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A Bilingual Advantage for Children with Autism: Effect of a Bilingual Education on Set Shifting in Children with Autism Spectrum Disorder

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Abstract

The proposed study will examine the effect of an early bilingual school environment on the set shifting abilities of children with autism spectrum disorder (ASD). More specifically, it will evaluate how an English-French bilingual education program affects the set shifting abilities of children with ASD compared to a monolingual English education program. Set shifting will be measured by the Dimensional Change Card Sort (DCCS) task both before and after the respective education programs. I hypothesize that there will be a main effect of both time point and education program on set shifting abilities such that *(a)* set shifting abilities will improve from pre-instruction to post-instruction, and *(b)* those who receive a bilingual education will outperform those who receive a monolingual education on set shifting ability overall. I also hypothesize that these main effects will be qualified by an interaction, such that *(c)* bilingual classroom instruction will result in better set shifting abilities particularly at post-instruction when compared to monolingual classroom instruction. If future results from this proposed study do indeed suggest that the proposed hypotheses are correct, it would be interesting to further explore what this would mean for a possible restructuring of current programs in place for the education of children with autism such as the Applied Behavior Analysis (ABA) program.

Keywords: autism, children, bilingual education, set shifting

Bilingual Education for Children with Autism: Effect of a Bilingual Education and Gender on Set Shifting and Inhibition in Children with Autism Spectrum Disorder

What is Bilingualism?

Bilingualism is widely defined as "the use of at least two languages either by an individual or by a group of speakers" (Moradi, 2014). According to the 2019 American Community Survey by the United States Census Bureau, 20.87% of American children between the ages of 5 and 17 speak a language other than English at home and can speak English "well" or "very well" (*Age by Language Spoken at Home by Ability to Speak English for the Population 5 Years and Over*, n.d.). This statistic does not include children who use only English at home and a different language in their everyday lives (e.g. at school or in their community), so the exact percentage of bilingual children in the United States is likely a little higher. For many, the first thing that comes to mind when they think of bilingualism is ambi-bilingualism, otherwise known as balanced bilingualism. This term refers to the ability to speak equally fluently in two languages, but it is actually quite rare, as most bilinguals have a dominant language (L1) that they are more proficient in compared to their non-dominant language (L2), resulting in unbalanced, or dominant bilingualism (Peal & Lambert, 1962). Bilingual capabilities move along a continuum (Beardsmore, 1986) with ambi-bilinguals on one end and monolinguals on the other. Research shows evidence for a lack of a bilingual advantage in bimodal bilinguals that speak one verbal language and one signed language (Emmorey et al., 2008) due to the different neural pathways that spoken and signed languages utilize. Therefore, for this proposed study, I am going to be referring to bilinguals of spoken languages only, not gestural languages.

Early and Late Bilingualism

Early bilingualism is defined as a child having learned two languages before the onset of adolescence, or the critical period (Penfield & Roberts, 1959), and it often leads to linguistic capabilities in both languages that are comparable to native proficiency. Late bilingualism, on the other hand, can be defined as a situation in which one acquires a second language after the critical period (Beardsmore, 1986). Although later first exposure is correlated with a decline in second-language proficiency (Hakuta et al., 2003), this decline happens gradually over one's lifespan, and one's ability to learn a second language is not suddenly lost at a certain age. While the deterioration in language acquisition ability can begin as early as six years old for some (Long, 1990), not all aspects of language acquisition ability begin to deteriorate at this age. For instance, more recent research indicates that grammar-learning abilities are preserved at native-like ability until nearly 18 years of age when it begins to deteriorate (Hartshorne et al., 2018). With late bilingualism, although one can achieve proficiency in the language they learn, they rarely achieve native-like fluency, as the older one gets, the more difficult it is for them to acquire a second language.

Compound, Coordinate, and Subordinate Bilingualism

In 1953, Uriel Weinreich proposed a way to classify the many types of bilinguals into three categories that focus on how individuals store and organize their linguistic codes (Weinreich, 1953). These categories include compound, coordinate, and subordinate bilingualism. Compound bilingualism is a form of early bilingualism in which children learn two languages in the same environment, thereby acquiring two sets of linguistic codes that are stored together for every unit of meaning. This kind of bilingualism usually develops when children are raised in already bilingual households, where the two languages are used simultaneously and often interchangeably. Coordinate bilingualism is another form of early bilingualism, but it differs from compound bilingualism in that a child acquires the two languages in separate contexts (e.g., different languages at home and school or different languages with each parent). Coordinate bilingualism leads the speaker to acquire two separate linguistic codes that are stored separately in two units of meaning. Behavioral studies support this compound-coordinate bilingual distinction (Jakobovits & Lambert, 1961; W. E. Lambert et al., 1958). Lastly, subordinate bilingualism is a type of late bilingualism where the speaker learns a second language but must translate it through their L1 to understand it. In this kind of bilingualism, the speaker acquires two sets of linguistic codes that share one unit of meaning which is only accessible through their L1.

The "Bilingual Advantage Hypothesis"

The executive system, which is important for the regulation of thoughts, behaviors, and emotions, is neurally based in the frontal cortex. Executive functions include a wide array of cognitive processes. Three of the most commonly reported ones that are often referred to as "core" executive functions include shifting, inhibitory control, and working memory (Baggetta & Alexander, 2016). A factor hypothesized to positively affect executive functioning (EF) is a bilingual environment. This hypothesis is referred to as the "bilingual advantage hypothesis," which proposes that the regular processing of multiple languages is beneficial to many aspects of one's EF throughout their lifetime. Both languages are activated in the bilingual brain even when only one is being used (van Heuven et al., 2008), so this bilingual advantage most likely stems from bilinguals' need to use EF to consistently manage and monitor their languages.

Executive Functioning in Autism

Autism Spectrum Disorder (ASD) is a "biologically based neurodevelopmental disorder… that affects as many as 1 in 68 children" (Marsh & Wolf, 2019), and is correlated with difficulties with EF. According to the DSM-5, the diagnostic criteria for ASD includes showing persistent deficits in two main areas: “social communication and social interaction across multiple contexts" as well as restricted, “repetitive patterns of behavior, interests, or activities" (American Psychiatric Association, 2017). Within the domain of social communication and social interaction, children with ASD struggle with deficits in social-emotional reciprocity; nonverbal communicative behaviors; and developing, maintaining, and understanding relationships. Symptoms associated with the domain of repetitive patterns of behavior, interests, or activities include stereotyped repetitive movements or speech, insistence on sameness and routine, restricted interests, and hyper- or hyporeactivity to sensory input. Children with ASD struggle with many executive functions including inhibition, cognitive flexibility, generativity, working memory, planning, and verbal fluency (Geurts et al., 2004; Van Eylen et al., 2015).

An executive function that is widely researched in relation to the bilingual advantage hypothesis is set shifting (Geurts et al., 2004; Granader et al., 2014), defined as the ability to switch between mental processes. Set shifting is used to change one’s thoughts and behaviors to adapt to new environments and situations. It is an important tool that helps people tolerate changes and easily transition from one activity to another. Studies show that bilinguals possess greater set shifting abilities than monolinguals (Barac & Bialystok, 2012; Bialystok, 2011; Esposito & Baker-Ward, 2013; Gonzalez‑Barrero & Nadig, 2019). This greater set shifting ability in bilinguals is attributed to the fact that they often shift between languages in their everyday lives, which requires stronger cognitive control than thinking and speaking in only one language. Moreover, children with ASD struggle most with cognitive flexibility as demonstrated by their difficulties with set shifting relative to both neurotypical children and children with other disorders such as ADHD (Granader et al., 2014; Panerai et al., 2014). This is evidenced by an inflexible insistence on sameness, routines, or ritual; highly intense and restricted interests; and difficulties with transitions. EF scores are also highly correlated with social perspective-taking ability for individuals with ASD (Ozonoff et al., 1991). Set shifting ability specifically is a very strong predictor of social understanding abilities in adolescents with ASD (Berger et al., 1993), indicating that it could at least partially contribute to social skill development in autism.

The Bilingual Advantage Debate and Autism

The research surrounding the bilingual advantage debate is mixed. Some research suggests that a bilingual advantage for children's EF is small and possibly nonexistent (Lowe, 2020). Other research shows support for the bilingual advantage hypothesis in both neurotypical people (Barac & Bialystok, 2012; Bialystok, 2011; Esposito & Baker-Ward, 2013) and those with ASD (Gonzalez‐Barrero & Nadig, 2019; Peristeri et al., 2020) for all three "core" executive functions including shifting, inhibition, and working memory, as well as in visual attention skills. Although children with ASD exhibit an atypical speech processing pattern (Russo et al., 2009), research shows that exposure to a bilingual environment does not result in any further language delays (Hambly & Fombonne, 2012; Wang et al., 2018) or delays in academic achievement for them (Myers, 2009). Myers (2009) compared the academic test scores of children across the U.S. in monolingual education programs and 50:50 English-Spanish dual language programs that included both native English and native Spanish speakers (Myers, 2009). Students included both neurotypical children and children with special education needs related to learning disability, developmental delay, emotional disturbance, and other health impairments. All students were in third, fourth, or fifth grade, and Standards of Learning (SOL) and Stanford 10 test scores administered in English were used to determine their level of academic achievement. There were no significant differences between the special-needs students in the dual language programs and their counterparts in the monolingual English-only programs at any grade level, showing no evidence that children with ASD learning a second language had any extra delays in academic achievement when included in bilingual education programs.

Furthermore, exposure to a bilingual environment is not associated with a negative impact on the functional communication or EF skills of children with ASD (H. Li et al., 2017) regardless of whether the bilingual language exposure began during infancy or post-infancy (Iarocci et al., 2017). A 2017 study conducted by Iarocci et al. (2017) looked at the parent ratings of functional communication and EF skills of children ranging in age from 6 to 16 years both with and without ASD. Parents rated their children on everyday tasks that reflected EF skills such as planning, anticipating, inhibiting/maintaining goal-directed activity, and appropriate reaction to environmental feedback. Their results showed that children and adolescents with ASD who were exposed to a bilingual environment did not significantly differ in functional communication or EF skills from their counterparts with ASD who were not exposed to a bilingual environment. Children and adolescents with ASD who were exposed to a bilingual environment were also less likely to have clinically significant EF ratings, suggesting that exposure to a bilingual environment could potentially be beneficial in reducing the risk of children with ASD having clinically significant EF impairments. A similar study was conducted by Li et al. in 2017 that used performance-based EF tasks to measure inhibitory control and set shifting abilities, as well as questionnaires to assess social, behavioral, and communication competence in bilingual and monolingual children both with and without ASD (H. Li et al., 2017). Their results were similar to those of Iarocci et al. (2017) such that a bilingual environment for children with ASD did not impede their EF, induce any further impairment in their social and communication skills, or result in any extra delays in their language development.

Some studies have also found that exposure to a bilingual environment is not only non-harmful but may be beneficial to the language development and EF of children with ASD (Howse, 2016; Seung et al., 2006). A 2016 study conducted by Howse comparing minimally verbal monolingual- and bilingual-exposed children with ASD found that monolingual-exposed children were five times more likely to remain minimally verbal by age six compared to their monolingual counterparts (Howse, 2016). Additionally, a 2006 case study by Seung et al. gave more support to the possibility of a bilingual environment being beneficial to a child with ASD and their EF skills. A bilingual language intervention resulted in the improvement of challenging behaviors associated with EF, such as tantrums, insistence on sameness, and perseverative behaviors, as well as improvements in expressive and receptive language abilities in a child with ASD (Seung et al., 2006). This case study followed a child diagnosed with mild-moderate autism as he underwent a two-year bilingual language intervention program with an additional focus on pragmatic skills at the parents' request. This focus on pragmatic skills entailed having the child practice negotiation when choosing toys for an activity, transitioning between tasks, social greetings and smiles, verbal requests, and turn-taking. The child's parents were bilingual in Korean and English, with Korean being their primary language. However, they only spoke Korean to the child. The language intervention began when the child was three years old, which was the same age that he began an all-English pre-kindergarten program where he was regularly exposed to English. The child underwent twice-weekly sessions of the bilingual language intervention lasting, at first, half an hour each which later increased to 45 minutes at 16 months into the intervention as he improved and his attention span increased. Being three years old with a severe language delay, the child began the program with limited speech. So, the first 12 months were spent primarily in Korean to lay down a linguistic foundation in his primary language. During those twelve months, he was also exposed to English through his pre-kindergarten program. After those first 12 months, English was incorporated into the bilingual language intervention until it was almost entirely given in English. By the end of the intervention, the child was receiving 90 minutes weekly of the all-English language intervention in addition to the English exposure that he received through his pre-kindergarten classroom each week. By the end of the program, the child had just turned five years old.

Throughout the intervention, the child's progress was assessed at 6-month intervals. These regular assessments showed a steady improvement in the child's language skills in both languages, as evidenced by his receptive and expressive language skills measured by the Peabody Picture Vocabulary Test-III and the Expressive Vocabulary Test. He also showed a steady increase in nonverbal communication skills and improvement in social interactions. There was also no reported regression in any adaptive functioning skills, including communication, daily living skills, socialization, and motor skills. By the end of the intervention, the child was able to achieve standard scores for receptive and expressive language skill testing done entirely in English, and there was a significant decrease in the child's aberrant behaviors, including tantrums, insistence on sameness, and perseverative behaviors. This case study is some of the only literature that shows the effect of a bilingual language intervention on the language and EF skills of a child with ASD. Although it was not a completely controlled experimental study, some important points that can be taken include that exposure to a bilingual environment over the course of two years was not only non-harmful to this child's language development and

EF-related behaviors but was possibly beneficial for the development and improvement of them as well.

Foreign Language Education in the U.S.

Research on the possibility of a bilingual advantage for children with ASD focuses primarily on compound or coordinate bilingual children exposed naturally to their second language before the age of five (Gonzalez‑Barrero & Nadig, 2019). However, many children are not exposed to a second language until they receive the opportunity for foreign language instruction through traditional language programs at school; an opportunity that some schools in the United States do not offer at all.

In the United States, there is no national compulsory foreign language education requirement. Instead, foreign language education requirements vary by state. Some children are provided with foreign language instruction as early as when they begin their formal, compulsory education, usually around the age of six (*State Education Reforms (SER)*, 2018a), while others do not receive any kind of second language instruction until late childhood or adolescence, and sometimes none at all. Even when children do receive second language instruction, they are often very minimally exposed, with only a couple of hours of instruction per week. According to a 2017 report by the American Councils for International Education, only 20% of children in grades k-12 are currently enrolled in foreign language classes in the U.S., and a state-by-state comparison revealed that only 35 out of 50 states and the District of Columbia have foreign language education programs in their k-8 schools (*New Report*, 2017).

Bilingual Education in the U.S.

Some children receive bilingual education which differs from traditional language programs in that it uses two languages to teach and assess students across many subjects whereas traditional language education programs teach a second language as a separate school subject (García & Woodley, 2012). According to a 2015 article by the American Federation of Teachers, there are an estimated one million elementary school students currently enrolled in bilingual education programs in the U.S., meaning that no more than 3% of elementary school students in the United States are receiving a bilingual education (Goldenberg & Wagner, 2015).

Research on how receiving a bilingual education upon entering formal schooling affects EF in neurotypical children was conducted in 2013 by Esposito and Baker-Ward. Their results showed evidence for a bilingual advantage in both switching and inhibitory control as a result of a 50:50 English-Spanish dual language program. Participants in the study were selected for the bilingual education program upon entering formal school at the age of five or six by lottery. Those who were not selected for the bilingual education program were placed into traditional monolingual English classrooms within the same school system instead. Children in the bilingual education program exhibited overall better inhibitory control and switching abilities compared to children in the monolingual English education program. This bilingual advantage was found across multiple grade levels and was also shown to improve with extended dual-language experience. As children spent more time in the bilingual education program, the gap between the monolingual and bilingual education groups' EF abilities increased. No significant differences were seen between language programs at the kindergarten level; however, second and fourth graders who were in the bilingual program increasingly outperformed those in the English program on the trail-making task which requires inhibition and switching ability. Although research shows positive effects of a bilingual education on the EF of neurotypical children, there have not been any studies, to my knowledge, looking at how a bilingual education beginning when a child with ASD reaches compulsory school-age affects EF.

Subtractive and Additive Programs. There are many different types of bilingual education, which can be defined as “any system of education in which the curriculum is presented to students in two languages" (Hurajová, 2015). In 1973, Wallace Lambert categorized the many kinds of bilingual education programs into two main categories: subtractive and additive programs (Wallace E. Lambert, 1973). Subtractive bilingual education programs focus on teaching a majority language—a language that is spoken by the majority of the population—to children whose L1 is a minority language—a language spoken by a minority of a population. This comes at the cost of fluency in that minority language because the program does not help them maintain it. For example, pull-out ESL programs where students are pulled out of their general education classroom for part of the day for ESL instruction qualify as subtractive bilingual education programs because their focus is on increasing a student’s English skills only. In contrast, additive bilingual education programs focus on helping children acquire another language while also continuing to build their L1 skills, with the goal being for students to become equally proficient in both languages. Included within the category of additive bilingual education programs are one-way programs (Boyle et al., 2015) and immersion programs (Genesee, 1985).

One-way bilingual education programs. One-way programs are programs in which children who all belong to one language group and have a common language background continue to develop their L1 abilities while simultaneously learning an additional language. Research shows one-way programs to be very effective for neurotypical children. A 2004 article by Collier and Thomas reported that by the end of fifth grade, 80%-100% of the achievement gap in the second language is closed for children who had no proficiency in their second language when they began their one-way bilingual education programs in kindergarten at the age of five or six (Collier & Thomas, 2004).

Alternate programs. Some one-way bilingual education programs are considered "alternate" programs because the alternation between languages is signaled by either time or subject matter. For instance, in some "alternate" programs, morning classes are taught in one language while afternoon classes are taught in the other. To ensure a balance between languages, the order is switched every so often since elementary school students tend to learn better in the morning (R. Dunn & Dunn, 1992). Other "alternate" programs teach subjects in one language one semester and then the other language the next, and continue to alternate every semester.

Concurrent programs. Another type of one-way bilingual education program is known as "concurrent," because classes are taught in both languages simultaneously. This is achieved through a two-teacher classroom in which each of the teachers speaks only one of the languages to the students. However, "concurrent" one-way programs are less effective than "alternate" one-way programs, as students tend to rely mostly on the teacher that speaks their L1 and thereby do not achieve a balance of input for both languages.

Immersion programs. Immersion programs are another type of additive bilingual education program that aim to teach monolingual children to develop fluency in an additional language, but they go about this differently than one-way programs. Immersion programs start by using the additional language as the only language of instruction before later on slowly increasing L1 language instruction so that, eventually, instruction time is split evenly between the two languages.

Research Question

The proposed study aims to answer the question, “How does a one-way, ‘alternate,’ bilingual education, beginning when a child with ASD enters formal schooling affect their set shifting abilities?”

Methods

Participants

Students

All students in the proposed study will be children with a chronological age of six years who are monolingual English speakers living in the United States with normal or corrected-to-normal vision and who are not color blind. They will have had no prior foreign language instruction, their parents will be monolingual English speakers, and they will only speak English at home and in their daily lives. All students will also have obtained a formal clinical diagnosis of ASD by a licensed clinician using the DSM-5 criteria and/or have earned at least the minimum cutoff score for autism of 30 on the Childhood Autism Rating Scale (CARS) (Schopler et al., 1988). To confirm the student’s autism diagnosis, parents will be asked to provide a copy of their child’s diagnostic report. If students have not received formal testing for an autism diagnosis through the CARS, they will undergo the CARS screening and diagnosis process through this study. Students will also not have an accompanying intellectual disability or language disorder. The Clinical Evaluation of Language Fundamentals, 5th edition (CELF-5) (Wiig et al., 2013) will be used to assess students’ language and communication skills, including whether they have a language disorder, and the Wechsler Intelligence Scale for Children, 5th edition (WISC-V) (Wechsler, 2014) will be used to assess IQ. The CARS and the CELF-5 will be administered to each child by the study’s substitute teachers, and the WISC-V will be administered by school psychologists from each of the schools into which the proposed study’s classrooms will be incorporated. Half of the students will be randomized into a one-way, “alternate” English-French bilingual education program and the other half will be randomized into a monolingual English education program. An a priori power analysis with 90% power, an effect size of .30, and an α error probability of .05 suggest that the target sample size should be 44, resulting in 22 students in each condition (monolingual/bilingual).

Teachers

A total of 12 teachers (8 main teachers, 4 substitute teachers) will be recruited for the proposed study. All teachers will be required to have earned a Master of Arts degree in Bilingual Childhood Special Education Studies (BISPED) from Columbia University with a focus on French/English dual language and immersion studies and a minimum GPA of 3.0. They will be required to hold a currently valid professional teaching certificate in the state of New York, with between three to five years of relevant teaching experience.

Design

Measuring Independent Variables

Childhood Autism Rating Scale (CARS). The CARS is a behavioral rating scale composed of 15 items based on direct behavior observation and an interview. It was developed to assess the presence and severity of ASD in children over two years of age, and it has high reliability and validity (Shin & Kim, 1998), with high diagnostic agreement with other diagnostic tools for autism, such as the Autism Diagnostic Observation Schedule (ADOS) and the Autism Diagnostic Interview-Revised (ADI-R) (Samms-Vaughan et al., 2017). The CARS is more easily administered than the ADOS and the ADI-R. Because the ADOS and ADI-R measure different aspects of ASD symptomatology and also use different methods to do so, most use the two instruments together (Robertson et al., 1999). This is very time-consuming, as the ADOS is listed as officially taking 40-60 minutes to be administered and the ADI-R takes 90 to 150 minutes, leading to a total combined administration time of 130-210 minutes. In contrast, administration time for the CARS takes 5 to 10 minutes. Scores for each of the domains on the CARS are rated on a scale from one to four, with one indicating typical development and four indicating severe impairment associated with ASD. Total scores range from 15 to 60, with scores of 30 and above indicating autism. A score of 30 will be the minimum CARS score for student participation in the proposed study.

Clinical Evaluation of Language Fundamentals, 5th edition (CELF-5). The CELF-5 is a language battery that assesses language ability through both observational and interactive measures for children ages 5 to 21. For children ages 5 to 8, it consists of nine subtests that, altogether, take between 30 to 45 minutes to be completed (Coret & McCrimmon, 2015). Scores from the subtests are differentially combined to form composite scores that reflect examinees' abilities in specific skills areas. These include a Core Language Score and four Index Scores: a Receptive Language Index that measures listening and auditory comprehension skills, an Expressive Language Index that measures expressive language skills, a Language Structure Index that measures semantic development, and a Language Memory Index that measures memory for language tasks. The CELF-5 has demonstrated high reliability and validity and has also been used to assess language impairment in individuals with ASD (Coret & McCrimmon, 2015; Gonzalez‑Barrero & Nadig, 2019). On the CELF-5, Core Language and Index scores of 85 and below indicate the presence of a language disorder. So, for the proposed study, students' minimum Core Language Score and Index Scores will be required to be within 1 *SD* below the mean of 100, at least 86, which indicates average language ability.

Wechsler Intelligence Scale for Children, 5th edition (WISC-V). The WISC-V is a tool used to assess the intellectual ability of children between the ages of 6 and 16, and it is often used in studies examining the bilingual advantage in children with ASD (Peristeri et al., 2020). It consists of 10 primary subtests, seven of which produce the Full-Scale Intelligence Quotient (FSIQ), and three of which are used to produce five primary index scores measuring verbal comprehension, visual-spatial ability, fluid reasoning, working memory, and processing speed. These 10 primary subsets take between 65 and 80 minutes to be administered. Six secondary subtests can be used in addition to the primary subtests to produce a more comprehensive assessment of intellectual ability. However, in consideration of past research suggesting that the WISC-V should be primarily interpreted with the FSIQ (Canivez et al., 2019; Dombrowski et al., 2015), only the 10 primary subtests that produce the FSIQ and its primary index scores will be used for this study. Students in this study will be required to earn a minimum composite score of 90, which indicates average intelligence.

One-way, Alternate English-French Bilingual Education Program. An additive bilingual education approach will be used for the proposed study in the form of a one-way, “alternate” bilingual education program. Students will continue to build their English skills while also learning French with the aim of helping them to become coordinate English-French bilinguals. The language of instruction will be determined by the time of day such that morning and afternoon classes will be taught in different languages, resulting in the instructional time being split evenly between the two languages every day. To ensure a balance between the languages, the order of the language of instruction will alternate every week, such that morning classes will be taught in English or French on alternating weeks. A one-way program was chosen instead of an immersion program because when children are taught solely in a language they barely understand, as is the case with the early years of immersive bilingual education programs, they are more frustrated, bored, and withdrawn (Berk, 2012). Throughout their elementary school years, they are also more likely to struggle and fall behind their peers whose L1 is the language of instruction (Kieffer, 2008). This is of even more concern for children with ASD who are already at risk of peer alienation and falling behind academically. In contrast, when both students' L1 and L2 are integrated into the curriculum, children learn the L2 faster and more easily and are also more involved in the classroom (Berk, 2012).

French was chosen for a number of reasons. First, it is a category I language, meaning it is one of the nine languages in the world that is most similar to English and is, therefore, one of the easiest to learn for native English speakers ("Foreign Language Training," n.d.). In turn, French takes a substantially smaller amount of time to learn compared to other, more difficult category II through IV languages such as German, Greek, or Chinese which can require up to nearly 74 times the hours to learn ("Foreign Language Training," n.d.). French is also a language that is not spoken very widely in the United States. According to the 2015 United States Census, only 0.43% of the population in the United States aged five years and over speaks French at home (Bureau, 2015). So, it is likely that the students in this study will not encounter French-speaking people outside of their school environment, thereby decreasing the chances of some children receiving more exposure and practice with the language than others.

Classroom Demographics. For each bilingual classroom, a two-teacher staffing model for languages will be used (Boyle et al., 2015). A two-teacher staffing model involves the use of separate teachers teaching content in each language, with one teacher providing instruction in only English and the other providing instruction in only French. Although both teachers never teach the same class together at the same time, both are bilingual in both of the languages in which students are taught, and collaborate regularly to coordinate curriculum and instruction for their students. Alternatively, a single-teacher staffing model employs only one teacher to provide instruction in both languages. A two-teacher staffing model was chosen over a single-teacher staffing model to ensure that students are better able to identify a model English speaker and a model French speaker. To match bilingual classrooms, a two-teacher staffing model will also be used in monolingual classrooms. However, in monolingual classrooms, both teachers will only be teaching in English, with the two teachers splitting the content between each other equally. Like in the bilingual condition, teachers in the monolingual condition will never teach the same class together at the same time but will collaborate regularly to coordinate curriculum and instruction for their students. There will also be one substitute teacher assigned to each classroom to cover any main teacher unable to teach.

According to the United Federation of Teachers (UFT), the ratio for special class staffing at the elementary level is a maximum of 12 students per class for every one full-time special education teacher (*Special Class Staffing Ratios*, n.d.). Therefore, with a total sample size of 44, there will be two classes of 11 students within each of the two conditions (monolingual/bilingual). This will require a total of 12 teachers to be recruited for the proposed study, with eight main teachers (four main teachers in each program) and four substitute teachers (one substitute teacher for each classroom), to cover any main teacher whenever they are unable to teach. From year one to year two of the program, all students and teachers will stay with the same class. They will, however, have the opportunity to interact with students and teachers from classes other than their own during recess and lunchtimes.

Program Length. According to the National Center for Education Statistics (NCES), an average school day in the U.S. for students k-12 is 6.64 hours (*Schools and Staffing Survey*

(SASS), 2009). The majority of states require children to be in school an average of 170 days out of the year (*State Education Reforms (SER)*, 2018b), and the average percentage of hours devoted to instructional time for core curriculum (English, math, science, social studies) is 67% (Perie et al., 1997). According to these statistics, children spend nearly 4.5 hours per day on core curriculum. For the proposed study, half of those hours would be spent in English and half would be spent in French. As is estimated by the United States Department of Foreign Service (FSI), it takes an average of 750 class hours of formal study in French for adults to achieve "Professional Working Proficiency" ("Foreign Language Training," n.d.). "Professional Working Proficiency" is achieved when a student can "speak the language with sufficient structural accuracy and vocabulary to participate effectively in most formal and informal conversations on practical, social, and professional topics" ("Foreign Language Training," n.d.). Therefore, it would take students in this proposed study a total of 334 days to achieve proficiency in the French language. This would be equivalent to roughly two full academic years in the one-way, "alternate" bilingual education program, which would amount to a total of 340 days.

Bilingual Education Program Manipulation Check. At the end of the two-year education program, students who underwent the bilingual education program will undergo the Échelle de Vocabulaire en Images Peabody (EVIP) (L. M. Dunn, 1993) as well as both the French and English versions of the Word Association Test (WAT) (Wallace E. Lambert, 1956). These assessments will act as manipulation checks for the bilingual education program to confirm students' bilingual proficiency. The EVIP will be used to measure the students' levels of receptive French language skills, and the WAT will be used as an expressive measure of their level of bilingualism. Both assessments will be administered to each child by the study's substitute teachers.

The EVIP is the French equivalent of the Peabody Picture Vocabulary Test (PPVT-4) (L. M. Dunn & Dunn, 2007), a widely used standardized measure of English receptive vocabulary for most ages and abilities. It is often used to measure the language abilities of French/English bilingual children with ASD (Gonzalez‑Barrero & Nadig, 2019). On average, it takes 10-15 minutes to complete. To administer the test, an examiner says a word and shows the participant a set of four pictures. Participants are then asked to point to one picture among the four that best represents the meaning of the word that was just spoken. Before beginning, a basal level of performance, or a "starting point" is identified when the participant correctly identifies eight consecutive items. There are then 175 words split between 12 sets of increasing difficulty, and the participant continues the task until they make six errors within eight consecutive items in a single set. This point is referred to as the ceiling level of performance. A raw score is calculated by adding the number of correct responses between the basal and ceiling score. Standard scores are then obtained by converting raw scores using the published norms. EVIP standard scores have a mean of 100 and a standard deviation of 15 (L. M. Dunn, 1993). However, the language abilities of English-French bilingual children with ASD between the ages of six and nine that do not have an intellectual disability and have average intelligence fall slightly below this standard, with a mean of 98 and a standard deviation of 16 (Gonzalez‑Barrero & Nadig, 2019). Therefore, students in the proposed study are expected to fall within this adjusted standard range, with scores ranging from 82 to 114. Should any students' scores happen to fall below the standard range, with scores below 82, they will be excluded.

The WAT is one of the most widely used measures of bilingual proficiency (Lee & Kim, 2011), and it has also been used with young children to determine how bilingualism correlates with mental flexibility (Peal & Lambert, 1962). Furthermore, a 2015 study by Jafari et al.

indicated that the WAT has strong inter-rater and intra-rater reliability, with an inter-rater reliability coefficient of .986 and an intra-rater reliability coefficient of .954 ($p < 0.001$) (Jafari et al., 2015). In accordance with Lambert's (1956) word administration procedures, students will be alternately presented with English and French words. For each word presented, students will be given 45 seconds to say as many words as they can think of in the same language as the stimulus word that seem to "go with" or "belong with" the stimulus word. In addition to an experimenter writing down students' words, students will also be recorded using a microphone to account for the possibility of the experimenter missing or mishearing words. Words from each language will be taken from Lambert's (1956) original lists of 16 words each, with English and French words being matched on part of speech, word frequency, and abstractness-concreteness of nouns. The words used for the English WAT will include: *large, garden, happy, idea, food, little, sad, dear, honor, child, house, peace, rich, thought, strong, bad.* The words used for the French WAT will include: *Maison, libre, pauvre, esprit, grand, idée, jour, ami, petit, triste, jeune, rouge, temps, argent, main, juste.* The number of associations that students come up with will be used for the calculation of a bilingual proficiency score:

> Bilingual Proficiency = [(Sum of correctly identified English words) - (Sum of correctly identified French words) / (Sum of correctly identified English words) + (Sum of correctly identified French words)] *100.

Positive scores indicate that the student's dominant language is English (L1 dominance) and negative scores indicate that the student's dominant language is French (L2 dominance). The absolute value of the bilingual proficiency score indicates how balanced the student's bilingualism is, with lower scores indicating a stronger balance between the two languages. Scores between 0 and +/-20 indicate balanced bilingualism whereas scores between +/-75 and

+/-100 indicate monolingualism. Students in the proposed study are expected to fall within the bilingual range. However, I expect that most will still be more English/L1-dominant, with scores falling between +21 and +74. The data of any students who happen to fall outside of this bilingual range, with scores from +/-75 to +/-100 will be excluded.

Set Shifting Measure: The Dimensional Change Card Sort Task (DCCS)

The Dimensional Change Card Sort Task (DCCS) (P. D. Zelazo et al., 1996) is commonly used as a nonlinguistic measure of set shifting abilities for both neurotypical children (Barac & Bialystok, 2012) and children with ASD that are both monolingual (Dichter et al., 2010) and bilingual (Gonzalez‐Barrero & Nadig, 2019). For this task, children are required to sort a series of bivalent test cards, first according to one dimension (e.g., color) during a "pre-switch phase," and then according to the other (e.g., shape) during a "post-switch phase" (see Figure 1). This standard version of the DCCS is used to assess the set shifting abilities of children during their preschool years, between the mental ages of 2.5 and 5 years. This task is also adaptable and can be made more difficult. For instance, a more difficult border version has been used after the standard post-switch phase with both older children and adults (Diamond & Kirkham, 2005). In the border version, switches are cued with symbols and presented more randomly with mixed instead of blocked trials. Cards that have a black border around them indicate to the participant that they must sort the card according to a particular dimension (e.g., color), and cards that do not have any border indicate to the participant that they must sort by the other dimension (e.g., shape) (see Figure 2). The border version usually includes children that are mentally older (i.e., above the age of five) and who first pass the standard version. The two versions are often used together to assess executive functioning across all ages. According to Zelazo (2006), most neurotypical three-year-olds have trouble switching to sorting by the new dimension in the standard version and instead continue sorting by the pre-switch dimension. It is not until children reach around five years of age that they can switch when told to do so (P. Zelazo, 2006).

The DCCS task was created as an analogous task to the Wisconsin Card Sorting Task (WCST) for young children. It is considered a more narrowly defined measure of set shifting, especially for young children, because of its simplicity. For instance, the DCCS has a smaller number of target cards and sorting rules than the WCST. Additionally, children are explicitly told the sorting rules on every trial of the DCCS whereas, in the WCST, they only get the sorting instruction at the beginning of a set. Therefore, the DCCS decreases the number of confounds that could be affecting performance, such as problems with working memory. Moreover, individuals with ASD perform better on tasks that provide clear and explicit instructions, such as the DCCS task, when compared to tasks where rules are more implicit and need to be inferred (Van Eylen et al., 2011).

Although moderately correlated, shifting and inhibition are separable EFs (Miyake et al., 2000), with neuroimaging evidence revealing that different areas of the brain are associated with shifting and inhibition. Colette et al. (2005) found that, although inhibition and set shifting involve overlapping areas of the brain such as the right intraparietal sulcus, the left superior parietal gyrus, and the left lateral prefrontal cortex, the left superior parietal cortex is uniquely involved in set shifting while the right intraparietal sulcus plays more of a role in inhibition (Collette et al., 2005).

In the literature, the DCCS is most often used as a measure of set shifting because of the need for participants to shift sorting dimensions. However, like most behavioral measures of set shifting, the DCCS task also involves other EFs, namely inhibition. In this task, inhibition is used to suppress irrelevant information after shifting from one dimension to another through the adoption of a new sorting rule and the suppression of the previous one. For this reason, a bilingual advantage for participants in passing the DCCS task has also been attributed to superior inhibitory control (Bialystok, 1999; Bialystok & Martin, 2004). However, different aspects of the DCCS task are used in studies that attribute success to inhibition versus set shifting. In studies that attribute it to inhibition (Bialystok, 1999; Bialystok & Martin, 2004), sorting accuracy is the only measure factored in their analyses. On the other hand, studies attributing success on the DCCS task to set shifting ability (Barac & Bialystok, 2012; Diamond & Kirkham, 2005; Dichter et al., 2010; Gonzalez‑Barrero & Nadig, 2019) factor in both accuracy and reaction time (RT) in their analyses, with RT on only correctly-sorted trials being the key factor in assessing set shifting ability such that faster RTs indicate better set shifting ability and vice versa. Moreover, RT is the measure in which a bilingual advantage in set shifting has most commonly been found (Prior & Gollan, 2011), with bilinguals exhibiting smaller switch costs (e.g., the delay observed when switching from one rule to another) than monolinguals.

The question of whether the DCCS task is more a measure of inhibition or shifting has not been directly evaluated. However, this question has been explored in regards to the WCST, its analogue task. By testing a two-path model with paths from shifting and inhibition in addition to two one-path models with paths from either shifting or inhibition, Miyake et al. (2000) found that the two-path model with paths from both shifting and inhibition was not statistically better than the one-path model with a single path from shifting. This study also showed shifting to have a more significant coefficient (.33) than inhibition (.09) for the full three-path model. Ultimately, these results indicate that inhibitory control does not significantly predict perseverance once shifting ability has been accounted for, and shifting ability is the most crucial EF component of perseverative errors in the WCST (Miyake et al., 2000). Therefore, shifting is most likely the most crucial EF component of perseverative errors in the DCCS task as well.

The DCCS task was originally developed as a live task; however, it has been modified to be done on a computer (Barac & Bialystok, 2012; Bialystok & Martin, 2004; Dichter et al., 2010; Gonzalez‑Barrero & Nadig, 2019). The administration of the task on a computer rather than in-person by a live experimenter allows a more precise recording of RT. Furthermore, as reviewed by Kenworthy et al. (2008), a number of studies demonstrate that individuals with ASD perform better on executive functioning tasks when they are administered on a computer rather than in-person by an experimenter (Kenworthy et al., 2008). This modality-specific performance difference for individuals with ASD has been demonstrated in set shifting tasks, such as the WCST (Ozonoff, 1995). In contrast, although neurotypical individuals tend to perform better on both modalities of the DCCS task compared to individuals with ASD, they do not show a significant difference in performance between modalities. Ozonoff (1995) reasoned that the difference in performance between modalities for those with ASD could be attributed to the reduced social demands of face-to-face interactions on the computerized version, helping them to sort more accurately on that version. It was reasoned that perseveration on the live task reflected, at least in part, social avoidance that often accompanies autism as well as a lack of social drive and motivation to receive and follow verbal feedback from a human examiner in the context of social interaction. A study conducted by Gonzalez-Barrero and Nadig (2019) that used the computerized DCCS task to assess the set shifting skills of monolingual and bilingual children with ASD compared to their neurotypical peers found that children with ASD seemed more engaged and motivated than their neurotypical peers with the computerized DCCS task. Some of the children with ASD were even described to have verbally expressed high levels of enjoyment, wanting to continue *"playing the computer game"* even after they had finished (Gonzalez‑Barrero & Nadig, 2019).

The proposed study will utilize a computerized DCCS task following the design from the 2019 study conducted by Gonzalez-Barrero and Nadig which had a similar student-participant pool that included six- to nine-year-old English monolingual and English-French bilingual children with ASD (Gonzalez‑Barrero & Nadig, 2019). I would act as the administrator for this task, with my main role being to set up the computer and ensure the task runs smoothly.

Two stickers (a red boat and a blue rabbit) will be placed on the "p" and "w" keys of the computer's keyboard, respectively. These stickers will act as the target stimuli according to which students will sort the test stimuli. The rest of the keyboard will be covered in a black cover to minimize distractions for the students. The computer screen will show bivalent images, such as red rabbits or blue boats, that will act as the test stimuli that students must sort first according to one dimension (e.g., color) for six trials, and then according to the other (e.g., shape) in a post-switch phase for another six trials. The order of the sorting dimensions (e.g., color then shape/shape then color) will be counterbalanced across students.

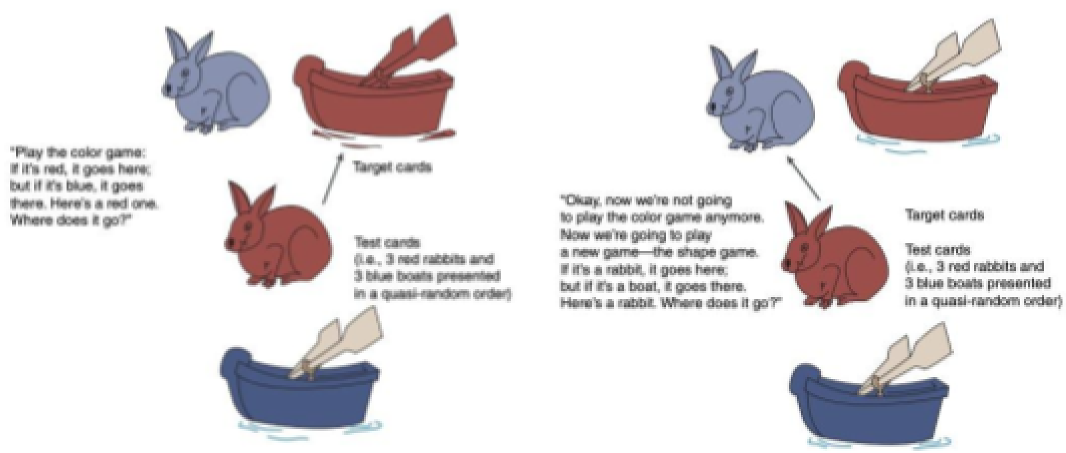
Before beginning the pre-switch phase, a demonstration phase (one trial) will occur during which the rules of the pre-switch phase will be explained and demonstrated by a character on-screen. After the demonstration phase, students will have to succeed on at least two out of three practice trials to move on to the pre-switch phase. During the practice trials, students will sort on the same dimension as the demonstration and pre-switch trials, and feedback will be given by a character on-screen about whether they sorted correctly or incorrectly with a green checkmark or a red x. However, on experimental trials, no feedback will be provided. Students will press one of the two stickers on the computer's keyboard to indicate where test stimuli should be sorted. For example, for the phase in which students have to switch by color, a student would match the color of the test object they see on the computer screen with the color of one of the stickers on the keyboard. At the beginning of each trial, before the student sees the test card, a character will show up on the computer screen and repeat the sorting rules. For example, if the child should be sorting by color, the character would say, "in the color game, all the blue ones go here" pointing to a box above the 'w' key with the same image (a blue rabbit) on it. The character will go on to say, "all of the red ones go here" pointing to a box above the 'p' key with the same image (a red boat) on it. When the test card is shown on the screen, the character will verbally label it by only its relevant dimension and prompt the student to sort it. For example, if an image of a red rabbit comes up on the screen, the character could say, "Now here's a red one. Where does this one go?" This pre-switch phase will continue for six trials. To pass, students must correctly sort on at least five out of six of the trials.

After six trials of the pre-switch phase, those who pass will move on to the post-switch phase. A character on-screen will announce that the sorting rules will change. For instance, if changing from sorting by color to shape, the character would announce, "okay, we are not going to play the color game anymore. Now, we are going to play the shape game," and the character will proceed to explain the rules of the shape game just as it did the color game. The subsequent six trials of the post-switch phase will be carried out exactly like the trials in the pre-switch phase, with the dimension by which the cards must be sorted being the only difference. To pass the post-switch phase, students must correctly sort on at least five out of the six trials.

Those who pass the post-switch phase will move on to the more difficult "border version" of the DCCS task consisting of 12 trials. On the border version, stimuli that have a black border around them must be sorted by a particular dimension (e.g., color), and stimuli that have no border must be sorted by the other (e.g., shape), with switches presented randomly on about 20% of the trials. To pass the border version, students must sort correctly on at least 9 of the 12 trials. Before beginning the border version, a character will show up on the screen and explain the rules, and the student will undergo a practice border version (two trials) with accompanying feedback. A student will only be allowed to begin the border version if they sort correctly on at least one of the practice trials. At the beginning of each trial, the character will repeat the rules by saying, “remember, if there’s a black border, you have to play the color game. But, if there’s no black border, you have to play the shape game.” After that, a test stimulus will show up on the screen. The on-screen character will announce whether or not the card has a black border and ask the student where it goes, after which the student will sort the card. This process will repeat for every trial until all 12 trials have been completed. As in the pre- and post-switch trials, no feedback on the child’s performance will be given by the character on the border version.

Figure 1

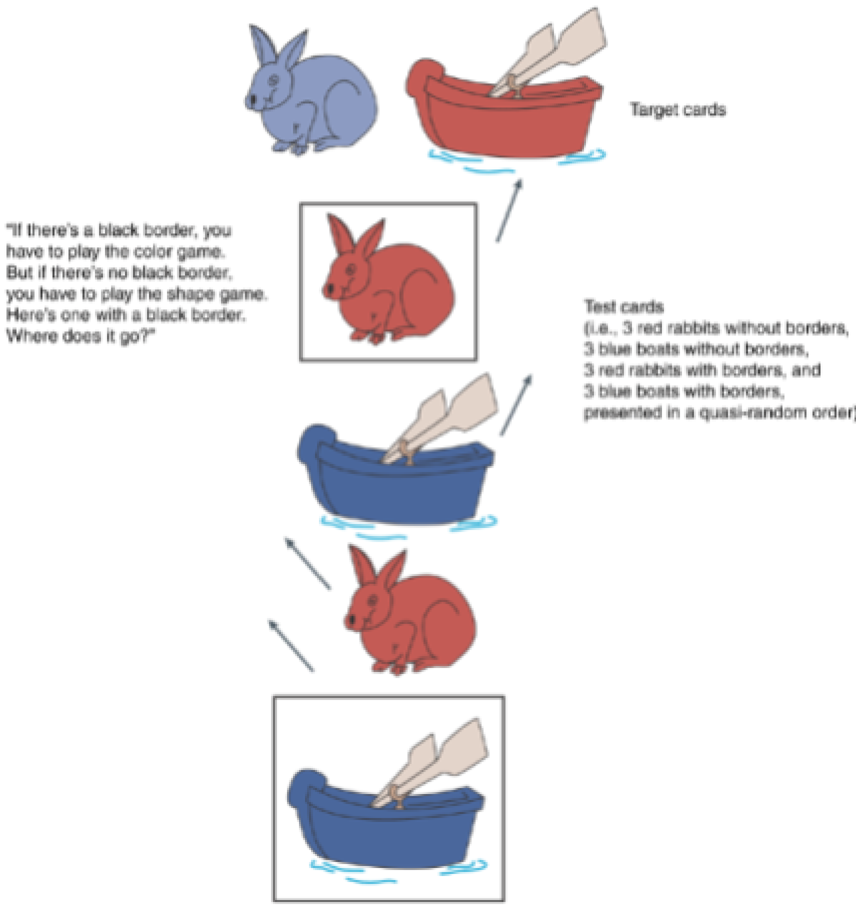
Pre- and Post-Switch Phases of the DCCS Task



Note. Reprinted from Zelazo, P. (2006). The Dimensional Change Card Sort (DCCS): A method of assessing executive function in children. *Nature Protocols*, *1*, 297.

Figure 2

Border Version of the DCCS Task



Note. Reprinted from Zelazo, P. (2006). The Dimensional Change Card Sort (DCCS): A method of assessing executive function in children. *Nature Protocols*, *1*, 299.

Procedure

Recruitment of teachers who meet the proposed study's criteria will occur before the recruitment of students. Before officially committing to the study, teachers will sign an informed consent agreement containing information on the study and what their roles will entail (see Appendix A). After all teachers are recruited, main teachers will be randomly assigned to classrooms in either the monolingual or bilingual education program conditions, and substitute teachers will randomly be assigned to one of the four classrooms. Within the bilingual program, main teachers will then be randomly assigned to teach in either French or English. After all teachers are randomized to their respective conditions and classrooms, student recruitment will begin. Like teachers, before being officially recruited to the study, parents of students will also sign an informed consent agreement containing information on the study and what their children's participation in the study will entail (see Appendix B).

For the proposed study, partnerships would be made with schools in New York that specialize in the education of children with ASD, or have programs that do, that would be willing to incorporate a bilingual education classroom into their school. Should a child withdraw from the study at any point, the integration of the proposed study's classrooms within already-existing educational settings would enable a smoother transition to a standard special education classroom within the same school. The goal would be for students in the proposed study to either attend their respective programs at one school that specializes in the education of children with ASD or to spread out the classrooms between multiple schools under the same organization that run the same special education program, such as NYC Autism Charter Schools or New York Schools that run the NYC Department of Education's ASD Nest Program. Classrooms could be spread between two or four schools (see Figure 3). In a two-school model, classrooms would be organized so that there would be one bilingual education classroom and one monolingual education classroom within each school. In a four-school model, each of the classrooms would be placed in one of the four schools. Ideally, all or most students would be recruited from the schools that have already partnered with the study's researchers. Therefore, in a two-school model, a goal of 22 eligible students would need to be recruited from each school, and a four-school model would need 11 from each, respectively. Should there be a situation in which not enough children can be recruited from the partner schools, additional students would then be recruited through autism organizations, schools, and therapy programs within New York.

Classes in both the bilingual and monolingual conditions will be exclusively made up of children who are students in the study and their recruited teachers. Children in the monolingual education program condition will simply receive the school's standard monolingual English instruction. Both teachers and parents of students will be blinded to the study's specific hypothesis that this bilingual program could influence the set shifting abilities of children with ASD. Instead, all will be told that the study is assessing the ability of children with ASD to learn a second language through educational instruction rather than through naturalistic acquisition from infancy.

After being officially recruited to the study, students will undergo a screening process confirming their autism diagnosis and severity level, their language abilities, and their intelligence levels. All of these assessments will occur at different "stages" of the experiment on separate days. Stage one of the study will consist of the autism diagnosis confirmation and severity level screener by the CARS. At stage two, the CELF-5 will be administered to assess language ability, and at stage three, the WISC-V will be administered to assess intellectual ability. Stage four will occur after all students have been screened. During this stage, students will be pairwise matched according to autism severity, language ability, and IQ. One student in each pair will be included in the bilingual education program and the other will be placed in a monolingual English education program. Those who are not included in the bilingual education program and those whose parents would like their child to continue their bilingual education after they participate in the study's bilingual program will be given the opportunity to be enrolled in a bilingual education program upon the completion of their time in the study. At stage five, students will undergo the DCCS task to measure pre-instruction set shifting ability. Children will then begin their respective educational programs at stage six, and stage seven will consist of the two-year time span during which students undergo their respective programs. At stage eight, children who underwent the bilingual education program will undergo the Échelle de Vocabulaire en Images Peabody (EVIP) (L. M. Dunn, 1993) as well as both the French and English versions of the Word Association Test (WAT) (Wallace E. Lambert, 1956). These assessments will act as manipulation checks for the bilingual education program to confirm students' bilingual proficiency.

Stage nine will be the final stage of the study during which students will once again undergo the DCCS task to measure their post-instruction set shifting ability (see Figure 4). Upon completion of the study, both teachers and parents of students will be debriefed on its true goals and specific hypotheses (see Appendix C for teacher debriefing; see Appendix D for parent debriefing).

Figure 3

Dispersion of Study Groups Within Two- and Four-School Models

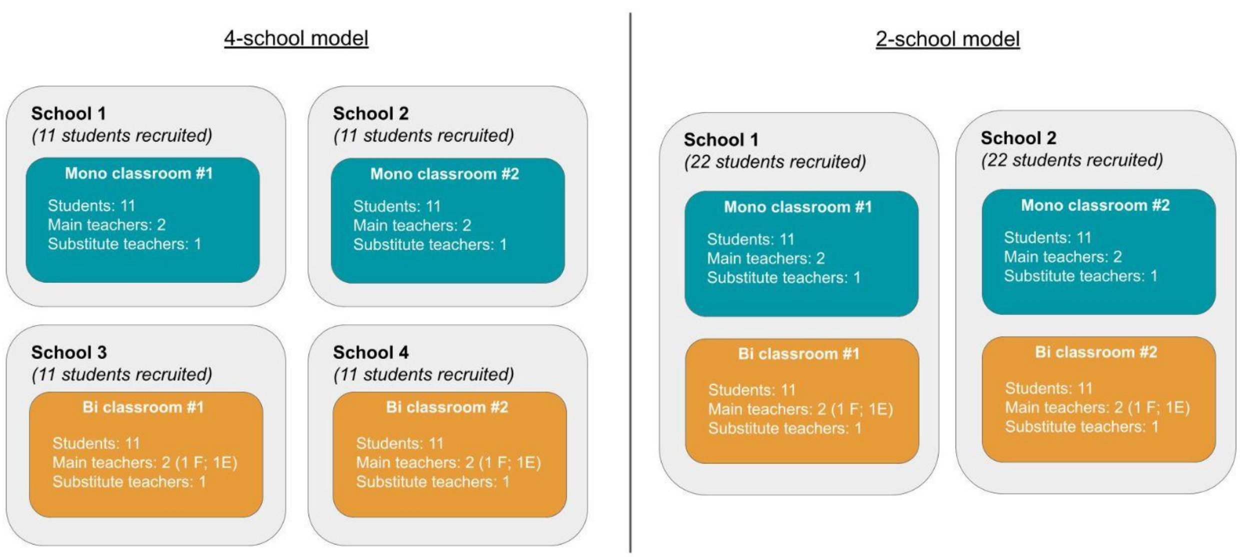
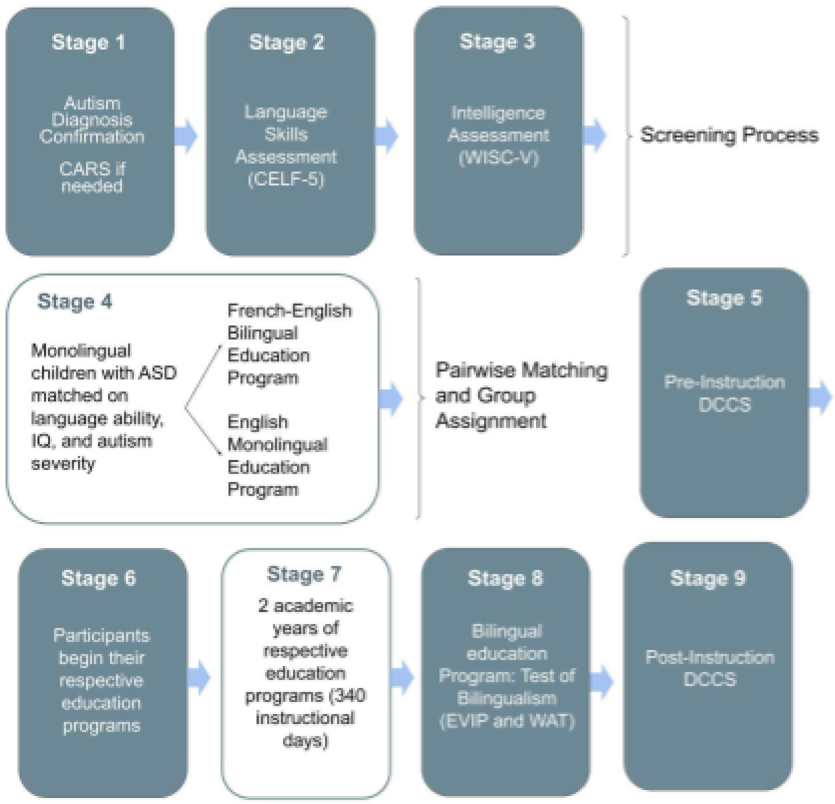


Figure 4

Student Study Stages



Predicted Results

In line with previous studies using the DCCS task to measure set shifting, set shifting abilities in the proposed study will be measured by incorporating both accuracy (i.e., pass/fail) on all phases of the DCCS task (pre-switch, post-switch, and border) and RT in milliseconds into my analyses. Following the DCCS analysis criteria of Gonzalez-Barrero and Nadig (2019) and Diamond and Kirkham (2005), only correct trials will be considered for RT analysis. Additionally, trials that are less than 200 milliseconds (ms) or 2.5 *SD* above the mean for each group will not be included, as these RTs are considered too fast or slow to reflect the processing of stimuli. The mean RT of the last two trials of the pre-switch phase will be subtracted from the mean RT of the first two trials of the post-switch phase to obtain a RT switch cost difference score (e.g., the delay observed when switching from one rule to another), with higher scores indicating more of a switch cost and thus worse set shifting abilities than lower scores. The mean RT on accurate trials on the border version (i.e., mixed condition) will also be examined between groups (monolingual program vs bilingual program). As children progress through the three phases of the DCCs task (pre-switch, post-switch, border), the tasks become more difficult. Research shows that this increased difficulty with each phase results in more participants passing the earlier phases than the later phases, with fewer passing the post-switch phase than the pre-switch phase and even fewer passing the border version than the post-switch phase (Gonzalez‐Barrero & Nadig, 2019; P. Zelazo, 2006). I predict that this same accuracy/passing pattern will occur in the proposed study at both pre-instruction and post-instruction and that there will be an overall increase in the passing rate on all phases of the DCCS task at post-instruction compared to pre-instruction (see Figure 5). As shown in Figures 6 and 7, I predict that a 2 (time point) X 2 (education program) mixed ANOVA will indicate:

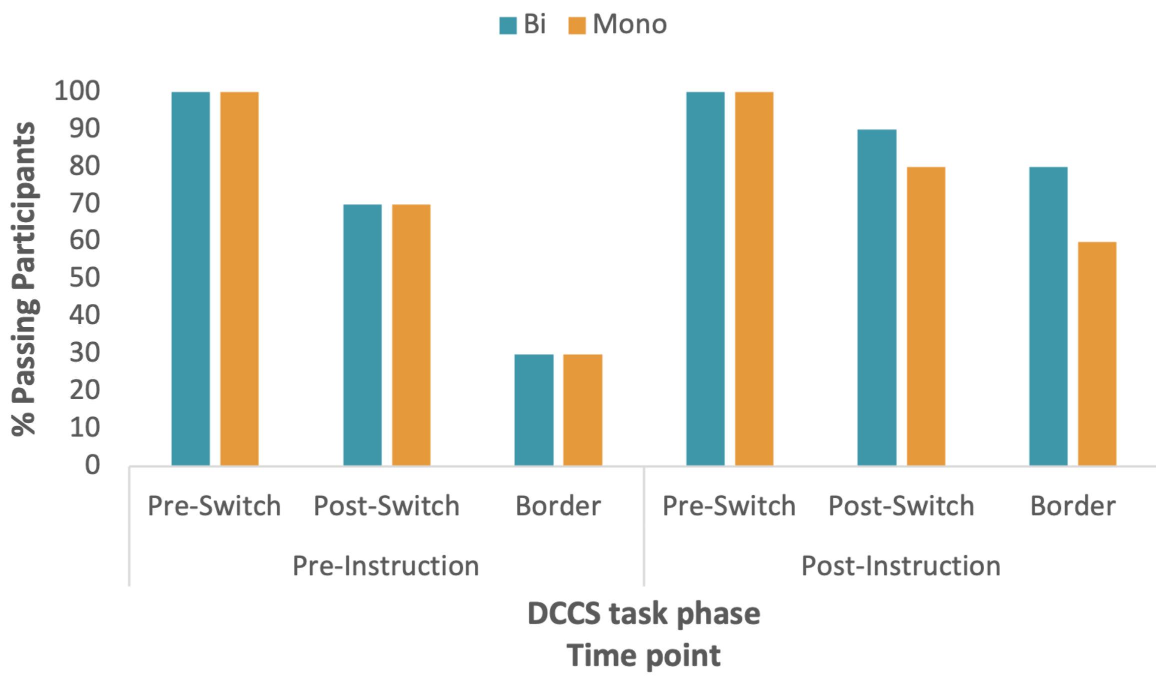
(a) a main effect of time point on RT switch costs (F (1,42) = 4226.48, $p < .001$) and border version RTs (F(1,42) = 2351.29, $p < .001$). This main effect of time point will reflect that, across both education programs, students will show lower post-instruction switch costs (M = 1033.45) and faster post-instruction border version RTs (M = 1809.70) compared to pre-instruction switch costs (M = 1537.02) and border version RTs (M = 1581.27), thereby indicating improved set shifting abilities from pre-instruction to post-instruction.

(b) I also predict a main effect of education program on RT switch cost ($F(1,42) = 4.57$, p <.001) and border version RTs ($F(1,42) = 4.46$, p =.04) such that those in the bilingual education program will show overall lower switch costs (M = 1143.80) and faster border version RTs (M = 1907.61) than those in the monolingual education program (M = 1426.68, M = 2136.14).

(c) I predict that these main effects will be qualified by a significant time point by education program interaction for RT switch costs ($F(1,42) = 1340.223$, p < .001) and border version RTs ($F(1,42) = 680.84$, $p < .001$). I hypothesize that the education programs will only significantly differ at post-instruction, with students in the bilingual education program showing smaller post-instruction switch costs (M = 750.23) and faster post-instruction border version RTs (M = 1581.27) compared to those in the monolingual education program at post-instruction (M = 1316.68, M = 2038.14) (see Figure 6 for switch cost difference score predictions; see Figure 7 for border version RT predictions).

Figure 5

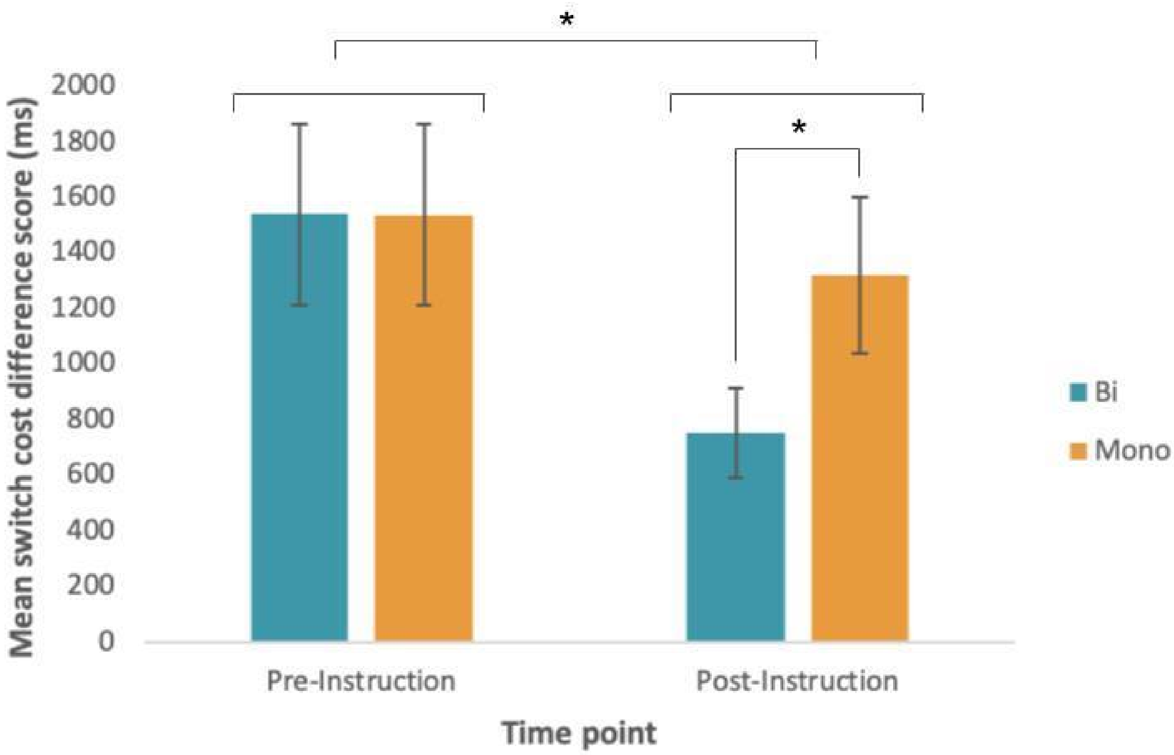
Predicted percentage of participants passing each phase of the DCCS task by group and time point



Note. Pre- and post-switch phase passing criteria: 5 correct trials out of 6. Border version passing criteria: 9 correct trials out of 12.

Figure 6

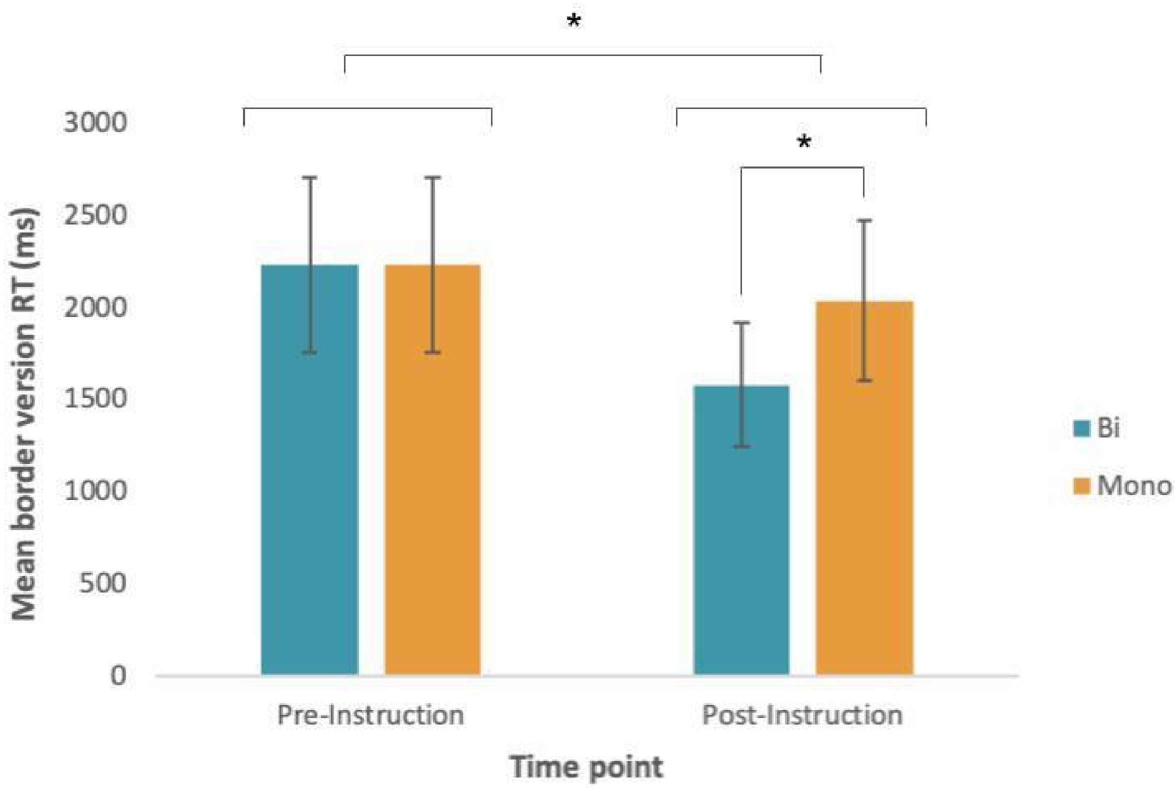
Predicted mean switch cost difference score on the DCCS task by group and time point



Note. Switch cost difference score = (mean RT of first two trials of post-switch phase) - (mean RT of last two trials of pre-switch phase). Error bars represent SEM (pre-instruction/bilingual SEM = 327.77, pre-instruction/monolingual SEM = 327.62, post-instruction/bilingual SEM = 159.95, post-instruction/monolingual SEM = 280.72). I predict a main effect of time point such that, across both education programs, students will show lower switch costs at post-instruction (M = 1033.45) than at pre-instruction (M = 1537.02). I also predict a main effect of education program such that students in the bilingual program will show overall lower switch costs (M = 1143.80) than students in the monolingual program (M = 1426.68). I hypothesize that these main effects will be qualified by an interaction such that switch costs will only differ significantly between education programs at post-instruction, with students in the bilingual program showing smaller switch costs at post-instruction (*M* = 750.23) than students in the monolingual program at post-instruction (*M* = 1316.68).

Figure 7

Predicted mean reaction time for border version of the DCCS task by group and time point



Note. Error bars represent SEM (pre-instruction/bilingual SEM = 476.28, pre-instruction/monolingual SEM = 476.32, post-instruction/bilingual SEM = 337.13, post-instruction/monolingual SEM = 434.53). I predict a main effect of time point such that, across both education programs, students show faster border version RTs at post-instruction (*M* = 1809.70) than at pre-instruction (*M* = 1581.27). I also predict a main effect of education program such that those in the bilingual education program will show overall faster RTs (*M* = 1907.61) than those in the monolingual education program (*M* = 2136.14). I hypothesize that these main effects will be qualified by an interaction such that border version RTs will only differ significantly between education programs at post-instruction, with students in the bilingual program showing faster border version RTs at post-instruction (*M* = 1581.27) than students in the monolingual program at post-instruction (*M* = 2038.14).

Discussion

The proposed study is designed to examine how learning a second language through a bilingual education beginning upon entrance to formal schooling affects the set shifting abilities of children with ASD. I hypothesize that there will be a main effect of both time point and education program on set shifting abilities such that *(a)* set shifting abilities will improve from pre-instruction to post-instruction as shown by smaller post-instruction switch costs and faster post-instruction border version RTs, and *(b)* those who receive a bilingual education will outperform those who receive a monolingual education on set shifting ability overall, with smaller switch costs and faster border version RTs. I also hypothesize that these main effects will be qualified by an interaction, such that *(c)* bilingual classroom instruction will result in better set shifting abilities particularly at post-instruction when compared to monolingual classroom instruction.

Hypothesis *(a)* is grounded in literature that shows a positive effect of age and formal schooling during the early elementary grades (grades one to four) on performance on set switching tasks (Mccrea et al., 2000). Hypothesis *(b)* is also grounded in literature that demonstrates a shifting advantage for bilinguals compared to monolinguals (Bialystok, 2011; Gonzalez‑Barrero & Nadig, 2019) as well as for neurotypical children in bilingual education programs compared to their counterparts in monolingual programs (Esposito & Baker-Ward, 2013). Furthermore, both languages are activated in the bilingual brain even when only one is being used (van Heuven et al., 2008). This practice of constantly processing and managing two different languages in the bilingual brain could increase EF skills, thus improving set shifting abilities and resulting in the predicted effect of children that have gone through a bilingual education program demonstrating better set shifting abilities than their counterparts that have experienced only a monolingual education.

I would like to note that the sample size listed in the preregistration for the proposed study does not accurately reflect the predicted sample size for the proposed study (see Appendix E). In the preregistration, the predicted sample size listed was 162. However, the final predicted sample size reported in this paper is 44, resulting in 22 students in each condition (monolingual/bilingual education program). The reason for this drastic change was because of an initial mistake I made in G*Power when conducting an a priori power analysis to determine sample size where I reported that I was planning to run a Multivariate Analysis of Variance (MANOVA) instead of an ANOVA by mistake. This resulted in a larger sample size than was actually needed for the statistical tests I was planning to run. This mistake was caught and corrected after I had written the preregistration which is the reason the preregistration does not accurately reflect the predicted sample size for the proposed study.

Limitations

Speech Processing in Autism

Children with ASD have atypicalities in the brainstem processing of speech (Russo et al., 2009). They are also naturally less salient for social stimuli, such as repetitive speech sounds compared to repetitive nonspeech sounds (Whitehouse & Bishop, 2008). This could present a limitation for the proposed study, as children in the bilingual education program could show less of a bilingual advantage than what might be expected in neurotypical children due to difficulties registering and orienting to salient stimuli in a bilingual environment. This could result in a lack of a significant difference between the groups' (monolingual vs. bilingual) post-instruction set shifting abilities. However, research also suggests that children with high functioning autism can use their EF skills to direct their attention to speech sounds when explicitly told to, causing the difference in orientation to speech versus nonspeech sounds to disappear. Moreover, those same children can orient normally to novel speech sounds when presented in a sequence of nonspeech, complex tones (Whitehouse & Bishop, 2008). Based on the current student-participant variable requirements I have put in place, a majority of students will be in the high-functioning range for autism. Therefore, I expect that they will have a stronger ability to orient toward social stimuli, such as speech sounds and novel language, compared to others that are lower on the autism spectrum. However, no limit was placed in regards to the severity of the autism diagnosis for students in the proposed study. So, there remains the possibility of students who are lower on the spectrum having more difficulty orienting to speech which could affect their ability to become bilingual. This could result in variation within the bilingual education condition, where some children will achieve a higher degree of bilingualism and show more of a set shifting benefit than others. It could be interesting, then, for a future study to look at how neurotypical children and children with ASD that go through this kind of bilingual education program differ in terms of variation in set shifting abilities within each respective group. I would expect that there would be more heterogeneity in the set shifting abilities of the group of children with ASD due to difficulties registering and orienting to salient stimuli in a bilingual environment.

Hyper- and Hypo- sensitivity and Language Acquisition

Patterns of responsiveness to sensory stimulation are important to consider when looking at language learning in children with ASD. Research shows that hyper- and hypo-sensitivity to sensory stimulation are differentially correlated with the language abilities of children with ASD

(Tomchek et al., 2015; Watson et al., 2011). In a study done in 2011 by Watson et al. on how patterns of sensory responsiveness, such as hyper and hypo-responsiveness, correlate with the language abilities of monolingual children with ASD, hyporesponsiveness, and sensory seeking was shown to be negatively associated with receptive and expressive language skills. The study also found that hyperresponsiveness was positively associated with language skills, although not significantly (Watson et al., 2011). Similar findings were also supported by Tomcheck et al. (2015) whose study showed that monolingual children with ASD who demonstrated hyporesponsivity to sensory stimulation had decreased receptive and expressive language skills while those who demonstrated more hyperresponsivity had better language skills (Tomchek et al., 2015). This negative correlation could be due to a decreased amount of registering and orienting to stimuli in an environment that could cause a child to miss language learning opportunities. These results could imply that the amount that children's language abilities benefit from a bilingual education could differ between children who demonstrate hyper- versus hypo-sensitivities to sensory stimulation. Because the proposed study is using a randomized block design through pairwise matching, I do not expect that this will not present much of a confound, as hyper- and hypo-sensitive children will be randomly distributed between the conditions. Nevertheless, future studies could examine this by including hyper- and hypo-responsiveness as an additional variable on which students are matched.

An Additional EF Measure of Inhibition

A study by Miyake et al. (2000) that assessed the validity of the WCST found that inhibitory control does not significantly predict perseverative errors in the WCST once shifting ability has been accounted for. The study also found that shifting ability is the most crucial EF component of perseverative errors in the WCST (Miyake et al., 2000). However, because the study looked only at the WCST and not the DCCS task, one cannot be completely sure that those results can be directly mapped onto the DCCS task, even though the DCCS task was created as an analogous task for young children to the WCST. Because of this, it could have been beneficial to include an additional EF test for inhibition to assess its relation to performance on the DCCS task in addition to set shifting ability, and to rule it out as a confound or an alternative explanation for success on the task.

Cost Barriers

I recognize that a large-scale, longitudinal study such as this one will incur high monetary costs. The proposed study's budget calls for roughly $1.6 million (see Appendix F), a very large amount of money that can create barriers to conducting research like this. An aspect of the study that could be changed to decrease this cost barrier includes the number of substitutes and the method of payment of teachers. This could mean only recruiting two rather than four substitute teachers to cover the four classrooms, or perhaps having the partner schools put the main teachers' salaries on the district's payroll rather than paying main teachers' salaries directly through the study. Doing this would cut the study's costs immensely and make the study more monetarily feasible.

Future Directions

Comparing Trilinguals

Trilinguals have been shown to outperform bilinguals on EF tasks (Madrazo & Bernardo, 2018). After this proposed study is conducted, an interesting future direction could be to investigate how an even larger language repertoire affects set shifting ability. This could be done by adding a third education condition made up of children with ASD who are already bilingual but are learning French as a third language to become trilingual. It could also be interesting to compare how native bilinguals and non-native bilinguals (e.g., those who learned their second language via the route like the one in this proposed study), differ in set shifting abilities after learning a third language through further bilingual instruction.

A Look into the Relationship Between Bilingualism and Theory of Mind

Research shows that EF scores are highly correlated with social perspective-taking ability for individuals with ASD (Ozonoff et al., 1991), and set shifting ability, in particular, is a very strong predictor of social understanding abilities in adolescents with ASD (Berger et al., 1993). These findings indicate that an additional outcome of the proposed study could include improvements in students' social skill development as a result of the improved set shifting abilities gained from the bilingual education program. Although I did not decide to explore this in my study, it would be interesting for a future study to incorporate social skill development as an additional dependent variable in order to better understand how a bilingual education could lead to improvements in it for children with ASD.

A Look into Gender Differences

I did not incorporate gender as a factor of primary interest in the proposed study and instead chose to homogenize gender to include only male children, thereby limiting the generalizability of the study's results to only one gender. However, a number of past studies have looked into the relationship between gender and EF. Some have found a behavioral difference between genders (Ren et al., 2009; Stoet et al., 2013) while others have not despite differential neural processes (Christakou et al., 2009; C. R. Li et al., 2009). Moreover, a number of studies looking at adults diagnosed later in life with high-functioning ASD found that females demonstrate better set switching abilities than males (Lehnhardt et al., 2015). This gender disparity could potentially be attributed to females on the higher end of the spectrum having better symptom-masking abilities than males (Szatmari et al., 2012; Werling & Geschwind, 2013). These studies were conducted with adult participants. It would be interesting to look into how this gender difference translates to the relative EF abilities between sexes for children with ASD, especially since there is a male bias in the prevalence of ASD that becomes more pronounced in the high-functioning range. A future study could replicate the proposed one with female students to compare how the bilingual advantage differs between genders.

Conclusion

Although research shows that exposure to a bilingual environment both during or after infancy is non-harmful to the language development and EF skills of a child with ASD (Hambly & Fombonne, 2012; Iarocci et al., 2017; H. Li et al., 2017; Myers, 2009; Wang et al., 2018), and may be beneficial (Howse, 2016; Seung et al., 2006), doubt persists. This persisting doubt results in many barriers that prevent children with ASD from having access to bilingual opportunities. Many bilingual parents of children with ASD fear that exposing them to a bilingual environment would confuse their children, causing additional delays in their language development. For this reason, many of these parents choose to raise their child in a monolingual environment, speaking only one language to their child, which is usually the majority language of the community that they live in (Beauchamp & MacLeod, 2017). Some parents in the U.S. whose L1 is not English still choose to speak only English to their child with ASD for this reason. However, these parents have expressed that doing this causes discomfort and can be difficult since English is a non-native language for them, causing them to speak less frequently to their child due to it feeling less natural (Yu, 2013). Additionally, most bilingual special education programs for children with ASD are designed for children who already live in a bilingual household or are immigrants who need extra help in learning English. And even then, these programs and services are limited (de Valenzuela et al., 2016; Marinova-Todd et al., 2016). Moreover, monolingual children with ASD are often selectively excluded from traditional bilingual education programs and steered toward English-only special education options (de Valenzuela et al., 2016), since many traditional bilingual education programs are not equipped to accommodate children with developmental disabilities. Some children with ASD who are in integrated classrooms that include both neurotypical children and children with developmental disabilities are even pulled out of their traditional classrooms when the time for foreign language instruction occurs (de Valenzuela et al., 2016). If future results from this proposed study suggest the predicted hypotheses to be true, this could be used as further evidence showing that a bilingual environment is not only non-harmful to a child with ASD but could potentially be beneficial to them as well. It could encourage bilingual education programs to be more inclusive of children with ASD and could also influence how current programs in place for the education of children with ASD, such as the Applied Behavior Analysis (ABA) program, are structured. These changes could include providing more bilingual opportunities, at least for those on the higher end of the spectrum, in these kinds of programs. Doing this could help to make the world more accessible for those with ASD by providing them with more opportunities to gain the ability to communicate in two languages, thereby opening up many future jobs and personal opportunities associated with our increasingly multilingual and global world.

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Appendix A
Sample Informed Consent Agreement (for teachers)

Study Title: Second Language Acquisition in Children with Autism
Investigator: Chandler O'Reardon

You are invited to take part as either a main or substitute bilingual special education teacher in a research study. This study will assess the abilities of children with autism to learn a second language (French) through two years of educational instruction rather than through naturalistic acquisition from infancy.

Participation in this study is voluntary. Teachers will be expected to continue through the two-year term (a total of 340 school days) but can withdraw if need be by notifying Chandler O'Reardon (co3575@bard.edu).

To participate, all teachers are required to have earned a Master of Arts degree in Bilingual Childhood Special Education Studies (BISPED) from Columbia University with a focus on French/English dual language and immersion studies and a minimum GPA of 3.0. Additionally, all teachers must hold a currently valid professional teaching certificate in the state of New York, with between three to five years of teaching experience.

Background: In this study, we hope to learn more about whether children with autism are able to learn a second language through educational instruction rather than by being raised in a bilingual household from infancy. We aim to do this by assessing children's language skills before and after a two-year bilingual (English/French) education program beginning when children are six years old.

What you will do in this study:
<u>Should you decide to participate as a main teacher:</u>

> You will be randomly assigned to one of two educational programs that will each run for two full academic years: a monolingual English education program or a bilingual (English/French) education program. The respective programs' classrooms will be located within schools in New York that specialize in the education of children with autism. You will be expected to teach on weekdays for a total of 170 days out of each year for two years. In the monolingual program, all teachers will be expected to teach in English, and in the bilingual program, teachers will be randomly assigned to teach in either French or English, but never both. In each program, there will be two classes of 11 students each. Two teachers will be assigned to each classroom, and will equally split instructional content between themselves. Teachers will never teach the same class together at the same time, and will instead be expected to collaborate regularly to coordinate curriculum and instruction for their students. In the bilingual program, the two teachers in charge of each classroom will teach content in separate languages, with one teacher providing instruction in only English and the other providing instruction in only French so that students are better able to clearly identify a model English speaker and a model French speaker.

Should you decide to participate as a substitute teacher:

You will be randomly assigned to one of two educational programs that will each run for two full academic years: a monolingual English education program or a bilingual (English/French) education program. The respective programs' classrooms will be located within schools in New York that specialize in the education of children with autism. You will be expected to be on-call to step in and teach a classroom of eleven children when a main teacher of that class is unable to teach. You will be primarily responsible for following the lesson plans already created by the main teacher to create a cohesive and consistent learning experience for students. Should a main teacher choose to withdraw from the study before its conclusion, you may take that teacher's place as the main teacher of their classroom.

Additionally, before and after the education programs begin, you will be responsible for administering a number of assessments to children in the study as part of a pre-program screening process as well as a post-program evaluation process. These assessments will involve intelligence and language assessments. There will be two pre-program assessments and two post-program assessments that you will administer. Each assessment requires 5 to 80 minutes to administer, and you may be administering multiple assessments to multiple children per day.

Risks and benefits: Other than the normal risks faced as a teacher in a typical special education classroom setting, there are no additional risks associated with this study. Additionally, your participation in this study will help improve the understanding of the language development of children with autism and could inform the future of educational services for children with autism.

Compensation:

Main teachers:

In exchange for participating in this study as a main teacher, you will receive a total of $157,420 over the course of the two years of your participation in the study. This amount will be paid in weekly installments of approximately $3,279.58 during the weeks that school is in session (roughly 48 weeks total throughout the two years).

Substitute teachers:

In exchange for participating in this study as a substitute teacher, you will receive a total of $101,578 over the course of the two years of your participation in the study. This amount will be paid in weekly installments of approximately $2,116.21 during the weeks that school is in session (roughly 48 weeks total throughout the two years).

You will also receive $12.50/hour for the administration and scoring of pre- and post-program assessments.

Rights as a participant: Teachers will be expected to continue through the two-year term (a total of 340 school days), but participation is completely voluntary and you may withdraw if need be by notifying Chandler O'Reardon (co3575@bard.edu). You will still receive compensation for any past participation up to the point of your withdrawal.

Confidentiality: Your information will be kept confidential by keeping your identity anonymous in any reports.

This study has been approved by the Bard College Institutional Review Board. If you have any additional questions about this research, please feel free to contact Chandler O'Reardon (co3575@bard.edu) or the Bard College Institutional Review Board (irb@bard.edu).

STATEMENT OF CONSENT:

By signing this document, you are agreeing to participate in this study. Make sure you understand what will happen in this study before your sign. If you have any questions about the study after you sign this document, you can contact Chandler O'Reardon using the contact information listed above.

"I understand what will happen in this study and what my role will be. My questions so far have been answered. I agree to take part in this study."

By signing below, I agree with the above **statement of consent.**

____
Name (printed)

___________________________________ _____________
Signature Date

Appendix B
Sample Informed Consent Agreement (for parents of students)

Study Title: Second Language Acquisition in Children with Autism
Investigator: Chandler O'Reardon

You are invited to have your child take part in a research study assessing the ability of children with autism to learn a second language (French) through educational instruction rather than through naturalistic acquisition from infancy.

Participation in this study is voluntary. You can choose for your child to participate in this study, and you can choose to end your child's participation at any time.

To participate, children must be male with a chronological age of six years who are monolingual English speakers (with monolingual English parents/guardians) living in the United States with normal or corrected-to-normal vision and no color blindness. All students must meet the criteria for having autism spectrum disorder as confirmed by an official clinical diagnosis by a licensed clinician using the DSM-5 criteria and/or by earning at least the minimum cutoff score for autism of 30 on the Childhood Autism Rating Scale (CARS). Students must also have no accompanying intellectual disability or language disorder. These eligibility requirements will be confirmed through a three-part screening process.

Background: In this study, we hope to learn more about whether children with autism are able to learn a second language through educational instruction rather than by being raised in a bilingual household from infancy. We aim to do this by assessing children's language skills before and after a two-year bilingual (English/French) education program.

What you will do in this study: Should you decide for your child to participate, your child will first be asked to undergo a series of evaluations confirming their autism diagnosis and assessing their level of intelligence and language ability to confirm their eligibility for the study. Each of these screening assessments will last between 5 and 80 minutes and will require your child to pay attention to visual (images) and auditory materials (instructions and verbal interaction) presented by both a computer and a live administrator. Your child may be asked to make simple judgments about materials presented to them by pressing buttons, speaking out loud, or physically interacting with objects through play. Your child's participation in these screening assessments will take place over the course of three separate lab visits, and your child will only be asked to complete one screening assessment per lab visit.

Should your child's eligibility be confirmed for the study through the above screening process, they will be randomly assigned to one of two educational programs that will each run for two full academic years: a monolingual English education program or a bilingual (English/French) education program. The respective programs' classrooms will be located within schools in New York that specialize in the education of children with autism. Each year, there will be a total of 170 school days (M-F). Teachers in both the monolingual and bilingual education programs will be certified with M.A. degrees in bilingual childhood special education studies from Columbia

University, hold professional teaching certificates, and have had at least three years of prior teaching experience.

Upon completion of the education programs, children will complete assessments to measure their intelligence and language abilities. Children who complete the bilingual education program will be asked to complete additional assessments to determine their post-program bilingual language abilities, each lasting between 10 and 45 minutes. All of these assessments will be very similar to the pre-program screening assessments your child would have gone through before entering into the educational program. Your child's participation in these post-program assessments will occur over the course of two lab visits.

Risks and benefits: Children in this study will have an equal chance of being placed in a monolingual or bilingual education program. Therefore, not all children will receive a bilingual education. Nonetheless, children in both programs will receive a quality education from highly qualified teachers certified in childhood education, bilingual education, and special education. If your child is not assigned to participate in the bilingual education program, or if you are interested in having your child continue to receive a bilingual education after they participate in the study, you will be given the opportunity to opt them into being enrolled in a bilingual program upon the completion of their time in the study.

The data from this study will help improve the understanding of the language development of children with autism and could inform the future of educational services for children with autism.

Compensation: In exchange for participating in this study, you will receive $12.50/hour for each task your child undergoes as part of the pre-program screening process or post-instruction assessment process.

In addition to the monetary compensation for screening- and post-instruction-assessments, all children will get to pick a small toy of their choice from a toy box each time they undergo an assessment.

Rights as a participant/Parent of a participant: Your child's participation in this study is completely voluntary, and you may withdraw your child from the study at any time without penalty. You will still receive compensation for your child's participation in any screening or post-instruction assessments up to the point of their withdrawal, and your child will be transferred to another classroom within the same school, requiring no physical change of schools.

Confidentiality: Your child's information and data from this study will be kept confidential by keeping their identity anonymous in any reports. Your child's name and any other information that can directly identify them will be stored separately from their data. Only the study's researchers will have access to your child's data.

This study has been approved by the Bard College Institutional Review Board. If you have any additional questions about this research, please feel free to contact Chandler O'Reardon (co3575@bard.edu) or the Bard College Institutional Review Board (irb@bard.edu).

STATEMENT OF CONSENT:
By signing this document, you are agreeing to your child's participation in this study. Make sure you understand what will happen in this study before you sign. If you have any questions about the study after you sign this document, you can contact Chandler O'Reardon using the contact information listed above.

"I understand what will happen in this study and what my child's role will be. My questions so far have been answered. I agree for my child to take part in this study."

By signing below, I agree with the above **statement of consent**.

____
Student name (printed)

____
Parent/Guardian name (printed)

___________________________________ ____________
Parent/Guardian signature Date

Appendix C
Sample Debriefing Statement (for teachers)

Study Title: Second Language Acquisition in Children with Autism
Investigator: Chandler O'Reardon

Thank you for participating in this study. This research is designed to learn more about how a bilingual education, beginning when a child with autism enters formal schooling, affects their set shifting abilities. Set shifting is an executive function that people use to change their thoughts and behaviors to adapt to new environments and situations. It is an important tool that helps people tolerate changes and easily transition from one activity to another. Research shows a set shifting advantage for bilingual children with autism when compared to their monolingual counterparts (Gonzalez‑Barrero & Nadig, 2019), and this advantage is also found in children who have participated in bilingual education programs (Esposito & Baker-Ward, 2013)**.** The present research aims to explore how two different education programs (monolingual vs. bilingual) differentially affect the set shifting abilities of children with autism. Your participation as a teacher in this study will help to inform what we understand about bilingualism gained from an academic environment. It will also help us to understand how bilingualism affects executive functioning, and specifically set shifting abilities in children with autism.

We did not initially reveal to you that this study was assessing the set shifting abilities of the children you were teaching because the children's performance may have been altered had you been aware of this key aspect of the study. When people are aware of the purpose of a study in great detail, they can often unintentionally change its results. For instance, had you known that we were assessing students' set shifting skills, in particular, this awareness could have led to you forming your own expectations about their set shifting abilities, leading to you interacting with them differently based on those expectations, thereby possibly changing the study's results.

Your participation is a critical part of the study, and we very much appreciate your participation! If you have any questions or concerns, please feel free to contact Chandler O'Reardon (by email at co3575@bard.edu).

Appendix D
Sample Debriefing Statement (for parents of students)

Study Title: Second Language Acquisition in Children with Autism
Investigator: Chandler O'Reardon

Thank you for participating in this study. This research is designed to learn more about how a bilingual education, beginning when a child with autism enters formal schooling, affects their set shifting abilities. Set shifting is an executive function that people use to change their thoughts and behaviors to adapt to new environments and situations. It is an important tool that helps people tolerate changes and easily transition from one activity to another. Research shows a set shifting advantage for bilingual children with autism when compared to their monolingual counterparts (Gonzalez-Barrero & Nadig, 2019), and this advantage is also found in children who have participated in bilingual education programs (Esposito & Baker-Ward, 2013). The present research aims to explore how two different education programs (monolingual vs. bilingual) differentially affect the set shifting abilities of children with autism. Your child's participation will help to inform what we understand about how bilingualism gained from an academic environment affects executive functioning, and specifically set shifting ability.

The card sorting task that your child participated in before and after their respective education programs was intended to measure their set shifting abilities before and after their time in the program. However, we did not initially reveal this information to you because your child's performance may have been altered had you been aware of this key aspect of the study. When people are aware of the purpose of a study in great detail, they can often unintentionally change its results. For instance, had you known that we were assessing your child's set shifting skills, in particular, this awareness could have led to you forming your own expectations about your child's set shifting ability, leading to you interacting with your child differently based on those expectations, thereby possibly changing the study's results.

Your child's data are a critical part of the study, and we very much appreciate your participation! If you have any questions or concerns, please feel free to contact Chandler O'Reardon (by email at co3575@bard.edu).

Appendix E
Preregistration

A Bilingual Advantage for Children with Autism: Effects of a Bilingual Education on Set Shifting in Children with Autism Spectrum Disorders

Public registration

Metadata

Preregistration Template from AsPredicted.org

Data collection

Have any data been collected for this study already? Note: 'Yes' is a discouraged answer for this preregistration form.

No, no data have been collected for this study yet.

Hypothesis

How does a bilingual education in the form of a one-way, "alternate" French-English bilingual education program beginning when a male child with ASD enters formal schooling affect their set shifting abilities as shown through a dimensional change card sort (DCCS) task? It is predicted that there will be a main effect of both time point and education program on set shifting abilities such that set shifting scores will be higher post-instruction than pre-instruction, and those who receive a bilingual education will outperform those who receive a monolingual education. It is also predicted that these main effects will be qualified by an interaction, such that bilingual classroom instruction will result in better set shifting abilities, particularly at post-instruction when compared to monolingual classroom instruction.

Dependent variable

Set shifting scores at both time points will be my two key dependent variables. Set shifting will be measured by a dimensional change card sort (DCCS) task before and after participants' respective education programs. Accuracy (i.e., pass/fail) on all phases of the DCCS task (pre-switch, post-switch, and border) and reaction time (RT) in milliseconds will be incorporated into the analyses. Following the DCCS analysis criteria of Gonzalez-Barrero and Nadig (2019) and Diamond and Kirkham (2005), only correct trials will only be considered for RT analysis, and trials that are less than 200 milliseconds (ms) or 2.5 SD above the mean for each group will not be included. Following the RT analysis approach of Dichter et al (2010), the mean RT of the last two trials of the pre-switch phase will be subtracted from the mean RT of the first two trials of the post-switch phase to obtain a RT switch cost difference score. The mean RT for the border version will be examined as well.

Conditions

How many and which conditions will participants be assigned to?

There will be two conditions in this 2-way, mixed, experimental design. Participants will be pairwise matched according to autism severity, language ability, and IQ. One participant in each pair will be included in the bilingual education program and the other will be placed into an English monolingual education program, thus resulting in two conditions: bilingual education and monolingual education.

Analyses

A 2(education program) x 2(time point) mixed factorial analysis of variance (ANOVA) will be used to test if there is a change in set shifting ability before and after the respective education programs (bilingual or monolingual), and if the two groups' scores at pre- and post-instruction differ signicantly from each other.

Outliers and Exclusions

Prior to participation in the study, participants will also undergo a screening process confirming their autism diagnosis and severity level, language abilities, and intelligence (IQ). Any participant whose score on the Childhood Autism Rating Scale is below 30, and/or who demonstrates below average abilities in their intelligence and language skills will not be allowed to participate in the study. Participants who are color blind and/or who are not monolingual English speakers prior to beginning the study will also not be allowed to participate. Finally, participants who do not complete the full course of the study or who are outliers whose scores are 3 or more SD away from the mean will be excluded.

Sample Size

Results from an a priori power analysis with 90% power, an effect size of .30 and an α error probability of .05 suggest that the target sample size should be 162, resulting in 81 participants in each condition (monolingual/bilingual).

Other

A test of bilingualism will be used at the end of the 2-year bilingual education program as a manipulation check on the bilingual education program's effectiveness in order to con rm participants' bilingual language abilities.

Name

A Bilingual Advantage for Children with Autism: Effects of a Bilingual Education on Set Shifting in Children with Autism Spectrum Disorders

Finally

Class project or assignment

Other

No response

Appendix F
Proposed Budget

As described in the proposed study's methodology, this longitudinal study would be conducted over a two-year period. To acknowledge all participants' (i.e., students, teachers, and task administrators) time and effort, I have tried to identify a sensible level of monetary compensation. As such, a large proportion of the proposed budget would be dedicated to such compensation.

For each stage of the student screening process, all individuals will be compensated through hourly payment approximating the New York minimum wage ($12.50/hour as of December 31, 2020 (Payroll, n.d.)). Individuals requiring payment during the screening process include students as well as substitute teachers and school psychologists running each task. In addition to the monetary compensation for screening assessments, all children will get to pick a small toy of their choice from a toy box each time they undergo an assessment, and $100 will be needed to fill this toy box. Incorporating both the time that it would take to get a student ready for each task as well as the task itself and its scoring by the administrator, the first stage consisting of the autism diagnosis confirmation and CARS is expected to take 20 minutes for students (student compensation: $4.17) and 50 minutes for administrators (administrator compensation: $10.38). The second stage consisting of the language assessment through the CELF-5 is expected to take one hour for students (student compensation: $12.50) and two hours for administrators (administrator compensation: $25). Finally, the third stage consisting of the intelligence level assessment through the WISC-V is expected to take 90 minutes for students (student compensation: $18.75) and 150 minutes for administrators (administrator compensation: $31.25).

- ➢ There will be 44 fully eligible students who undergo and pass all three stages:
  - ○ [($35.42 for all 3 stages for students x 44 fully eligible students) + ($66.63 for all 3 stages for teacher administrators x 44 runs for teacher administrator) = $4,490.20].
- ➢ I also expect that some prospective students will go through some/all of the screening process, but will not meet all of the eligibility requirements.
  - ○ I will budget for five not passing the first stage:
    [($4.17 for stage 1 for students x 5 non-passing students) + ($10.38 for stage 1 for teacher administrators x 5 ineligible runs for teacher administrator) = $72.75]
  - ○ and 10 not passing the second or third stage:
    [($12.50 for stage 2 for students x 10 non-passing students) + ($25 for stage 2 for teacher administrators x 10 ineligible runs for teacher administrator) = $375]
    [($18.75 for stage 3 for students x 10 non-passing students) + ($31.25 for stage 3 for school psychologist administrators x 10 ineligible runs for school psychologist administrator = $500].

All of this would amount to a rough total of $5,537.95 needed for the student screening process.

Each student in this study will undergo a pre- and post-instruction assessment of set switching through the DCCS task. Each session is estimated to take 30 minutes to complete. With New York minimum wage, each student would receive a total of $12.50 for completing both the pre- and post-instruction set shifting assessments through this task, so a total of $550 will be needed for the compensation of students that undergo the pre- and post-instruction DCCS tasks ($12.50 for both pre- and post-assessment x 44 students).

Students in the bilingual education program will undergo two bilingual language checks through the EVIP and the WAT. The EVIP is expected to take 20 minutes for students and 30 minutes for teachers, and the WAT is expected to take 30 minutes for students and 40 minutes for teachers. With New York minimum wage, each student who undergoes the bilingual education program will receive a total of $10.42 for completing both of these tasks upon completion of the program. Teachers administering this task will receive a total of $14.58 for administering both of these tasks to one student. With 22 children in the bilingual education program, $550 will be needed to compensate students and teachers who undergo and administer the EVIP and WAT, respectively [($10.42 x 22 students) + ($14.58 x 22 runs for teacher administrators)].

All teachers will receive weekly compensation for their participation in the study at the end of every week during which school is in session.

- Main teachers:
  - According to the Bureau of Labor Statistics, full-time special education teachers in New York that teach in the kindergarten and elementary school setting earn an average of $78,710 annually as of May 2019 (*Special Education Teachers*, n.d.). All main teachers in the study will be compensated a total of $157,420 over the course of the two years of their participation in the study. This amount will be paid in weekly installments of approximately $3,279.58 during the weeks that school is in session (roughly 48 weeks total throughout the two years).
- Substitute teachers:
  - Substitute teachers will also receive a weekly compensation every week that school is in session. As of March 2021, the average special education substitute teacher's salary in New York was $50,789 (Salary.com, n.d.). All substitute teachers in the study will be compensated a total of $101,578 over the course of the two years of their participation in the study. This would result in weekly payments of approximately $2,116.21 during the weeks that school is in session (roughly 48 weeks total throughout the two years).

The total budget needed for the compensation of both main and substitute teachers over the course of this two-year longitudinal study would be $1,665,672 ($157,420 x 8 main teachers + $101,578 x 4 substitute teachers).

The cost of assessment materials would take up the remainder of the proposed budget. Including the cost of the CARS complete kit ($237), the CELF-5 kit ($716.50), the WISC-V complete kit ($1,350), and the EVIP kit ($265), the total cost of assessment materials would amount to approximately $2568.50.

Adding up all compensation and assessment material expenses, **the proposed budget amounts to a rough total of $1,674,878.45.**

Appendix G
Glossary of Terms

Additive program: A type of bilingual education that focuses on helping children acquire another language while also continuing to build their L1 skills.

Alternate program: A type of bilingual education program where the alternation between languages is signaled either by time or subject matter.

ASD: Autism spectrum disorder

Bilingual advantage hypothesis: Proposes that the regular processing of multiple languages is beneficial to many aspects of one's EF throughout their lifetime.

Bilingual education: An educational system that uses two languages to teach and assess students across many subjects.

CARS: The Childhood Autism Rating Scale. Assesses the presence and severity of ASD in children over two years of age.

CELF-5: The Clinical Evaluation of Language Fundamentals, 5th edition. A language battery that assesses language ability through both observational and interactive measures for children ages 5 to 21.

Coordinate bilingualism: A form of early bilingualism where a child acquires their two languages in separate contexts (e.g., different languages at home and school or different languages with each parent).

DCCS task: The Dimensional Change Card Sort Task

EF: Executive functioning

EVIP: The Échelle de Vocabulaire en Images Peabody. The French equivalent of the Peabody Picture Vocabulary Test (PPVT). A measure of French receptive vocabulary.

L1: Dominant language. Most often one's first language.

L2: Non-dominant language. Most often one's second language.

One-way bilingual education program: a bilingual education program in which children who all belong to one language group and have a common language background continue to develop their L1 abilities while simultaneously learning an additional language.

RT: Reaction Time

Set shifting: The ability to switch between mental processes. Used to change one's thoughts and behaviors to adapt to new environments and situations. Helps people tolerate changes and easily transition from one activity to another.

Switch cost difference score: The delay observed when switching from one rule to another on the DCCS task. Obtained by subtracting the mean RT of the last two trials of the pre-switch phase from the mean RT of the first two trials of the post-switch phase.

WAT: The Word Association Test. Used as a measure of bilingual proficiency.

WISC-V: The Wechsler Intelligence Scale for Children, 5th edition. Assesses the intellectual ability of children between the ages of 6 and 16.