998; Jusczyk, Cutler & Redanz, 1993; Moon, Cooper & Fifer, 1993). Furthermore, newborns also exhibit verbal outputs (cries') that reflect the melodic contour of their native language (Mampe, Friederici, Christophe & Wermke, 2009). The early sensitivity to native speech patterns has been shown to influence verbal phonetic perception in newborns, particularly that between the age of 6 to 12 months, infants' non-native phonetic perception slowly declines, while their sensitivity to native-speech phonetic contrasts increases (Kuhl et al., 2006). Many studies that examined speech perception in bilingualism have shown that bilinguals have poorer performance on L2 speech recognition tasks in background noise compared to their monolingual counterparts (Mayo, Florentine & Buus, 1997; Shi, 2010). Furthermore, it has been shown that bilinguals, regardless of AoA for L2, perform poorer than monolinguals on speech perception tasks. However, bilinguals who acquire L2 before the age of seven have an overall better performance on speech perception tasks than late bilinguals who acquire L2 after the age of seven (Weiss & Dempsey, 2008). It is important to note that when it comes to the effects of critical periods on speech perception, an argument can be made that the AoA of L2 should be much earlier than those mentioned for participants to be considered bilinguals.

Importance of AoA in Bilingualism

In this review, of the nine studies used, four reported no information on AoA when studying bilingual effects on EF tasks. These four studies did not include any information regarding the AoA neither in the text nor in any additional information such as figures, tables or supplemental material. Of the four studies that did not report AoA, we found that three studies (Arizmendi et al., 2018; Bialystok & DePape, 1999; Bialystok, 2010) all found no advantage between monolinguals and bilinguals in EF tasks that required some auditory/verbal processing. Both Desjardins and Fernandez (2017) and Kousaie and colleagues (2014) reported very large ranges of AoA; Desjardins and Fernandez (2017) reported AoA before seven years old, and Kousaie and colleagues (2014) reported AoA to be before 13 years old. The outcomes of both studies showed that monolinguals and bilinguals performed similarly in EF tasks that required some auditory/verbal processing. Considering that accumulating evidence implying that AoA is an important variable to consider when studying the effects of one's linguistic status, it is possible that the large ranges of AoA included in this review are at least partly responsible for the variance in the results found across the different studies. It is reasonable to assume that AoA will affect the demonstration of bilingual advantages and/or disadvantages as the length of experience with each of the languages is probably critical for the cognitive and perceptual changes to develop. Furthermore, the large variability in AoA was not only found between the selected studies but within studies as well, with bilingual participants who were grouped into the same testing group despite a wide range of AoA. Previous studies have shown that there are critical differences between late bilinguals and early bilinguals in terms of neurocognitive benefits (Mechelli et al., 2004; Hernandez, Hofmann & Kotz, 2007). Considering that AoA is judged to be one of the main parameters that mainly determine L2 performance, it is imperative that it is taken into consideration by matching populations on AoA when making conclusions about cognitive advantages in the bilingual population.

Stimuli Modality Bias in Literature Assessing Bilingual Advantage

The bilingual EF advantage is well studied across literature where EF task stimuli are nonverbal or presented visually only (Prior & Macwhinney, 2009; Houtzager, Lowie, Sprenger & De Bot, 2017; Schroeder & Marian, 2012; Barac & Bialystok, 2012; Naeem, Filippi, Periche-Tomas, Papageorgiou & Bright, 2018). This review highlights the lack of research that assess EF abilities in bilinguals when the tasks that utilize an auditory stimuli modality and require some auditory/verbal processing. Of the nine selected studies used in this review, all with the exception of one study (Foy & Mann, 2014), used at least one EF task in which stimuli modality was visual only. Only six studies used at least one task in which the stimuli were presented in the auditory modality only with five of them including verbal or speech processing (Bialystok & DePape, 2009; Kousaie et al., 2014; Bialystok, 2010; Warmington, Kandru-Pothineni & Hitch, 2018; Desjardins & Fernandez, 2017) and one study also included an EF task with auditory stimuli with no verbal or speech processing (Bialystok & DePape, 2009). There is considerable evidence suggesting that verbal and nonverbal stimuli could be processed via various neural pathways across all individuals (Binder et al., 2000; Hickok & Poeppel, 2007), and yet there seems to be a lack of research that assess bilinguals' performance using EF tasks that integrate auditory speech perception.

An argument can be made that the approach to evaluating EF in bilinguals has primarily been visual and that bilinguals may perform differently compared to monolinguals when given tasks that include auditory stimuli modality and speech perception. One important measure of EF is inhibition, which is defined as the ability to suppress irrelevant information. A common way to assess inhibition is through Stroop tasks, where one stimulus factor is to be named, while a second factor is ignored. In the articles used in this review, five studies measured the effects of bilingualism on tasks that required inhibition (Arizmendi et al., 2018; Desjardins & Fernandez, 2018; Desjardins, Bangret & Gomez, 2020; Kousaie et al., 2014; Bialystok & DePape 2009). Of these five studies that measured inhibition, three used the Stroop task (Bialystok & DePape, 2009, Arizmendi et al., 2018; Kousaie et al., 2014) and two used a forced-attention dichotic listening task to measure inhibition (Desjardins, Bangret & Gomez, 2020; Desjardins & Fernandez, 2018). The modality of the Stroop task stimuli presentation varied across the studies. Arizmendi and colleagues (2018) used a Stroop task in which the stimulus was presented in the visual modality only, however they did not report the outcome of the tasks due to low reliability. The other two studies that used a Stroop task included one where the stimulus was mainly visual with some auditory verbal/speech processing (Kousaie et al., 2014), and another used an auditory Stroop task where the stimuli was mainly auditory and there were two versions, verbal and nonverbal (Bialystok & DePape 2009). The two studies that used a forced-attention dichotic listening task included stimuli that was presented in the auditory modality with some verbal processing (Desjardins & Fernandez, 2018) and stimuli presented mainly visually with some auditory verbal processing (Desjardins, Bangret & Gomez, 2020). For all of the studies that studied inhibition, regardless of the modality of the stimuli, the outcome indicated either a bilingual advantage (Kousaie et al., 2014;) or no advantage between the monolinguals and bilinguals (Foy & Mann, 2014; Bialystok & DePape 2009; Desjardins, Bangret & Gomez, 2020; Desjardins & Fernandez, 2018). In a study by Knight and Heinrich (2017), adults performed two Stroop tasks (visual and auditory) and results showed that visual Stroop measures were entirely uncorrelated with auditory Stroop measures, signifying that the two types of Stroop tasks may be measuring different properties of cognition, rather than assessing a single modality-independent general cognitive ability.

Stimuli Modality and Outcomes

We expected to a see a bilingual advantage for a majority of the EF tasks that included only a visual presentation of stimuli, we found this to be true. Due to the supporting evidence that monolinguals outperform bilinguals in verbal working memory tasks (Bialystok, 2010), we expected to find that in most cases monolinguals would have an advantage over bilinguals in EF tasks that require verbal working memory. In addition, we expected monolinguals experience less effort when the EF task required speech perception or auditory processing due to the large number of studies demonstrating the greater difficulties bilinguals and second language learners experience when listening to speech under adverse acoustic conditions (Weis & Dempsey, 2008, Mayo, Florentine & Buus, 1997). Our findings only partially supported our expectations with most outcomes showing that under these tasks' requirements bilingual individuals were not able to outperform those who are monolinguals. However, there were a few tasks which required auditory verbal processing, and yet there was found a bilingual advantage. For the EF tasks that included visual and auditory verbal stimuli, most resulted in no advantage as well. Given the small amount of EF tasks conducted using auditory stimuli and the disparities on how bilinguals were defined in the studies, it is not surprising that these outcomes were found to be too few and too varied to provide a clear picture of the stimuli modality effect.

It has been shown that bilinguals have greater ability to store and recall auditory information when compared to monolinguals (Motlagh, Jalivand & Silbert , 2018). In addition, the effects of verbal verses nonverbal stimuli in EF tasks have also been investigated in the bilingual population, showing that bilinguals outperform monolinguals on nonverbal auditory tasks, but there are no differences apparent in verbal auditory tasks (Foy & Mann, 2014). In this review we aim to highlight that that the stimuli modality of EF task in literature assessing bilinguals has not been systematically studied despite evidence which support the need to examine bilingual EF performance using both auditory and visual stimuli as linguistic exposure may affect visual and auditory processes differently. Moreover, greater attention should be given to the inclusion criteria used for bilingual participants, such as the AoA, since. as bilingual exposure may affect auditory skills and speech perception at a much earlier critical age than those previously found when testing EF using visual stimuli alone

CONCLUSION

The present review aims to examine based on previous findings whether the modality of the EF tasks used when testing monolingual and bilingual participants has an effect on the outcome regarding whether a bilingual advantage exists or not across the general population. When taking into account the many factors that play a role into being bilingual, it is important to note that these methodological inconsistencies and mixed results across literature make it difficult to draw definitive conclusions about the existence of a bilingual effect. It would be beneficial to this field of study if there were agreed on guidelines regarding the inclusion criteria needed to define as a bilingual as well as assessment tools or tests to estimate the bilingual effects on EF.

In everyday life, EFs control and regulate behaviors which ultimately define success in many socially immersive environments such as a classroom and work settings. It is known that our environments can influence our attention, working memory and auditory processing. It is important to continue to investigate how bilinguals are affected in these environments in which they are heavily reliant on auditory processing and speech perception. An outcome in favor of the existence of a bilingual effect in EF tasks that require verbal/speech processing would offer the incentive for the application of an increase of bilingual programs in schools and more awareness in central auditory processing disorder evaluations. If a bilingualism truly affects EF skills across matched populations, it should demand additional exploration on how this advantage or disadvantage affects daily EF tasks that require auditory processing and are vital for academic performance.

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