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## **The Impact of Bilingualism on the Executive Functions of Autistic Children: A Study of English-Arabic Children**

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**Lay Summary:** Contrary to widespread belief, but in line with previous research, this study showed that speaking two languages did not harm thinking skills in autistic children. The thinking skills evaluated in this study included the ability to focus over a period of time, the ability to resist distractions, the ability to move back and forth between tasks, and the ability to use short-term memory. In fact, speaking two languages might help reduce difficulties that autistic children might face when focusing over a period of time.

**Abstract:** There is evidence to suggest that certain executive functions are impaired in autistic children, contributing to many daily challenges. Regular use of two languages has the

potential to positively influence executive functions, though evidence is mixed. Little is known about the impact of bilingualism on the executive functions of autistic children, with only a handful of studies published worldwide to date. This study investigated the impact of bilingualism on sustained attention, interference control, flexible switching and working memory, in Arabic-English autistic children ( $n = 27$ ) and their typically developing peers ( $n = 66$ ), aged 5 to 12 years old. Groups were matched on age, non-verbal IQ and socioeconomic status, and completed a battery of computerized tests. Results showed an advantage for bilingual autistic children relative to their monolingual peers in sustained attention, and equivalent performance between bilingual and monolingual autistic children on all other executive functions. There were no generalized positive effects of bilingualism, and typically-developing children performed better than autistic children on all measures. The findings indicate that bilingualism does not negatively impact the executive function skills of autistic children, and that it might mitigate difficulties in sustained attention.

**Keywords:** Dual Language, Second Language Exposure, Autism, Cognition

## **Introduction**

Executive functions abilities play a significant role in various educational (Allan, Hume, Allan, Farrington, & Lonigan, 2014; Dekker, Ziermans, Spruijt, & Swaab, 2017) and social outcomes (Hughes, White, Sharpen, & Dunn, 2000; Murphy, Shepard, Eisenberg, & Fabes, 2004) for typically developing children, also having a broader impact on quality of life (Tangney, Baumeister, & Boone, 2004). There is evidence to suggest that executive function (EF) skills are impaired in autistic children (Demetriou et al., 2017; Lai et al., 2017), though the profile of EF in autism is characterized by significant heterogeneity (Geurts, Sinzig,

Booth, & Happé, 2014; Pellicano, 2010). Executive functions have been proposed to make a pivotal contribution to key features of autism such as repetitive behaviors (Mostert-Kerckhoffs, Staal, Houben, & Jonge, 2015). They may also influence communication and social interaction challenges (Leung, Vogan, Powell, Anagnostou, & Taylor, 2016) and have a negative impact on quality of life (Vries & Geurts, 2015). Therefore, there is clear evidence of individual differences between autistic individuals in their EF profiles, but the factors that influence EF development and outcomes in autism are still poorly understood (Demetriou et al., 2017). One candidate factor could be bilingual exposure.

Bilingualism is a skill shared by more than half of the world's population (Grosjean, 2010). A range of markers of bilingualism have been related to enhanced EF development in typically developing children, including earlier age of acquisition of languages (Kapa & Colombo, 2013), higher proficiency in languages (Niharika & Ramesh Kumar, 2013), and frequency of switching between languages (Prior & Gollan, 2011). The impact of bilingualism on EFs in typically developing children remains hotly debated, with evidence for (Barac, Bialystok, Castro, & Sanchez, 2014; Bialystok, 2001) and against (de Bruin, Treccani, & Della Sala, 2015; Dick et al., 2019; Paap & Greenberg, 2013) a bilingual advantage. A full account of the complexities and challenges within the existing literature are beyond the scope of this paper, but see Paap and Greenberg (2013) and de Bruin, Treccani, and Della Sala (2015) for important discussions of the relevant issues.

A prominent explanatory framework for the theoretical relationship between bilingualism and EF is the adaptive control hypothesis (Green & Abutalebi, 2013). This model argues that language context is a key determinant of the impact of bilingualism on EF. In a single language context, one language is spoken in one environment while the other language is

spoken in another distinct environment (e.g., English at school and Arabic at home). No switching between the two languages is required. In a dual language context, both languages are spoken within the same environment, resulting in frequent switching. In a dense-switching language context, speakers alternate between the two languages within single statements, or adapt words from one language to integrate with another. The adaptive control hypothesis claims that a dual-language context places the highest demand on the EF skills of sustained attention, inhibitory control, and switching relative to other contexts.

In support of this, there is evidence from typically developing children that the frequency with which early bilinguals (defined as those who start to use their L2 before the age of 7; Lenneberg, 1967) switch between their languages on a daily basis is a significant predictor of flexible switching error rates on a number-letter task (Soveri, Rodriguez-Fornells, & Laine, 2011). It has also been demonstrated that early bilinguals who reported frequently switching between their languages had a task switching advantage on a color-shape task, while bilinguals who reported less frequent language switching performed equivalently, compared with monolingual peers (Prior & Gollan, 2011). Likewise, there is evidence of an association between interference control skills (e.g., the Flanker task) and language switching abilities in balanced bilinguals (Verreyt, Woumans, Vandelandotte, Szmalec, & Duyck, 2016). These findings support the theoretical relationship between language switching and key EF domains in bilingual individuals.

Disadvantages in EF domains for bilingual typically developing (Dick et al., 2019) and bilingual autistic (Gonzalez-Barrero & Nadig, 2017) children are very rarely in evidence. Despite this, parents (Hampton, Rabagliati, Sorace, & Fletcher-Watson, 2017) and practitioners (Moore & Pérez-Méndez, 2006) have concerns about raising autistic children

speaking more than one language. Such deficit views of bilingualism may negatively impact autistic children's linguistic, social and cultural development (Uljarević, Katsos, Hudry, & Gibson, 2016; Yu, 2013). Moreover, there is a small but growing body of evidence showing that bilingualism does not have a detrimental impact on language outcomes for autistic children (Hambly & Fombonne, 2012; Uljarević et al., 2016).

In the EF domain, evidence remains sparse, but one study found no differences between autistic children who were exposed to a second language or not, on parent-reported EF outcomes (assessing problem solving, attentional control, behavioral control and emotional control) (Iarocci, Hutchison, & O'Toole, 2017). However, in this study, despite this lack of statistical differences in mean EF ratings between the language exposure groups, autistic children who had been exposed to a second language were less likely to have EF ratings in the clinically significant range of concern. In another study, autistic children exposed to a second language > 10% of the time had reduced parent-reported difficulties compared with autistic monolinguals on inhibitory self-control and flexible switching (Ratto, Potvin, Pallathra, Saldana, & Kenworthy, 2020).

Using directly-assessed measures of EF, one study reported bilingual autistic children performed similarly to their monolingual peers on EF outcomes using three tasks assessing inhibitory control (Stroop task, Simon task, Go/No-Go) and one task assessing flexible switching (Wisconsin Card Sorting Task) (Li, Oi, Gondo, & Matsui, 2017). Two studies found tentative evidence of a bilingual advantage for autistic children relative to their monolingual peers using direct tasks assessing inhibitory control (Li et al., 2017) and flexible switching (Gonzalez-Barrero & Nadig, 2017) domains. However, in each case, only a single variable revealed a bilingual advantage out of two candidate outcome variables, so it is

unclear whether these effects are robust. Furthermore, in the latter study, when using a parent report measure, there were no significant differences between bilingual and monolingual autistic children on flexible switching scores.

Combined, these quantitative studies in the language and EF domain support the idea that bilingualism is not detrimental to autistic children's development. In addition, there is qualitative evidence that bilingual autistic children educated in multilingual environments view bilingualism as an enriching aspect of their identities and linguistic repertoires (Howard, Katsos, & Gibson, 2019).

The current study investigates the impact of bilingualism on EF skills, focusing on domains relevant to the adaptive control hypothesis – sustained attention, flexible switching, and interference control – but also measuring working memory as an active control condition which is not hypothesized to be influenced by bilingual exposure. The study takes place in a dual-language environment (United Arab Emirates), presenting an ideal opportunity to examine the predictions of the Adaptive Control Hypothesis. According to this model, a dual-language context is most likely to result in advantages for the aforementioned EF domains. Therefore, the current work tests this hypothesis in relation to Arabic-English bilinguals.

The United Arab Emirate's leading language is Arabic and it is one of the world's top five most spoken languages, having over 240 million native speakers (Adams & Fleck, 2015). English is widely accepted as the lingua franca as an estimated 90% of the population is migrant (non-nationals) (De Bel-Air, 2015). In addition to the dual Arabic-English language context, a triglossic context exists with three different varieties or dialects of spoken Arabic; Classical Arabic (i.e., Arabic used in the Quran and literary works), Modern Standard Arabic



(i.e., Arabic used in formal communications), and Colloquial Arabic (i.e., Arabic used in dialects and everyday language) (Sabbah, 2015). In his investigation of language in education in the United Arab Emirates, Al Sharhan (2007) illustrated that Emirati children are required to develop all three varieties as part of their education.

Therefore, based on the theoretical model under investigation, we pose the following question: what is the impact of bilingualism on the EF domains most relevant to a dual-language context, in a group of school-aged autistic children? We hypothesize the following: First, we predict that bilingual children will outperform monolingual children on measures of flexible switching, sustained attention and interference control. We predict no influence of bilingualism on working memory. In addition, we will explore interactions between diagnostic status and bilingualism in their effect on EF scores, but based on the current literature, make no firm predictions about EF performance between autistic bilinguals and typically developing bilinguals.

## **Methods**

### *Participants*

Ninety-three children aged between 5 and 12 years were recruited into the study ( $M = 9.16$  years,  $SD = 1.98$  years). Monolingual children spoke either English ( $n = 39$ ) or Arabic ( $n = 3$ ), and bilingual children spoke both English and Arabic. All bilinguals spent significant amounts of time in dual-language switching environments, where both Arabic and English were actively used within one context (i.e., school / educational context, and sometimes also the home context) but with different individuals.

The inclusion criterion for autistic children was a formal diagnosis of autism based on DSM-IV or DSM-V criteria, confirmed by the referring organizations (e.g., autism center) or by a parent. Non-verbal IQ and language screening tools were administered to further determine eligibility and language status. All children had a non-verbal IQ score of ‘intellectually average’ or above, as screened by the Raven’s Colored Progressive Matrices (CPM) (Raven & Court, 1998b). There were no uncorrected visual deficits, hearing deficits, cognitive disabilities and co-morbidities (e.g., ADHD). Language status (bilingual or monolingual) was screened based on a combination of parent language report and direct expressive and receptive vocabulary measures. The Child Language Experience and Proficiency Questionnaire (Marian, Blumenfeld, & Kaushanskaya, 2007) (collecting language history, current exposure, current use and proficiency data) was administered to parents, in either Arabic or English. Expressive vocabulary was measured with the Picture Naming Test (Kharkhurin, 2008) in Arabic and/or English. Receptive vocabulary was measured with the Peabody Picture Vocabulary Test, 4<sup>th</sup> ed. in English (Dunn & Dunn, 2007) and the Arabic Picture Vocabulary Test (Shaalán, 2010) in Arabic.

Determination of a child’s bilingual status was based on a combination of the following indicators: (a) > 20% of current exposure to each of the two languages at home or school, according to parent report, (b) > 20% of current active speaking in each of the two languages at home or school, according to parent report, (c) > 20% proficiency score (24 correct responses out of a possible total of 120) in each of the two languages according to the Picture Naming Test, rated by the researcher. raw

Language proficiency was assessed based on the accuracy of participants’ written responses to the objects in the Picture Naming Test. Determination of a child’s monolingual status was

based on a combination of the following indicators: (a) had not been exposed to a language other than Arabic (or English if their first language was English) for more than 20% of their lifetime, (b) if exposed to a second language, < 20% of current active speaking at home or school, according to parent report, (c) if exposed to a second language, < 20% proficiency score according to the Picture Naming Test, rated by the researcher.

Ethical approvals were obtained from the University of Edinburgh (School of Philosophy, Psychology and Language Sciences, Application 102-1718/2), the Abu Dhabi Department of Education and Knowledge, and the UAE Ministry of Community Development. All parents and participants gave informed consent.

Details of participant characteristics are presented in Table 1. A series of one-way analysis of variance (ANOVA) confirmed no significant differences between the monolingual and bilingual autistic and typically developing (TD) groups on the following six characteristics: chronological age ( $p = 0.486$ ); non-verbal IQ ( $p = 0.454$ ); maternal education level ( $p = 0.140$ ); maternal continuous years of education ( $p = 0.663$ ); paternal education level ( $p = 0.095$ ); and paternal continuous years of education ( $p = 0.230$ ).

*-Insert Table 1-*

### *Materials*

Explicit, computerized measures of EF were selected to capture each EF domain of theoretical interest. We selected tasks that minimize cross-talk between underpinning domains (e.g., flexible switching tasks with minimal working memory demands).

*Flexible Switching.* A computerized dimensional change card sorting task (DCCS task) (Diamond, Carlson, & Beck, 2005) was administered. In the pre-switch phase, participants sort images based on their color (indicated by a rainbow cue at the top of the screen), with 5 out of 6 correct trials needed to pass. In the post-switch phase, participants sort images based on their shape (indicated by a shape cue at the top of the screen), with 5 out of 6 correct trials needed to pass. Finally, in the mixed condition color-shape game, participants sort images based on either shape or color (indicated by a rainbow or shape cue at the top of the screen), with 9 out of 12 correct trials needed to pass. For each trial, an image appears in the middle of the screen and participants sort the image by dragging it to a red truck or blue star (e.g., in color trials, a blue image should be dragged to the blue star). Participants complete 14 practice trials with feedback and must answer correctly at least 4 trials to move on to the experimental trials. Outcome variables include accuracy, switch costs (i.e., the mean reaction time of the first two trials from the post-switch phase minus the mean reaction time of the last two trials from the pre-switch phase), as well as mean RTs in the pre-switch, post-switch, and mixed trials condition. The DCCS is reported to have good re-test reliability (Beck, Schaefer, Pang, & Carlson, 2011).

*Interference Control.* In the Simon Task (di Pellegrino, Ciaramelli, & Làadavas, 2007; Simon, 1969), participants are required to respond as quickly and as accurately as possible to a red or blue square presented on the computer screen by pressing the left button for blue squares and the right button for red squares, regardless of the square's position. For congruent trials, the position of the square and the response button match (e.g., a red square presented on the right) and for incongruent trials, the position of the square and the response button do not match (e.g., a blue square presented on the right). The task consists of 10 practice trials with feedback and 56 experimental trials without feedback. The main outcome

measures are the mean congruent RT, the mean incongruent RT, and the Simon interference effect (i.e., mean incongruent RT / mean congruent RT). The Simon task is reported to have good re-test reliability (Wostmann et al., 2013).

*Sustained Attention.* In the Psychomotor Vigilance Task (PVT) (Lara, Madrid, & Correa, 2014), participants are asked to press the space bar as soon as a black circle starts to fill in red in a clockwise direction. Once participants respond, their RT is displayed on the computer screen. If a response is made too soon (i.e., pressing before the red starts to appear) or a response is not made (i.e., the entire circle is filled in red), feedback is given stating “too quick” or “too slow”. Participants perform 5 practice trials and then 88 experimental trials. Outcome measures include mean RT and the number of false starts (RT <100 ms). The PVT is reported to have high re-test reliability (Wilson, Dollman, Lushington, & Olds, 2010).

*Working Memory.* Object and abstract picture versions of the computerized Self-Ordered Pointing Task (SOPT) (Cragg & Nation, 2007; MacPherson, Phillips, & Della Sala, 2002) were administered. The SOPT assesses the ability to arrange, perform, and monitor a sequence of responses. In both versions, participants are presented with an array of black and white pictures of objects or abstract pictures. Participants are repeatedly presented with the array and instructed to choose one of the items in the array by touching the screen, each time choosing an item that has not been previously selected. Therefore, participants have to monitor their previous choices while they prepare each new response. The position of the items changes across presentations. Participants perform 3 trials containing 4 pictures each (i.e., practice trials), followed by 3 trials containing 6 pictures each, then 3 trials containing 8 pictures each, and finally, 3 trials containing 10 pictures each. For each trial, the array is presented the same number of times as the set size (e.g., for a trial with 10 pictures, the array

is presented 10 items). The outcome variables are SOPT mean errors for each set size. The SOPT is reported to have very good re-test reliability for total errors (Ross, Hanouskova, Giarla, Calhoun, & Tucker, 2007).

### *Procedure*

Participants were recruited with the cooperation of 22 institutions (e.g., autism centers), across three Emirates (Abu Dhabi, Dubai, Sharjah) between March 2018 and April 2019. Recruitment calls were circulated via schools, centers, research mailing lists, social media, and autism-related conferences and workshops. Participants were assessed individually over 1-3 sessions, depending on the participant. For bilinguals, tasks were administered according to each child's communicated language preference / dominance (English / Arabic). For the large majority of bilinguals, that language was English.

Raven's Colored Progressive Matrices was always administered first to screen for non-verbal IQ (i.e., only children with a score of 'intellectually average' and above were eligible for participation). The computerized tasks were not administered in any particular order as participants varied in their motivations, preferences and moods. Every attempt was made to administer the flexible switching task first, as it is more engaging, and makes participants feel relaxed and comfortable, followed by the interference control and working memory tasks, ending with the sustained attention tasks. Language screening assessments were administered either before or after the computerized tasks, depending on the participant. Determination of language status (bilingual or monolingual) took place after the research session completion, upon securing both parent and direct ratings of language and calculating respective scores.

## Results

Statistical analyses were performed in SPSS (24). The data were screened to ascertain if they were normally distributed and log10 transformations were applied if the data were skewed. For our continuous outcome variables, two-way analysis of variance (ANOVA) were conducted with diagnostic group (Autistic, TD) and language group (monolingual, bilingual) as between-subject factors. For our categorical variables, Fisher's exact tests were run, first examining diagnostic group effects, and then examining bilingualism. In cases where the assumption of normality was not met after the data were transformed, we used non-parametric Mann Whitney tests. The p-value was Bonferroni adjusted to avoid Type 1 errors (0.05 / the number of outcome variables per EF task). The adjusted alpha level for significance is presented for each outcome variable. Means and standard deviations on all EF outcomes are provided in Table 2.

*-Insert Table 2-*

### *Flexible Switching*

*DCCS Accuracy / Passing.* Across all four groups, 86% to 100% of participants passed the pre-switch phase (5 out of 6 correct trials), 75% to 97% of participants passed the post-switch phase (5 out of 6 correct trials), and 60% to 100% of participants passed the mixed condition phase (9 correct trials out of 12) – see Figure 1a. The pre- and post-switch data were not analyzed given the ceiling effects observed (Diamond & Kirkham, 2005).

The alpha level for significance was set at  $p < 0.050$ . For the mixed condition, a Fisher's exact test for analysis of dichotomous outcomes revealed a significant effect of diagnostic group, where the number of autistic participants that passed was significantly lower than the number of TD participants, but only in the bilingual group,  $p = .000$ . The monolingual autistic and monolingual TD groups did not differ significantly,  $p = .121$ . A second Fisher's exact test revealed the effect of language group was also not significant in both the autistic groups ( $p = .400$ ) and the TD groups ( $p = 1.000$ ).

*DCCS Switch Cost.* The alpha level for significance was set at  $p < 0.025$ . A 2 (diagnostic group) x 2 (language group) ANOVA on switching cost (RT) revealed that the main effect of diagnostic group was not significant,  $F(3, 81) = 4.43, p = .038, \eta_p^2 = .05$  (see Figure 1b). Similarly, neither the main effect of language group,  $F(3, 81) = .20, p = .648, \eta_p^2 = .00$ , nor the interaction between diagnostic group and language group,  $F(3, 81) = 2.81, p = .097, \eta_p^2 = .03$ , were significant.

*DCCS Mean RT Mixed Condition.* The alpha level for significance was set at  $p < 0.025$ . For the mixed condition, only correct trials and trials with  $RT > 200$  ms were considered (Diamond & Kirkham, 2005). For the autistic participants, 15% of trials were excluded and for the TD participants, 13% of trials were excluded. A 2 (diagnostic group) x 2 (language group) ANOVA revealed a significant main effect of diagnostic group,  $F(3, 81) = 7.09, p = .009, \eta_p^2 = .08$  where the TD participants were faster (lower RT scores) than the autistic participants (see Figure 1c). However, the main effect of language group was not significant,  $F(3, 81) = .00, p = .940, \eta_p^2 = .00$ . Finally, the interaction between diagnostic group and language group was not significant,  $F(3, 81) = .44, p = .506, \eta_p^2 = .00$ .



-Insert Figure 1-

### *Sustained Attention*

Only trials  $\geq$  to 100 ms and  $\leq$  1000 ms were included in the RT analysis. Trials below 100 ms were considered false starts (responses based on anticipation rather than stimulus display) and trials greater than 1000 ms were considered lapses (missed responses) (Lara et al., 2014). For autistic participants, 16% of trials were excluded and for the TD participants, 13% of trials were excluded.

*PVT Mean RTs.* The alpha level for significance was set at  $p < 0.025$ . A 2 (diagnostic group) x 2 (language group) ANOVA revealed a significant main effect of diagnostic group,  $F(3, 84) = 9.97, p = .002, \eta_p^2 = .10$  where TD participants were significantly faster than autistic participants (see Figure 2a). There was no significant main effect of language group,  $F(3, 84) = .41, p = .523, \eta_p^2 = .00$  or interaction between language group and diagnostic group,  $F(3, 84) = .17, p = .677, \eta_p^2 = .00$ .

*PVT false starts.* The alpha level for significance was set at  $p < 0.025$ . A 2 (diagnostic group) x 2 (language group) ANOVA revealed no significant main effect of language group,  $F(3, 84) = 2.57, p = .113, \eta_p^2 = .03$  or a significant main effect of diagnostic group,  $F(3, 84) = .02, p = .88, \eta_p^2 = .00$  (see Figure 2b). There was, however, a significant interaction between language group and diagnostic group,  $F(3, 84) = 6.62, p = .012, \eta_p^2 = .07$ . Post-hoc independent samples t-tests revealed autistic bilinguals had significantly lower mean false starts than autistic monolinguals,  $t(21) = 3.503, p = .002$ .

-Insert Figure 2-

### *Interference Control*

*Congruent RTs.* Only correct trials and RTs > 200 ms and < 2000 ms (di Pellegrino et al., 2007) and were included in the analysis. 16% of the autistic participants' data and 13% of the TD participants' data were excluded. The alpha level for significance was set at  $p < 0.016$ . A 2 (diagnostic group) x 2 (language group) ANOVA demonstrated no significant main effect of diagnostic group,  $F(3, 83) = 5.73, p = .019, \eta_p^2 = .06$  (see Figure 3a). Similarly, there was no significant main effect of language group,  $F(3, 83) = .05, p = .814, \eta_p^2 = .00$ , nor interaction between language group and diagnostic group,  $F(3, 83) = .20, p = .656, \eta_p^2 = .00$ .

*Incongruent RTs.* Only correct trials and trials with RTs > 200 ms and < 2000 ms were included in the RT analysis. For autistic participants, 20% of trials were excluded and for the TD participants, 17% of trials were excluded. The alpha level for significance was set at  $p < 0.016$ . A 2 (diagnostic group) x 2 (language group) ANOVA revealed a significant main effect of diagnostic group,  $F(3, 83) = 10.05, p = .002, \eta_p^2 = .10$ , where the autistic participants were significantly slower on incongruent trials compared to the TD participants (see Figure 3b). However, there was no significant main effect of language group,  $F(3, 83) = .01, p = .917, \eta_p^2 = .00$ , or an interaction between language group and diagnostic group,  $F(3, 83) = .943, p = .334, \eta_p^2 = .01$ .

*Interference effect.* The alpha level for significance was set at  $p < 0.016$ . A Mann-Whitney Test revealed no significant main effect of language group,  $U = 782, p = .189, \eta^2 = .01$  or diagnostic group,  $U = 574, p = .169, \eta^2 = .02$  (see Figure 3c).

-Insert Figure 3-

*Working Memory: Object and Abstract Versions*

The alpha level for significance was set at  $p < 0.05$ . Separate 2 (diagnostic group) x 2 (language group) ANOVA was run on each condition and revealed a significant main effect of diagnostic group, where the autistic participants made significantly more errors than the TD group on all items (see Figure 4) on: (a) Object version 6-items,  $F(3, 83) = 8.83, p = .004, \eta_p^2 = .09$ ; (b) Object version 8-items,  $F(3, 83) = 4.58, p = .035, \eta_p^2 = .05$ ; (c) Object version 10-items,  $F(3, 83) = 9.40, p = .003, \eta_p^2 = .10$ ; (d) Abstract version 6-items,  $F(3, 84) = 6.87, p = .010, \eta_p^2 = .07$ ; (e) Abstract version 8-items,  $F(3, 84) = 6.61, p = .012, \eta_p^2 = .07$ ; (f) Abstract version 10-items,  $F(3, 84) = 4.57, p = .035, \eta_p^2 = .05$ .

There was no significant main effect of language group on any condition (see Figure 4): (a) Object version 6-items,  $F(3, 83) = .25, p = .618, \eta_p^2 = .00$ ; (b) Object version 8-items,  $F(3, 83) = 2.74, p = .101, \eta_p^2 = .03$ ; (c) Object version 10-items,  $F(3, 83) = .80, p = .372, \eta_p^2 = .01$ ; (d) Abstract version 6-items,  $F(3, 84) = .05, p = .814, \eta_p^2 = .00$ ; (e) Abstract version 8-items,  $F(3, 84) = .43, p = .514, \eta_p^2 = .00$ ; (f) Abstract version 10-items,  $F(3, 84) = 1.03, p = .313, \eta_p^2 = .01$ .

Similarly, there was no significant interaction between language group and diagnostic group on any condition (see Figure 4): (a) Object version 6-items,  $F(3, 83) = .01, p = .905, \eta_p^2 = .00$ ; (b) Object version 8-items,  $F(3, 83) = 2.14, p = .147, \eta_p^2 = .02$ ; (c) Object version 10-items,  $F(3, 83) = .01, p = .916, \eta_p^2 = .00$ ; (d) Abstract version 6-items,  $F(3, 84) = 0.97, p = .327, \eta_p^2 = .01$ ; (e) Abstract version 8-items,  $F(3, 84) = .05, p = .812, \eta_p^2 = .00$ ; (f) Abstract version 10-items,  $F(3, 84) = .35, p = .555, \eta_p^2 = .00$ .

*-Insert Figure 4-*

## **Discussion**

The current study investigated the impact of bilingualism in autistic and TD children, on a specific set of EF skills, namely interference control, flexible switching, sustained attention and working memory. All data were collected in the United Arab Emirates. To our knowledge, this is the first investigation to (a) include Arabic-speaking children and (b) take place in the Arab world / Arab states. Working in this setting provides a valuable opportunity to diversify autism research samples, given that the vast majority of psychological research has been drawn from WEIRD (western, educated, industrial, rich, and democratic) samples (Henrich, Heine, & Norenzayan, 2010; Nielsen, Haun, Kärtner, & Legare, 2017).

The adaptive control hypothesis suggests that the EF domains of interference control, sustained attention and flexible switching - should be subject to a positive impact of bilingualism, for this sample from a dual-language context. We also included an assessment of working memory, which is not hypothesized to be influenced by bilingualism, as an active EF control task. We found no support for the adaptive control hypothesis. Across a range of reaction time and accuracy variables, no main effects of language group were detected. Specifically, in the typically-developing sample, bilingualism had no discernable effect on EF, in line with some other reports (Gonzalez-Barrero & Nadig, 2017; Paap & Greenberg, 2013). We did, however, find consistent effects of diagnostic group, such that autistic children made more errors and were slower to respond in nearly every outcome variable assessed. The presence of this pattern indicates that despite the modest sample size, we did have adequate power to detect effects of interest in all tasks. Our data yielded one instance of

an interaction between language group and diagnostic status. In sustained attention, our autistic bilingual participants out-performed their monolingual peers, and even typically developing peers (both bilingual and monolingual) by making significantly fewer false starts. This finding might suggest less impulsivity or perhaps greater patience with the task within the autistic bilingual group.

There are some limitations that must be addressed. First, while we made every effort to maximize our sample size via nation-wide collaborations (participants were recruited from 20+ institutions located in three cities), we acknowledge that our monolingual autistic sample is small compared to the other groups. As this can result in a loss of power, we followed Maxwell and Delaney's (2003) recommendation to use Type III sums of squares which is robust to variable sizes of groups being compared. Second, although selected with autistic participants in mind (e.g., computerized, explicit), the EF measures used in the current work lack validity and reliability information for use with autistic samples. Third, we were reliant on a single EF measure per domain, in an effort to reduce assessment demands on participants. Future research would benefit from the inclusion of multiple direct measures to assess each EF domain. For example, the sustained attention task revealed a bilingual advantage for autistic children, and had a large number of trials. It is possible that the relatively small number of trials on the flexible switching mixed condition might have masked potential effects of bilingualism.

Finally, it must be acknowledged that the UAE as a nation is a multilingual environment. All of the children in this study, including monolinguals, are exposed to a second language in their community. However, this concern is ameliorated by some key factors. Our monolingual children were below threshold on our robust proficiency criteria, drawn from

monolingual homes and taught / instructed in one language at school, meaning that the impact of the wider cultural context was significantly diluted. Ultimately, our results should be interpreted as relevant to bilingual language use and proficiency, rather than mere passive exposure.

Although novel, the finding of a bilingual advantage for autistic children in this sustained attention outcome variable should be taken as preliminary evidence and interpreted with caution, given the lack of a bilingual advantage for autistic children in other outcome variables of sustained attention (i.e., reaction times). In addition, we detected no bilingual advantage for TD children across all outcome variables from the sustained attention task. A replication with a larger but similarly well-characterized sample and ideally with multiple measures of sustained attention would be a useful next step. In flexible switching, the TD bilinguals showed greater accuracy than autistic bilinguals, but there were no differences between the monolingual groups in this case. Visualization of the data suggests this result was driven by very poor performance of the autistic bilingual group on this task. Our finding of no TD bilingual advantage on any EF outcome variable was echoed by other studies investigating bilingualism in childhood autism, using similar measures and bilingualism categorization (Gonzalez-Barrero & Nadig, 2017).

We did not find evidence of widespread executive function advantages associated with being bilingual in our sample. Since autistic children generally struggle with executive function tasks like those in our study, there is substantial room for improvement in executive domains. This might make it easier to detect bilingual advantages in an autistic than a TD sample, and so it is striking that we did not on the whole find bilingual advantages. On the other hand, our data also make it clear that bilingualism does not result in a disadvantage for autistic children.

Despite concerns from parents and practitioners, we found no evidence that autistic children's executive function abilities are detrimentally affected by learning and using two languages.

The investigation of bilingualism in matched autistic and TD groups, recruited in a dual-language switching environment has a number of strengths. We captured a range of EF components relevant to the adaptive control hypothesis, and used a rigorous procedure to determine bilingual and monolingual status. Our sample, while modest, was well matched on age, multiple components of socio-economic status, and non-verbal IQ. It is unsurprising that across diagnostic, language, and interaction analyses, the size of the effects ranged from low to medium, consistent with previous literature published at this interface. Nonetheless, our autistic participants were cognitively able, school-aged, proficient bilinguals, living in dual-language contexts and so replications and extensions are required to determine the generalizability of our results.

In summary, our current study showed that performance on most tests assessing EF abilities did not differ among monolingual and bilingual children, which speaks against the adaptive control hypothesis. In our sample, the regular use of two languages did not positively influence executive functions in either autistic or TD children, except one measure of sustained attention where bilingual autistic children showed an advantage compared to their monolingual peers. However, this single finding should be interpreted with caution. On all other tests, autistic children made more errors and were slower to respond, regardless of their language group. Together, these findings join a growing body of literature showing that bilingualism does not negatively impact the executive functions of autistic children.

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## Tables

**Table 1** Participant Demographics by Group

|                                     | Monolingual<br>Autistic<br>(N=10)<br>M (SD) | Monolingual<br>TD<br>(N=32)<br>M (SD) | Bilingual<br>Autistic<br>(N=17)<br>M (SD) | Bilingual<br>TD<br>(N=34)<br>M (SD) |
|-------------------------------------|---|---------------------------------------|---|-------------------------------------|
| Participant age ( <i>months</i> )   | 99.11<br>(22.78)                            | 111.03<br>(27.74)                     | 115.56<br>(24.24)                         | 110.50<br>(19.63)                   |
| Non-verbal IQ                       | 86.10<br>(11.19)                            | 88.26<br>(12.35)                      | 80.18<br>(9.30)                           | 87.60<br>(10.24)                    |
| Paternal education level            | 5.88<br>(1.24)                              | 6.40<br>(1.24)                        | 5.20<br>(1.47)                            | 6.26<br>(1.10)                      |
| Paternal education ( <i>years</i> ) | 17.13<br>(3.31)                             | 18.10<br>(3.13)                       | 16.20<br>(1.98)                           | 17.53<br>(1.63)                     |
| Maternal education level            | 5.50<br>(1.77)                              | 5.83<br>(1.26)                        | 4.92<br>(1.16)                            | 5.82<br>(0.86)                      |
| Maternal education ( <i>years</i> ) | 17.00<br>(3.33)                             | 16.67<br>(1.53)                       | 15.83<br>(1.52)                           | 16.88<br>(1.06)                     |
| Receptive Vocab English             | 107.63<br>(38.77)                           | 110.91<br>(26.94)                     | 86.92<br>(23.98)                          | 120.26<br>(34.93)                   |
| Receptive Vocab Arabic              | -   | -                                     | 50.45<br>(25.63)                          | 71.16<br>(24.39)                    |
| Expressive Vocab English            | 88.40<br>(32.51)                            | 110.94<br>(7.23)                      | 74.87<br>(19.17)                          | 100.48<br>(16.50)                   |
| Expressive Vocab Arabic             | -   | -                                     | 61.40<br>(22.73)                          | 65.39<br>(19.20)                    |
| Autistic Symptomatology             | 69.80<br>(16.14)                            | -                                     | 67.91<br>(10.28)                          | -                                   |
| Gender (M/F)                        | 8/2   | 13/19                                 | 10/7                                      | 8/26                                |

*Note.* Education level = 0 (none), 1 (less than high school), 2 (high school), 3 (professional training), 4 (partial college), 5 (college), 6 (some graduate), 7 (masters), 8 (doctorate); Autistic Symptomatology = as assessed by the Social Responsiveness Scale-2: 76 or higher (“severe deficits”), 66 to 75 (“moderate deficits”), 60 to 65 (“mild to moderate deficits”), 59 and below (“no deficits”); M = mean; SD = standard deviation; TD = typically developing; Non-verbal IQ = percentile scores as assessed by the Raven’s Colored Progressive Matrices; Receptive Vocab English = standard scores as assessed by the Peabody Picture Vocabulary Test 4<sup>th</sup> Ed.; Receptive Vocab Arabic = standard scores as assessed by the Arabic Picture Vocabulary Test; Expressive Vocab English = raw scores as assessed by the Picture Naming Test; Expressive Vocab Arabic = raw scores as assessed by the Picture Naming Test.

**Table 2** Results from Executive Function Measures by Group

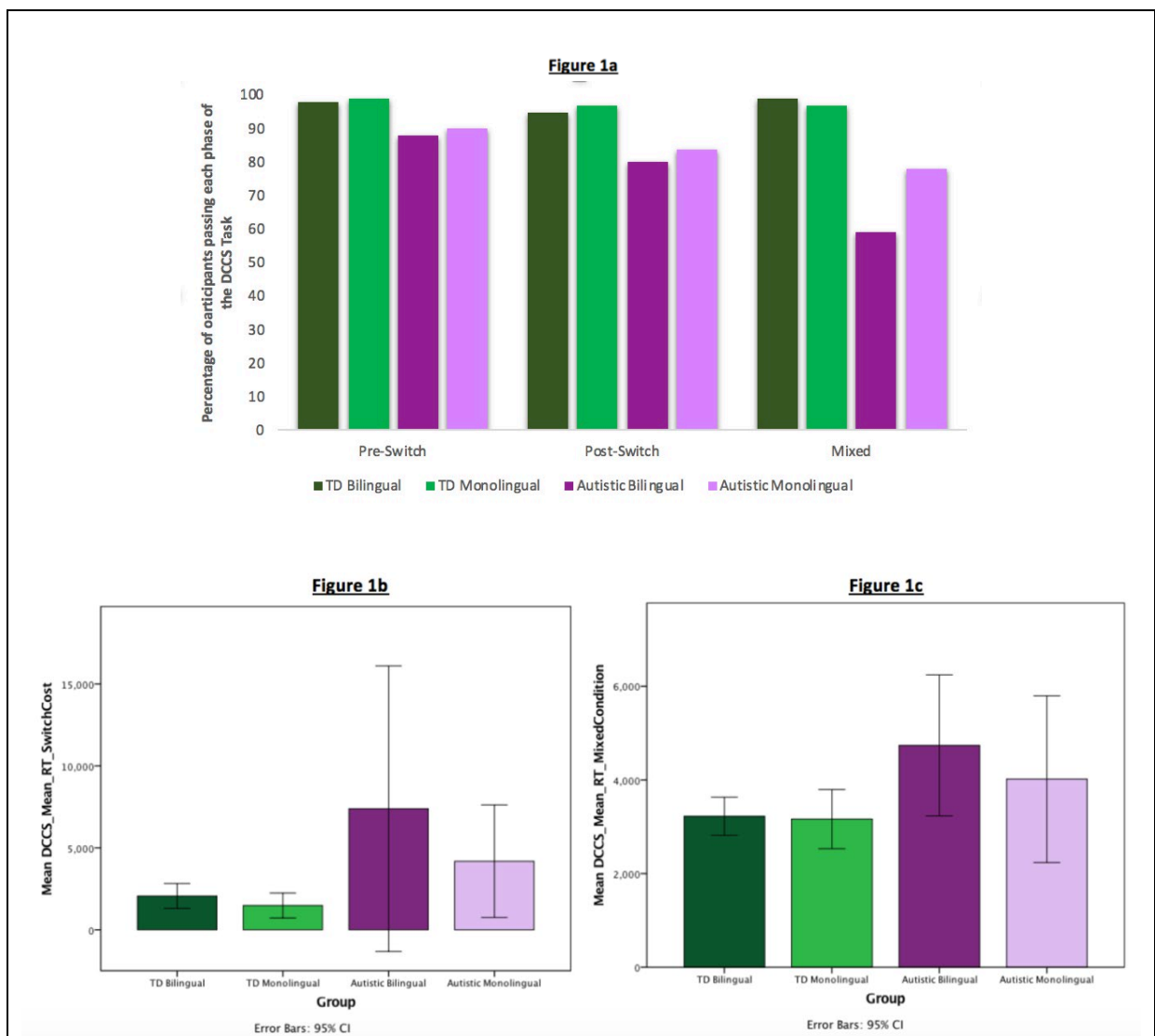
|   | Monolingual<br>Autistic<br>M (SD) | Monolingual<br>TD<br>M (SD) | Bilingual<br>Autistic<br>M (SD) | Bilingual<br>TD<br>M (SD) |
|---|-----------------------------------|-----------------------------|---------------------------------|---------------------------|
| <i>DCCS</i>                                 | ( <i>n</i> = 9)                   | ( <i>n</i> = 31)            | ( <i>n</i> = 14)                | ( <i>n</i> = 31)          |
| <b>Task accuracy</b>                        |                                   |                             |                                 |                           |
| Pre-switch <sup>a</sup> (6 trials)          | 5.56 (.72)                        | 5.94 (.25)                  | 5.57 (.75)                      | 5.97 (.18)                |
| Post-switch <sup>a</sup> (6 trials)         | 5.33 (.86)                        | 5.77 (.49)                  | 5.00 (.67)                      | 5.58 (.62)                |
| Mixed condition <sup>a</sup> (12 trials)    | 9.78 (2.22)                       | 11.35 (.91)                 | 9.21 (2.22)                     | 11.29 (.90)               |
| <b>RT in milliseconds</b>                   |                                   |                             |                                 |                           |
| Pre-switch <sup>a</sup>                     | 9058 (9415)                       | 2932 (1085)                 | 6163 (5011)                     | 3198 (1097)               |
| Post-switch <sup>a</sup>                    | 6965 (3694)                       | 3611 (2280)                 | 6463 (6189)                     | 3586 (1735)               |
| Mixed condition <sup>a</sup>                | 4735 (2935)                       | 3163 (1723)                 | 4327 (2290)                     | 3224 (1112)               |
| Switch cost in milliseconds                 | 4939 (4464)                       | 1484 (2067)                 | 7129 (16284)                    | 2061 (2071)               |
| <i>SOPT</i>                                 | ( <i>n</i> = 8)                   | ( <i>n</i> = 31)            | ( <i>n</i> = 15)                | ( <i>n</i> = 34)          |
| Abstract Errors Set Size 6 <sup>a</sup>     | 1.66 (1.00)                       | 1.01 (.69)                  | 1.44 (.85)                      | 1.14 (.60)                |
| Abstract Errors Set Size 8 <sup>a</sup>     | 4.70 (1.61)                       | 3.77 (1.85)                 | 5.06 (1.42)                     | 3.94 (1.37)               |
| Abstract Errors Set Size 10 <sup>a</sup>    | 2.58 (.66)                        | 2.22 (.99)                  | 2.95 (.88)                      | 2.32 (.90)                |
| Object Errors Set Size 6 <sup>a</sup>       | 1.33 (.83)                        | .73 (.82)                   | 1.21 (.59)                      | .66 (.66)                 |
| Object Errors Set Size 8 <sup>a</sup>       | 3.14 (1.87)                       | 2.79 (2.22)                 | 4.76 (1.24)                     | 2.89 (1.98)               |
| Object Errors Set Size 10 <sup>a</sup>      | 2.42 (.93)                        | 1.65 (1.02)                 | 2.69 (.82)                      | 1.86 (1.03)               |
| <i>PVT</i>                                  | ( <i>n</i> = 8)                   | ( <i>n</i> = 31)            | ( <i>n</i> = 15)                | ( <i>n</i> = 34)          |
| RT in milliseconds <sup>a</sup>             | 513 (86)                          | 430 (94)                    | 498 (137)                       | 422 (77)                  |
| False starts <sup>b,c</sup>                 | 13.78 (4.96)                      | 9.97 (7.85)                 | 6.29 (4.51)                     | 12.39 (10.30)             |
| <i>Simon Task</i>                           | ( <i>n</i> = 8)                   | ( <i>n</i> = 31)            | ( <i>n</i> = 15)                | ( <i>n</i> = 34)          |
| Congruent RT in milliseconds                | 694 (65)                          | 577 (115)                   | 632 (110)                       | 583 (83)                  |
| Incongruent RT in milliseconds <sup>a</sup> | 747 (92)                          | 624 (133)                   | 715 (114)                       | 650 (105)                 |
| Interference effect                         | 1.15 (.11)                        | 1.07 (.08)                  | 1.13 (.11)                      | 1.11 (.09)                |

*Note.* M = mean; SD = standard deviation; TD = typically developing; DCCS = Dimensional Change Card Sorting Task; SOPT = Self Ordered Pointing Task; PVT = Psychomotor Vigilance Task.

<sup>a</sup>Main effect of diagnostic group, <sup>b</sup>Interaction effect between diagnostic and language groups, <sup>c</sup>Significant difference between autistic monolinguals and autistic bilinguals.

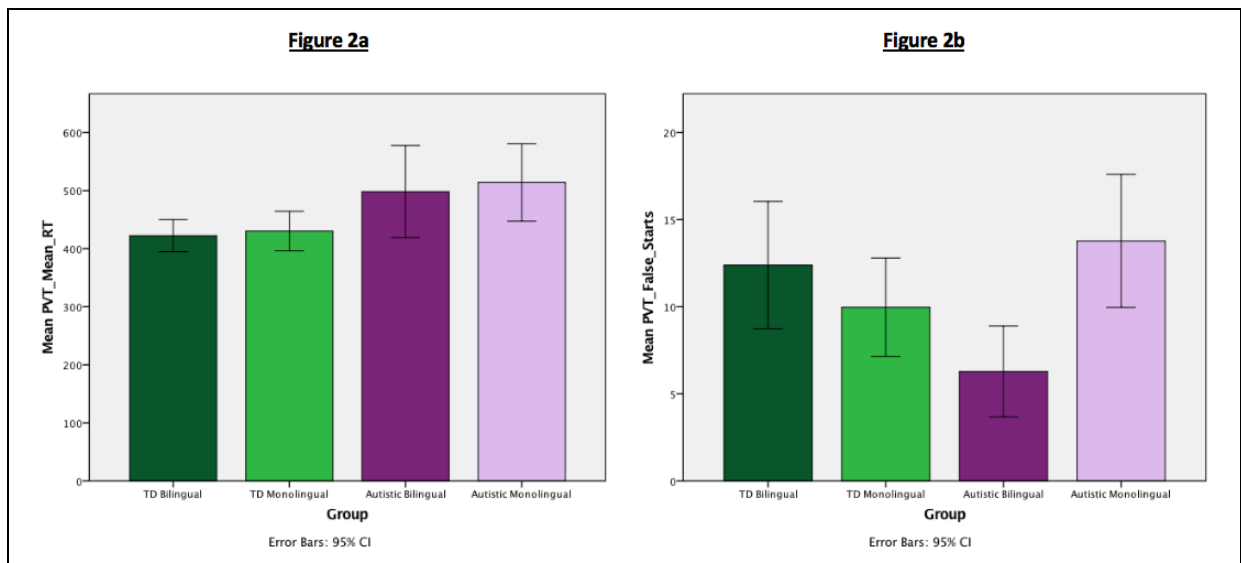
## Figure legends

Figure 1: Performance by group on flexible switching outcome variables



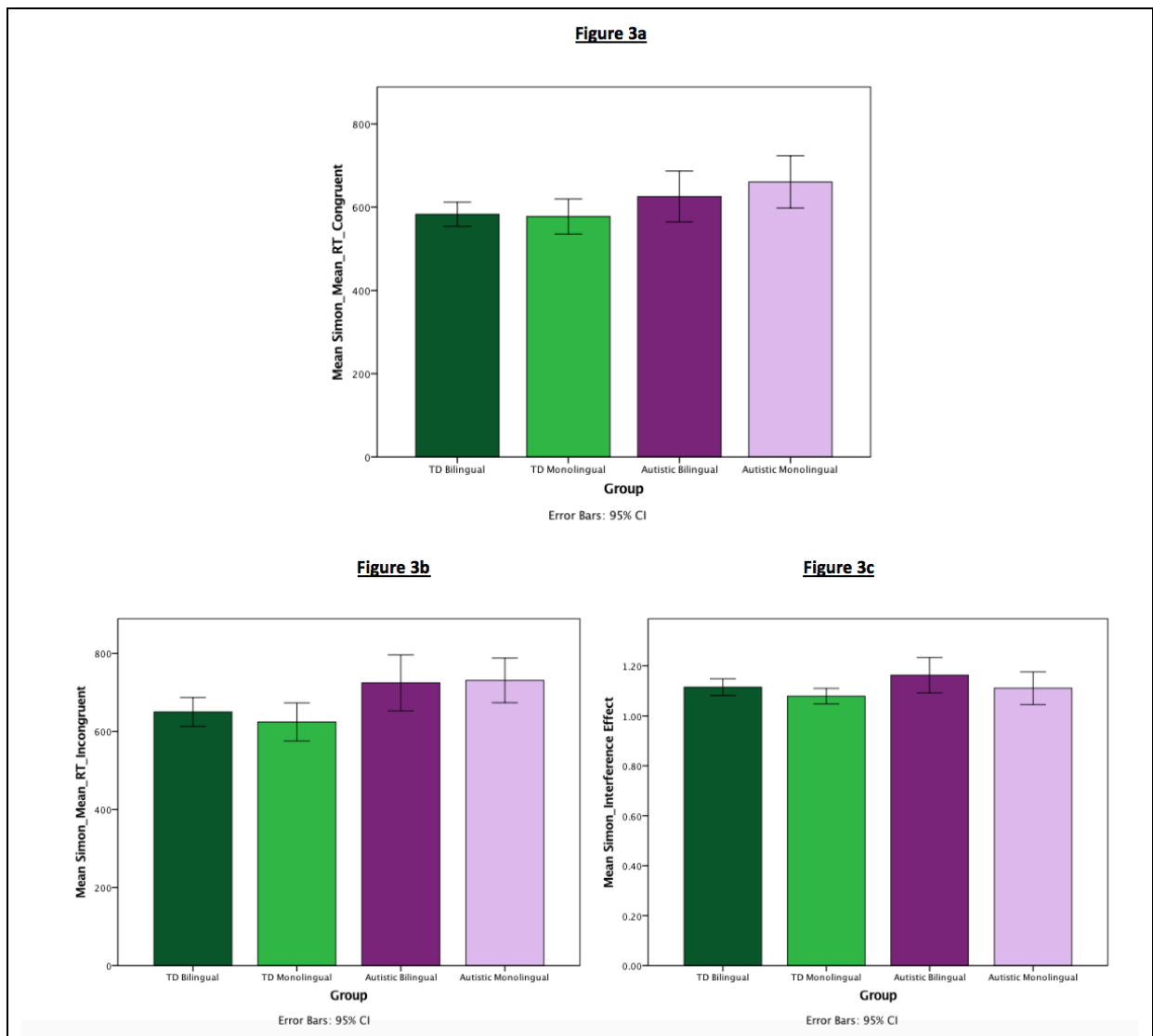
*Note.* Figure 1a displays the percentage of participants passing each phase of the DCCS task; Figure 1b displays the mean RT switch costs and error bars (95% confidence intervals) for the DCCS task; Figure 1c displays the mean RT on mixed condition trials and error bars (95% confidence intervals) for the DCCS task.

Figure 2: Performance by group on sustained attention outcome variables



*Note.* Figure 2a displays the mean RT and errors bars (95% confidence intervals) for the PVT task; Figure 2b displays the mean false starts and errors bars (95% confidence intervals) for the PVT task.

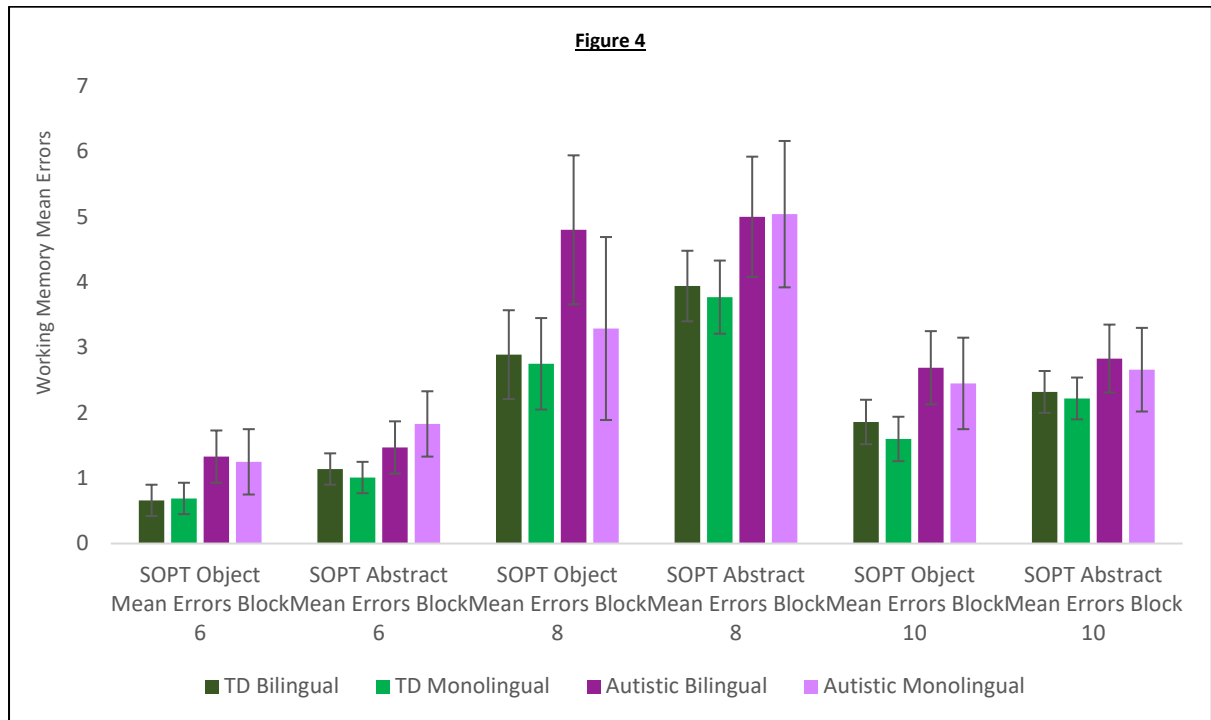
Figure 3: Performance by group on interference control outcome variables



*Note.* Figure 3a displays the mean RT congruent trials and errors bars (95% confidence intervals) for the Simon task; Figure 3b displays the mean RT on incongruent trials and errors bars (95% confidence intervals) for the Simon task, Figure 3c displays the mean interference effect and errors bars (95% confidence intervals) for the Simon task.



Figure 4: Performance by group on working memory outcome variables



*Note.* Figure 4 displays the mean errors and errors bars (95% confidence intervals) for the SOPT task in both object and abstract versions.