BILINGUALISM MEETS AUTISM: EXECUTIVE FUNCTION & THEORY OF MIND

**Bilingualism meets Autism: Examining the relationship of executive function & theory**

**of mind**

By

DIANA SÁNCHEZ

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**Abstract**

Bilingualism and multilingualism have gained increased recognition for their cognitive and sociocultural advantages. Studies found that speaking more than one language can lead to enhanced cognitive functions. These cognitive processes are said to be prerequisites for Theory of Mind (ToM), the capacity to interpret the beliefs, intentions, and emotions of others. Most of the research in bilingual advantage has focused on neurotypical populations, resulting in research gaps concerning the experience by autistic individuals raised in additive multilingual environments. Research suggests that the constant need for autistic bilinguals to navigate and adapt to different linguistic contexts and perspectives throughout their interactions might translate into an augmented ability to consider diverse viewpoints and mental states, potentially contributing to improved executive function and theory of mind performance. This study aims to further explore whether bilingualism has a modulating effect on cognitive and theory of mind performance in autistic and non-autistic adults. To achieve this goal, the study will employ various measurement instruments, including the Language Experience and Proficiency Questionnaire (LEAP-Q) to assess language proficiency and experience, the Autism-Spectrum Quotient (AQ) to explore autism-related traits, and the Reynolds Adaptable Intelligence Test (RAIT) to gauge nonverbal performance. Cognitive performance will be assessed through the Flanker, N-Back, and the Backward tasks which measure inhibition, attention, flexibility and working memory. Theory of Mind performance will be measured by The Awareness of Social Inference Test (TASIT). This study aims to investigate the relationship between bilingualism, cognition, and theory of mind, with a particular focus on neurodivergent populations.

*Keywords:* bilingual advantage, neurotypical, neurodivergent, theory of mind (ToM) Flanker, Backward Corsi and N-Back tasks

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CHAPTER ONE: INTRODUCTION

Bilingualism and multilingualism have gained increasing recognition for their cognitive and sociocultural advantages, marking a shift from earlier notions that these practices might lead to cognitive impairment (Antoniou, 2019). Notably, Peal and Lambert’s research in 1962 provided early evidence of cognitive advantages associated with bilingualism, which subsequent studies have corroborated. Further studies revealed additional benefits which encompass professional opportunities and sociocultural benefits, such as maintaining strong family connections (Fox & Webb, 2019).

However, recent studies have challenged some of these advantages, suggesting that bilingualism alone may not significantly enhance cognitive skills, suggesting that these benefits may be context-dependent (Davis et al., 2022; Paap, 2019; Paap & Greenberg, 2013). Paap and colleagues (2015) argued that previous studies suggesting a bilingual advantage resulted directly from uncontrolled variables such as social economic status, language dominance, language use, sample size, culture differences, among others may have inflated the magnitude of observed cognitive advantages in earlier studies. However, it is commonly agreed that multilingualism evolves and is highly dependent on several variables that may be unique to each individual (Fox & Webb, 2019).

Despite ongoing debate concerning the cognitive consequences of bilingualism in neurotypical individuals, there is a growing body of evidence suggesting potential benefits for neurodivergent populations, including those with autism spectrum disorder (ASD) (Davis et al., 2021). Specifically, studies now highlight the advantages experienced by autistic individuals raised in additive multilingual environments. Studies have documented improved social relationships (Howard et al., 2019), increased access to hobbies and interests (Nolte et al., 2021), and enhanced self-understanding and empathy (Davis et al., 2021). Furthermore, cognitive benefits have been observed in areas such as sustained attention (Sharaan et al., 2010), task switching (Davis et al. 2022), and even theory of mind (Peristeri et al., 2021), a concept often associated with challenges in the autistic population (Demetriou et al., 2018; Fox & Webb, 2019; Livingston et al., 2019).

This intriguing finding aligns with the hypothesis that bilingualism may enhance cognitive flexibility in autistic populations (Gonzalez-Barrero & Nadig, 2017). The constant need of bilinguals to navigate and adapt to different linguistic contexts and perspectives throughout their interactions might translate into an augmented ability to consider diverse viewpoints and mental states, potentially contributing to improved theory of mind performance (Peristeri et al., 2021; Navarro & Conway, 2021).

Despite growing interest in the potential benefits of bilingualism for neurodivergent individuals, the precise relationship between bilingualism, cognitive performance, and theory of mind in the autistic population remains unclear. This study aims to address this gap by investigating how bilingualism modulates cognitive and theory of mind performance in autistic and non-autistic individuals. The findings from this study hold the potential to uncover valuable insights, shedding light on the advantages and challenges associated with bilingualism in the autistic population. Furthermore, these insights can offer practical and clinical implications for educational and treatment delivery models.

CHAPTER TWO: LITERATURE REVIEW

**Bilingual advantage hypothesis**

The bilingual advantage hypothesis states that individuals who speak more than one language exhibit superior executive function skills over monolinguals because they manage two languages (Bialystok, 2017; Paap, 2019). This advantage is attributed to the cognitive demands of managing and switching between two languages, leading to heightened cognitive control and flexibility (Paap, 2019; Samuel et al., 2018). According to the hypothesis, bilinguals engage in constant cross-linguistic activation the language process (Poarch & Krott, 2019) and as result activate and enhance cognitive control mechanisms. Some enhanced cognitive functions include working memory (Grundy & Timmer, 2017), attention and inhibition control (Karimi & Rad, 2021), and cognitive flexibility (Adi-Japha et al., 2010).

Studies, such as that conducted by Verreyt and colleagues (2015) have illustrated that balanced bilinguals who frequently switch between languages exhibit reduced congruency effects compared to unbalanced bilinguals or balanced non-switching bilinguals. The results suggested that the performance of the balanced bilinguals was better because they were activating and using both languages. Similarly, research by Costa and colleagues (2008) found that bilinguals performed at a faster rate and better on a cognitive task (Flanker) when congruent and incongruent performance was measured (Costa et al., 2008). Additional studies interested in exploring the bilingual advantage phenomena have looked at specific cognitive measurements. Ware and colleagues (2020) conducted a meta-analysis of 170 studies and found that the bilingual advantage was task dependent. Their results revealed that participants performed better on four of the seven tasks administered. Improved performance was observed on the Attentional Network, Stroop, Task-Switching Paradigms, and Card Sort tasks. Additional studies have expanded their research by examining differences between monolingual and bilingual brains.

Numerous studies have investigated alterations in brain structures potentially attributed to bilingualism. Such structural changes within the brain have been noted to include differences in grey and white matter and the frontal lobe (Li et al., 2013; Schlegel et al., 2012), suggesting the significant role of neuroplasticity. For instance, Stein and colleagues (2012) observed such changes in the left inferior frontal gyrus of foreign native English speaking students learning German in Switzerland. Following an intensive three-week language course, structural alterations were monitored and measured, with subsequent assessments conducted five months later. The findings indicated that these changes were associated with the acquisition of another language, underscoring the dynamic impact of language learning on brain structure.

**Interpreter advantage hypothesis**

The Interpreter Advantage Hypothesis presents an alternative perspective challenging the Bilingual Advantage Hypothesis (Garcia, 2014). This hypothesis proposes that prolonged engagement in specific activities, such as those performed by professional interpretation, fosters cognitive skill enhancement through domain-specific training. The hypothesis specifically suggests that cognitive and linguistic demands encountered by professional interpreters contribute to improved working memory, enhanced attentional control, and increased cognitive flexibility (García, 2014; Nour et al., 2020). Empirical research has substantiated this claim, revealing that interpreters outperform both bilingual non-interpreters and monolinguals in relevant cognitive tasks.

Henrard and Van Daele (2017) conducted a comparative study involving professional interpreters, translators, and monolinguals, revealing notable differences in performance across the groups. Specifically, interpreters exhibited superior cognitive performance compared to both translators and monolinguals, indicating that the cognitive demands associated with continual dual-language switching directly influenced their cognitive abilities within their professional domain. Similarly, Liu et al. (2004) investigated professional simultaneous interpreters and interpreter students at various stages of their training. Their findings demonstrated that experienced interpreters displayed enhanced cognitive performance across tasks. Additionally, Bajo et al. (2000) explored linguistic processing and reported that professional interpreters outperformed non-interpreter bilinguals, further supporting the notion of cognitive advantages associated with interpreter practice.

**Executive Function**

Executive functions (EF), also known as cognitive processing or cognitive control, are high level cognitive processes that underpin various aspects of behavior, learning adaptation, and independence in individuals. These processes come into play when individuals engage in activities such as planning a trip, using transportation, resisting temptations, multitasking, or switching between different tasks. These processes are believed to be supported by structures in the frontal lobe of the brain (Gilbert & Burgess, 2008) and are essential for daily functioning and success in various life domains, including academic achievement (Diamond, 2013; O’Connor, 2018).

Studies aiming to understand the executive function in bilingual and monolingual individuals often utilize cognitive tasks to assess these cognitive processes. While no single task can fully isolate and measure a specific executive function, behavioral measures derived from these tasks can provide valuable insights into an individual's cognitive performance. These cognitive processes and their respective measurements typically encompass three core executive functions (Diamond, 2013): inhibition (interference control, selective attention, cognitive inhibition), working memory, and cognitive flexibility (shifting).

***Inhibitory Control***

The first core of executive function is inhibitory control, refers to an individual's capacity to regulate attention, behavior, thoughts, or emotions to override strong distractions. It enables individuals to exercise choice in their behavior and reactions by suppressing irrelevant stimuli or impulses. Inhibitory control encompasses various aspects, including attentional control, which allows individuals to focus selectively while ignoring competing stimuli, and self-control, which involves resisting temptations and impulsivity (Diamond, 2013). Psychological measures commonly used to assess inhibitory control include the Stroop task, Simon task, Flanker task, antisaccade task, go/no-go tasks, and stop-signal tasks.

***Working Memory***

Another core of the executive function is working memory (WM), which involves temporarily holding information in mind and manipulating it for immediate use. Working memory can be divided into verbal and nonverbal (visual-spatial) components and plays a critical role in tasks requiring reasoning, problem-solving, and planning (Diamond, 2013). Psychological tasks that assess working memory can include activities that ask participants to reorder items. This can include asking participants to repeat the numbers (e.g., 18, 9, 3, 20) they just heard in a numerical order or repeat words (e.g., cat, elephant, bee, lion, dinosaur) in size order. Some of the widely used tasks include the visual-spatial Corsi Block test, Working Memory Assessment (AWMA) battery, Self-Ordered Pointing task, and the N-Back task.

***Cognitive Flexibility***

The final core of executive function is cognitive flexibility, which encompasses the ability to shift perspectives spatially (e.g., viewing things from different angles) or interpersonally (e.g., considering others' viewpoints). Cognitive flexibility involves inhibiting one's current perspective and activating working memory to adopt an alternative viewpoint, facilitating adaptive thinking and behavior (Diamond, 2013). It also includes changing how we think, the opposite of rigidity, rigid or fixed thinking (Petrolini et al., 2023). Psychological tasks commonly employed to study cognitive flexibility include the Wisconsin Card Sorting task, Dimensional Change Card Sort Test (DCCS), N-Back task, and the Flanker task.

In summary, executive function encompasses high-level cognitive processes crucial for behavior, learning, and adaptation. These processes, including inhibitory control, working memory, and cognitive flexibility, are supported by frontal lobe structures and are essential for daily functioning. Understanding executive function provides valuable insights into cognitive performance and its relationship to the bilingual advantage and neurodivergent status.

**Bilingualism and autism**

Recent studies discussed the benefits experienced by autistic individuals raised in additive multilingual environments. Research highlights enhancements in various domains, including improved social relationships (Howard et al., 2019), broader access to hobbies and interests (Nolte et al., 2021), and heightened self-understanding and empathy (Davis et al., 2021). Additionally, cognitive benefits have been noted, such as improved sustained attention (Sharaan et al., 2022), enhanced task-switching abilities (Davis et al., 2022), and bolstered theory of mind capacities (Peristeri et al., 2021), a concept often challenging for individuals on the autism spectrum (Demetriou et al., 2018; Fox & Webb, 2019; Livingston et al., 2019). These findings resonate with the notion that bilingualism may bolster cognitive flexibility in autistic populations (Gonzalez-Barrero & Nadig, 2017). The inherent demand for navigating diverse linguistic contexts and perspectives in bilingual interactions could potentially cultivate an enriched ability to comprehend varied viewpoints and mental states. Consequently, this may contribute to improved theory of mind performance (Peristeri et al., 2021; Navarro & Conway, 2021).

**Theory of Mind (ToM)**

Theory of Mind (ToM) refers to the capacity to comprehend the beliefs, knowledge, and intentions of others based on their behavior, enabling individuals to predict, interpret, and explain actions (Andreou et al., 2020; Navarro Garcia, 2021). This cognitive ability underpins various complex tasks, including communication, criticism, deception, irony, aggression, and problem-solving. While much research on ToM has focused on children, studies have revealed developmental milestones in ToM. For instance, children under three years old typically fail false-belief tasks, indicating that ToM is still developing at this stage, whereas four-year-olds tend to pass such tasks (Goetz, 2003; Naito et al., 2004).

Exploring ToM in bilingual individuals has uncovered intriguing findings. Bilingual children have shown superior performance in ToM tasks compared to their monolingual counterparts (Goetz, 2003; Greenberg et al., 2013), hinting at potential enhancements linked to bilingual experiences. Similarly, studies involving adults have demonstrated bilingual advantages in ToM-related tasks. For example, Rubio-Fernandez and Glucksber (2012) observed that bilingual college students exhibited fewer eye fixations than monolinguals during false-belief tasks. Additionally, Navarro and Conway (2021) found that bilingual adults outperformed monolinguals in tasks requiring perspective-taking abilities. These findings suggest that bilingualism may enhance individuals' capacity to consider others' perspectives.

Research indicates that ToM continues to develop gradually throughout the lifespan, becoming more refined in adulthood (Carpendale & Chandler, 1996; Dumontheil et al., 2010). Cultural factors have also been shown to influence ToM (Wu & Keysar, 2007). Deficits in ToM skills, reflected in difficulties in understanding others' perspectives, beliefs, intentions, and emotions, can impact social interactions and pragmatic skills (Brewer et al., 2017). ToM competency is closely linked to the development of social competence (Kovács, 2009). Furthermore, deficits in executive function have been associated with impaired ToM abilities, particularly in individuals with autism (Adesope et al., 2010; Carlson & Meltzoff, 2008; Solomon et al., 2009).

Performance of ToM among bilingual adults is underexplored and the present study aims to investigate the influence of bilingualism and neurodivergent status on executive function and Theory of Mind (ToM) performance. By conducting a comparative analysis involving both neurotypical and neurodivergent populations, the study seeks to expand current knowledge on the bilingual advantage hypothesis and its implications for cognitive processes. Specifically, the research will explore how bilingualism and neurodivergent status may moderate the relationship between executive function, ToM, and individual characteristics such as gender and IQ. Through a comprehensive examination of these factors, the study aims to provide valuable insights into the cognitive mechanisms underlying bilingualism and neurodivergence.

CHAPTER THREE: THE PRESENT STUDY

**Introduction**

Many studies have examined the bilingual advantage hypothesis by exploring the relationship of cognitive performance of monolingual and bilingual speakers (Verreyt et al., 2015). However, numerous studies have shown that an enhanced cognitive system may not be solely dependent on the acquisition and use of multiple languages (Paap 2014; Paap et al., 2015). Precisely studies like Antón and colleagues (2014) suggest that socioeconomic status, culture, and unique lifestyles could influence cognitive performance. Further, most of these studies have looked at neurotypical people (Bialystock, 2017; Costa et al., 2008; Samuel et al., 2018). However, there is a growing interest in the potential benefits of bilingualism for neurodivergent individuals, the precise relationship between bilingualism, cognitive performance, and theory of mind in the autistic population remains unclear and is an area that warrants further research. This study aims to address this gap by investigating how bilingualism modulates cognitive and theory of mind performance in autistic and non-autistic individuals. The findings from this study hold the potential to uncover valuable insights, shedding light on the advantages and challenges associated with bilingualism in the autistic population. Furthermore, these insights can offer practical and clinical implications for educational and treatment delivery models.

The proposed study aims to answer the following questions:

1. Do neurotypical or neurodivergent status, bilingualism, and/or IQ moderate executive function and ToM performance among adult participants?

Hypothesis 1: It is hypothesized that group status, bilingualism, and IQ will influence executive function and ToM performance. Specifically, it is expected that IQ and group status will moderate performance on cognitive tasks.

1. Does the degree of bilingualism (language use) as measure by the Language History Questionnaire (LHQ) influence executive function and ToM performance in neurotypical and neurodivergent populations?

Hypothesis 2: It is hypothesized that higher levels of language use will be associated with improved executive function and ToM performance across both neurotypical and neurodivergent groups. Conversely, lower language use may correlate with reduced cognitive and social-cognitive abilities.

1. Does gender moderate executive function and ToM performance in neurotypical and neurodivergent populations?

Hypothesis 3: It is hypothesized that gender will moderate the impact of neurodivergent status on executive function and ToM performance. This suggests that gender differences within groups may lead to variations in cognitive and social-cognitive abilities among neurodivergent individuals, possibly influencing their performance in specific domains.

**Methodology**

***Participants***

Prospective participants for this study must meet eligibility criteria. The study welcomes adults between the ages of 18 and 60. Eligible participants must possess proficiency in understanding, speaking, and reading in English. Participants who additional languages, other than English are highly encouraged to participate. Furthermore, individuals identifying as autistic are strongly encouraged to participate, given the focus on neurodivergent populations. Additionally, to uphold autonomy and independence in decision-making, all participants must be free of legal guardianship. This criterion ensures that participants have the capacity to provide informed consent and engage autonomously in the study procedures. By adhering to these eligibility criteria, the study aims to recruit a sample reflective of the targeted research objectives.

Studies investigating the bilingual advantage in adults have demonstrated variability in sample sizes, ranging from 45 participants (Olulade et al., 2016) to as high as 145 participants (Dong et al., 2016). Notably, the sample size is often reduced when participants are categorized into subgroups based on language proficiency, age, gender, or other factors. Similarly, research on multilingual autistic adults has shown a wide range of participant numbers, with some studies including 50 participants (Nolte et al., 2021) and others involving larger samples, such as 297 participants (Digard et al., 2020). In line with these considerations, the current study aims to recruit a total of 80 participants. This sample will comprise two main groups: 40 neurotypical participants and 40 neurodivergent participants. Each group will be further stratified into monolingual and bilingual subgroups to allow for comprehensive analysis of language effects on cognitive and social-cognitive performance.

***Recruitment***

To ensure a robust participant sample, recruitment efforts will employ a multifaceted approach. Flyers containing detailed information about the study (see Appendix A) will be disseminated within academic settings, including universities such as Rutgers, CUNY, Long Island University, and PACE. Additionally, outreach will extend to relevant organizations, including the American Speech-Hearing Association, Hispanic Caucus, Asian Pacific Islanders groups, Autism Speaks, and the World Autism Organization. Social media platforms will also be contacted. Furthermore, the investigator will directly liaise with these organizations to provide comprehensive information about the study and its significance within the field. This proactive engagement strategy will facilitate participant recruitment and enhance awareness of the research objectives. In recognition of the global reach of bilingualism and autism, efforts will be made to recruit participants both domestically and internationally. Leveraging online research platforms, such as Prolific, will enable the recruitment of participants from diverse geographical regions.

***Materials***

The materials of the proposed study will be divided into two phases. In the first phase, participants will engage with three questionnaires, accessible online. Subsequently, upon the completion of the first phase, participants will be prompted to schedule a virtual in-person meeting to complete the last three tasks of the study.

**Demographic Questionnaire.** The participants will be asked to complete an online demographic questionnaire (see Appendix B). This questionnaire is designed to gather essential information regarding participants' demographic characteristics, including age, gender, and education level. By collecting this data, the questionnaire aims to provide a comprehensive profile of the participants, facilitating a nuanced understanding of the sample composition and supporting the analysis of the study's findings. Some of the questions used on this questionnaire came from the Language Experience and Proficiency Questionnaire (Marian et al., 2007) and the Language History Questionnaire (Li et al., 2019). The demographic questionnaire will constitute Phase one of the study and will be accessible to participants without any time constraints. This approach allows participants to complete the questionnaire at their convenience, ensuring accurate and thorough responses.

**Language Questionnaire.** Participants will be asked to complete the Language History Questionnaire (LHQ3) online (see Appendix C). The LHQ-3 serves as a validated instrument for gathering self-reported data on language proficiency among bilingual and multilingual individuals. This questionnaire is instrumental in acquiring detailed insights into participants' linguistic backgrounds. Similar to the demographic questionnaire, the administration of the LHQ-3 will comprise Phase one of the study and will be accessible to participants without any time constraints.

**Neurodivergent Task.** Participants identifying as autistic individuals will complete the online autism spectrum quotient (AQ-10) questionnaire (see Appendix D). The AQ-10 was developed to provide a brief, self-reported measure of autistic traits for adults (Baron-Cohen et al., 2001). This questionnaire has been widely utilized to gauge autism-related characteristics and has demonstrated utility in identifying individuals who may benefit from further evaluation (National Institute for Health and Care Excellence, 2012) and has been used to examine autism traits in research and within clinical groups (Westwood et al., 2016). The AQ-10 questionnaire plays a pivotal role in Phase one of the study, offering valuable insights into participants' neurodivergent profiles and further supporting analyses and interpretations. Similar to the demographic and language proficiency questionnaires, the AQ-10 will be accessible to participants without any time restrictions.

**Intelligence Quotient.** Participants will complete the two subtests of the Fluid Intelligence Index, as depicted in Figure 1 and Figure 2. This index serves as a nonverbal reasoning intelligence task, assessing domains such as perceptual speech, working memory, abstract reasoning, and visuospatial reasoning (Tucker-Drob et al., 2022). The selection of the Fluid Intelligence Index is grounded in its capacity to evaluate cognitive abilities independent of acquired learning and accumulated knowledge. The chosen subtests, Sequences (SEQ) and Nonverbal Analogies (NVA), are components of Reynolds Adaptable Intelligence Test (RAIT) and will be completed during Phase two of the study and will be administered via a virtual in-person platform. These subtests have been specifically designed to mitigate the influence of variables such as education level, verbal comprehension, and cultural background (Checa & Fernández-Berrocal, 2015), ensuring the validity and reliability of the intelligence assessment across participant profiles.

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| --- | --- | --- | --- |
| **Figure 1**  *Sample question of the Sequences subtest* | | | |
|  |  | ? |  |
| A | B | C | D |
| *Note.* The figure presented is a replica of the subtest question of a published task (Reynolds, 2014) that cannot be replicated due to copyright restrictions. | | | |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Figure 2**  *Sample question of the Nonverbal Analogies subtest* | | | | | | |
| A close-up of a pencil  Description automatically generated with low confidence | : | Background pattern  Description automatically generated with low confidence | : | ? | : | Easel Art Painting Drawing - Easel Clipart PNG Image | Transparent PNG Free  Download on SeekPNG |
| Black contour paint brush icon Royalty Free Vector Image  A |  | A black and white drawing of a paint roller  Description automatically generated  B |  | A black background with a black square  Description automatically generated with medium confidence  C |  | Shape  Description automatically generated with low confidence  D |
| *Note.* The figure presented is a replica of the subtest question of a published task (Reynolds, 2014) that cannot be replicated due to copyright restrictions. | | | | | | |

**Social-Cognitive Task.** Participants will complete the Awareness of Social Inference Test-Short (TASIT-S). This task will be used to assess theory of mind (ToM), social cognition by using videos of naturalistic everyday conversations. The TASIT-S consists of three parts that measure one’s ability to recognize emotions in others and make inferences regarding their thoughts and intentions (McDonald, et al., 2018). This task is part of phase two and will be completed virtually in-person.

**Cognitive Tasks.** Participants will complete three executive cognitive tasks designed to assess various components of cognitive functioning, including inhibitory control, selective attention, attention control, cognitive flexibility, and working memory. Participants will complete the Flanker (see Figure 3), N-Back (see Figure 4), and Backward Corsi tasks (see Figure 5), which have been programmed utilizing the PsyToolkit software by Stoet (2010, 2017). The Flanker, N-Back, and Backward tasks represent established tasks for evaluating executive functions and have been selected based on their demonstrated efficacy in capturing key cognitive processes relevant to the study objectives. By incorporating these tasks into Phase 2 of the study, the investigator aims to obtain comprehensive insights into participants' cognitive abilities within a controlled and standardized testing environment. Participants will engage with these cognitive tasks virtually in-person, ensuring adherence to standardized administration procedures.

Here are demos for each task:

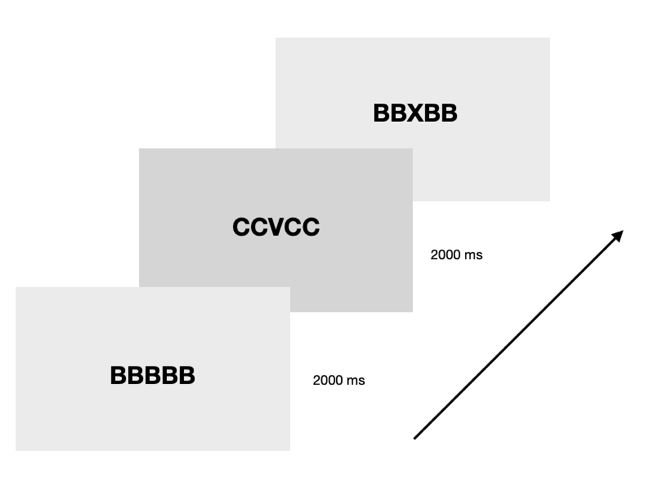
Flanker task: <https://www.psytoolkit.org/experiment-library/experiment_flanker.html>

N-Back task: https://www.psytoolkit.org/experiment-library/experiment\_nback2.html

Backward Corsi task: https://www.psytoolkit.org/experiment-library/experiment\_backward\_corsi.html

**Figure 3**

*Flanker task*



**Figure 4**

*N-Back task*

**A diagram of a graph

Description automatically generated with medium confidence**

**Figure 5**

*Backward Corsi task*

Diagram

Description automatically generated

**Analysis**

The results of this quantitative study will be analyzed in R, a language and environment for statistical computing (R Core Team, 2022). A multiple linear regression analysis will be used to examine the effects of several independent variables, including age, IQ, bilingual status, neurodivergent status on participants’ performance across social-cognitive (TAST-S) and cognitive tasks (Flanker, Backward Corsi, N-Back). To facilitate comparability and interpretability of results, the continuous variable of age will be standardized. Furthermore, the raw scores obtained from the Reynolds Adaptable Intelligence Test and the Awareness of Social Inference Test-Short will be standardized relative to their respective normative samples, enabling meaningful comparisons and insights into participants' performance profiles.

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APPENDIX

APPENDIX A: RESEARCH STUDY FLYER

A poster for a foreign language course

Description automatically generated

APPENDIX B: DEMOGRAPHIC QUESTIONNAIRE

1. Enter Participant ID or name.
2. What is your age in year?
3. What country do you live in?
4. What is your birth gender?
5. If you have ever immigrated to another country, please provide name of country and date of immigration here.
6. Please name the cultures (religious, ethnic, national, etc) with which you identify. (Examples of possible cultures include US-American, Chinese, Jewish-Orthodox, French, Indigenous, Polish, Korean, Christian, Muslim, Hindu, etc.)
7. How many years of formal education do you have?
8. Please check your highest education level (or the approximate equivalent to a degree obtained in another country):
9. What is your parent's highest level of education?
10. What is your current occupation (teacher, business owner, barista, retired, student, etc.)?
11. Do you identify as an autistic person?
12. Additional Comments can be inserted below.

APPENDIX C: LEAP-Q

A form with text and numbers

Description automatically generated with medium confidence

A white paper with black text

Description automatically generated

A group of people with a questionnaire

Description automatically generated with medium confidence

A white sheet of paper with text

Description automatically generated

APPENDIX D: AQ-10

Top of Form

1. I often notice small sounds when others do not.

1. Definitely Agree
2. Slightly Agree
3. Slightly Disagree
4. Definitely Disagree

2. When I’m reading a story, I find it difficult to work out the characters’ intentions.

1. Definitely Agree
2. Slightly Agree
3. Slightly Disagree
4. Definitely Disagree

3. I find it easy to "read between the lines" when someone is talking to me.

1. Definitely Agree
2. Slightly Agree
3. Slightly Disagree
4. Definitely Disagree

4. I usually concentrate more on the whole picture, rather than the small details.

1. Definitely Agree
2. Slightly Agree
3. Slightly Disagree
4. Definitely Disagree

5. I know how to tell if someone listening to me is getting bored.

1. Definitely Agree
2. Slightly Agree
3. Slightly Disagree
4. Definitely Disagree

6. I find it easy to do more than one thing at once.

1. Definitely Agree
2. Slightly Agree
3. Slightly Disagree
4. Definitely Disagree

7. I find it easy to work out what someone is thinking or feeling just by looking at their face.

1. Definitely Agree
2. Slightly Agree
3. Slightly Disagree
4. Definitely Disagree

8. If there is an interruption, I can switch back to what I was doing very quickly.

1. Definitely Agree
2. Slightly Agree
3. Slightly Disagree
4. Definitely Disagree

9. I like to collect information about categories of things.

1. Definitely Agree
2. Slightly Agree
3. Slightly Disagree
4. Definitely Disagree

10. I find it difficult to work out people’s intentions.

1. Definitely Agree
2. Slightly Agree
3. Slightly Disagree
4. Definitely Disagree

Bottom of Form