Journal of Attention Disorders
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Journal of Attention Disorders published online 29 March 2014
DOI: 10.1177/1087054714527790

The online version of this article can be found at:
http://jad.sagepub.com/content/early/2014/03/27/1087054714527790

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Journal of Attention Disorders
1–15

DOI: 10.1177/1087054714527790
jad.sagepub.com

The Joint Effect of Bilingualism and ADHD on Executive Functions

Billy Mor[1], Sarin Yitzhaki-Amsalem[1], and Anat Prior[1]

Abstract

Objective: The current study investigated the combined effect of ADHD, previously associated with executive function (EF) deficits, and of bilingualism, previously associated with EF enhancement, on EF. **Method:** Eighty University students, Hebrew monolinguals and Russian Hebrew bilinguals, with and without ADHD participated. Inhibition tasks were a Numeric Stroop task and a Simon arrows task. Shifting tasks were the Trail Making Test (TMT) and a task-switching paradigm. **Results:** Participants with ADHD performed worse than controls, but we did not find a bilingual advantage in EF. The negative impact of ADHD was more pronounced for bilinguals than for monolinguals, but only in interference suppression tasks. Bilingual participants with ADHD had the lowest performance. **Conclusion:** Bilingualism might prove to be an added burden for adults with ADHD, leading to reduced EF abilities. Alternatively, the current findings might be ascribed to over- or under-diagnosis of ADHD due to cultural differences between groups. These issues should be pursued in future research. *(J. of Att. Dis. 2014; XX(X) 1-XX)*

Keywords

language, adult ADHD, cognitive control, executive function

Introduction

ADHD is strongly associated with weaknesses in several executive function (EF) domains (e.g., Barkley, 1997; Boonstra, Oosterlaan, Sergeant, & Buitelaar, 2005; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Conversely, a recent growing body of evidence suggests a positive relation between lifelong bilingualism and enhanced performance in EF tasks in comparison with monolinguals (e.g., Bialystok, Craik, & Luk, 2008; Hernandez, Costa, Fuentes, Vivas, & Sebastian-Galles, 2010; Prior, 2012; Prior & MacWhinney, 2010; for a review, see Bialystok, Craik, Green, & Gollan, 2009). The bilingual advantage versus the ADHD disadvantage raises an intriguing question about the nature of the combined effect of lifelong bilingualism and ADHD on EF, which was addressed in the current study.

EFs are higher cognitive abilities that enable us to control and regulate thought and action (Friedman et al., 2006; Willcutt et al., 2005). The broad definition of EFs has given rise to diverse frameworks, identifying different EF components (for recent reviews, see Diamond, 2013; Jurado & Rosselli, 2007), and a recent factor analysis differentiates three distinct EF domains: updating of working memory, inhibition, and shifting (Miyake & Friedman, 2012). Of these three components, ADHD has mainly been linked to weakness in inhibitory abilities (Barkley, 2006), and inhibition has also been the component most widely investigated in studies examining possible bilingual advantages in EF (Costa, Hernandez, & Sebastian-Galles, 2008). Shifting has also been identified as an area of interest in bilinguals and individuals with ADHD (Prior & MacWhinney, 2010, and Boonstra et al., 2005, respectively). Working memory, in contrast, has not been identified as an area of special strength for bilinguals (Bialystok, 2009), and therefore was not investigated directly in the current study.

There is wide agreement in the research community that ADHD persists into adolescences and adulthood, though the symptoms most evident in adults are the inattentive symptoms (Erk, 2000). Among adults, the prevalence of ADHD is at 3% to 5% (e.g., de Zwaan et al., 2012; Murphy & Barkley, 1996). Discrepancies in the rates of ADHD prevalence across studies might reflect different cultural approaches (Timimi & Taylor, 2004), but are mainly due to a lack of unified diagnostic criteria (Tsal, Shalev, & Mevorach, 2005), especially for adults (Barkley, 2006). Although the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; *DSM-IV*; American Psychiatric Association [APA], 1994) provides diagnostic criteria for ADHD in adults, these were originally designed for school-age children and are still

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based on validation studies that were conducted on that age group (Riccio et al., 2005). Thus, the reduction of ADHD symptoms in adulthood may also indicate a reduction in the reliability of diagnostic criteria. Due to the absence of a reliable set of criteria, the individual diagnosis of ADHD is a result of a clinical decision-making process. To determine a diagnosis of ADHD, most diagnosticians rely on a combination of assessment tools, such as clinical interviews, behavioral rating scales, and neuropsychological tests (Davidson, 2008; Nigg, 2005; Tsal et al., 2005).

As mentioned above, meta-analyses and reviews have reported extensive difficulties in different EF domains in children (Doyle, 2006; Nigg, 2005; Willcutt et al., 2005) and adults with ADHD (Hervey, Epstein, & Curry, 2004; Schoechlin & Engel, 2005). A robust ADHD disadvantage in interference suppression has been identified (Boonstra, Kooij, Oosterlaan, Sergeant, & Buitelaar, 2010; King, Colla, Brass, Heuser, & von Cramon, 2007; Nigg et al., 2005) and demonstrated in conflict resolution tasks, such as the Stroop task (e.g., Boonstra et al., 2010; King et al., 2007; Nigg et al., 2005; van Mourik, Oosterlaan, & Sergeant, 2005) and the Simon arrows task (e.g., Sebastian et al., 2012). The ADHD disadvantage has also been demonstrated for the shifting component of EF. Two studies using the Trail Making Task (TMT; Boonstra et al., 2005; Nigg et al., 2005) revealed poorer performance for participants with ADHD on Part B, which serves as a measure for shifting. Children and adults with ADHD have also been found to have larger switching costs in a task-switching paradigm in comparison with controls (Cepeda, Cepeda, & Kramer, 2000; King et al., 2007). Although weakness in measures of inhibition and shifting among ADHD participants has been consistently demonstrated, recent research has concluded that an impairment in EF is most likely not the cause of ADHD, and claim that a finding of poorer EF is not sufficient for a diagnosis of ADHD (e.g., Boonstra et al., 2005; Nigg et al., 2005; Willcutt et al., 2005). Thus, meta-analyses have revealed that some participants with ADHD do not demonstrate a deficit in EFs, which strengthens the assumption that deficiencies in EFs are a corollary but not the singular root cause of ADHD (e.g., Willcutt et al., 2005).

The prevalence of bilingualism in the world is constantly rising, and it is estimated that currently two thirds of children are raised in bilingual environments (Bialystok et al., 2009). As mentioned earlier, bilingualism has been recently found to have a positive impact on EF (for a review, see Bialystok et al., 2009). This cognitive advantage due to language experience might be explained by the constant need of bilinguals to suppress the nonrelevant language while using the relevant language (Bialystok et al., 2009; Green, 1998). The bilingual advantage in EF has been demonstrated in nonlinguistic paradigms, suggesting a generalization beyond the language domain. For example, Bialystok et al. (2008) found that bilinguals had smaller interference effects in a Simon arrows task than monolinguals, indicating better conflict resolution. However, in the same study, there was no difference between bilinguals and monolinguals in their ability to inhibit a prepotent response. Thus, the bilingual advantage is evident in parts—but not all—of inhibition subcomponents. More evidence for the bilingual advantage in interference suppression comes from a study by Hernandez et al. (2010), using a numerical version of the Stroop task (see Figure 1). Although both Simon and Stroop paradigms are considered measures of conflict resolution, the tasks differ in the source of the conflict; in the Simon paradigm, the nonrelevant information is spatial (the location of the stimulus on the screen), leading to stimulus–response conflict, while in the Stroop paradigm, the nonrelevant information is an attribute of the stimulus itself, leading to stimulus–stimulus conflict (Liu, Banich, Jacobson, & Tanabe, 2004). As expected, bilinguals showed smaller interference effects in comparison with monolinguals, which again indicate a bilingual advantage in conflict resolution.

The bilingual advantage is also expressed in enhanced shifting abilities, perhaps due to the constant need of bilinguals to monitor two languages and switch between them. Prior and MacWhinney (2010) reported smaller switching costs in a task-switching paradigm for bilinguals in comparison with monolinguals, indicating a bilingual advantage in the ability to shift between tasks. A further study by Bialystok (2010) also reported a bilingual advantage in the TMT in 10-year-old children (Reitan & Davidson, 1974), a task that also requires shifting between dimensions.

The evidence for bilingual advantages in both inhibition and shifting may be attributed to the moderate correlation between the two domains (Miyake & Friedman, 2012; Miyake et al., 2000), raising the possibility of a shared mechanism (Prior & MacWhinney, 2010). An alternative notion is that bilingual advantages might not be attributed to better inhibitory and shifting function alone, but to better general executive processing. In a recent review, Hilchey and Klein (2011) proposed that bilinguals actually had a tendency to be overall faster than monolinguals in both congruent and incongruent trials in several studies, including conflict resolution tasks (e.g., Bialystok & DePape, 2009). Moreover, this tendency seemed to appear mainly among young adults. The advantage in overall reaction time (RT) may be an indicator of a more general executive advantage, beyond the inhibition and shifting domains, perhaps due to more general conflict-monitoring mechanisms that might be involved in managing multiple languages.

Thus, there is accumulating evidence for a bilingual advantage in inhibition and shifting, and there is also evidence for more global executive functioning advantage (Hilchey & Klein, 2011). However, several recent studies have raised questions regarding the extent and generalizability of such effects. Specifically, the diversity in the literature regarding the nature of the association between

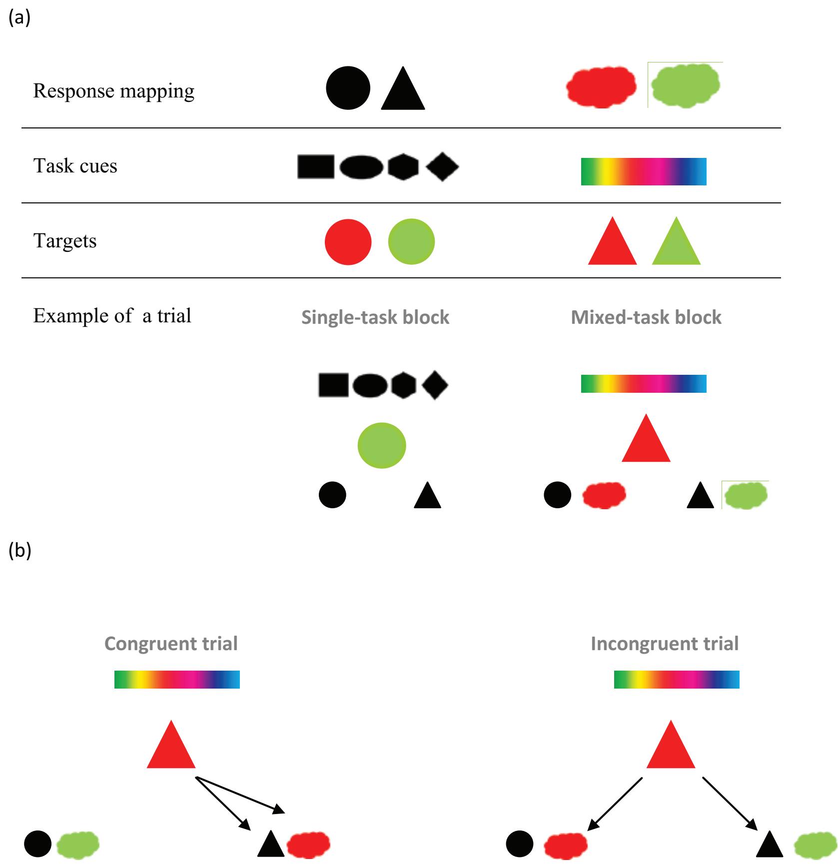

Figure 1. Schematic representation of the task-switching paradigm: (a) stimuli and cues and (b) congruent and incongruent trials.

bilingualism and EF indicates that this relation is more complex than first appears. Indeed, recent studies proposed that different individual characteristics might serve as confounding factors, such as age (e.g., Bialystok et al., 2008), age of second language acquisition, language proficiency, and even the specific language combinations (Prior & Gollan, 2011; Tao, Marzecova, Taft, Asanowicz, & Wodniecka, 2011). For example, Tao et al. (2011) compared English monolinguals and two groups of Chinese–English bilinguals who immigrated to Australia at different ages, which led to differences in proficiency in their native language (Chinese). Although both bilingual groups outperformed the monolingual group in executive control, the more balanced bilingual group showed greater enhancement in conflict resolution. Furthermore, a recent comprehensive study did not find any differences across several EF tasks between bilinguals and monolinguals (Paap & Greenberg, 2013). Thus, a full understanding of the extent and degree of possible bilingual advantages in EF is yet to be achieved. However, we suggest that examining the possible interactions of lifelong bilingualism and ADHD in the domain of EF might shed light on this issue.

The current study focuses mainly on *Shifting*, which refers to the ability to shift between mental sets or tasks, and *Inhibition*, which is defined as a general ability to suppress dominant or prepotent responses. According to research, the general ability of inhibition might be divided into subcomponents. Although different theoretical models propose different divisions—based on behavioral (e.g., Barkley, 1997; Bunge, Hazeltine, Scanlon, Rosen, & Gabrieli, 2002) and imaging evidence (Aron, 2011; Dalley, Everitt, & Robbins, 2011; Sebastian et al., 2012)—these seem partially overlapping. In the present study, we refer to two main components, using the following terminology: The inhibition subcomponent which represents the ability to avoid a habitual response will be addressed as *habitual response suppression*, whereas the subcomponent which represents the ability to ignore nonrelevant information will be addressed as *interference suppression*. The subcomponents of inhibition may also represent a sequence of actions, of which interference suppression is considered the earliest component.

The bilingual advantage versus the ADHD disadvantage in EFs raises an intriguing question: Might the lifelong experience of bilingualism, and its concomitant strengthening of EF, act as an ameliorating factor on the EF deficits of bilingual individuals with ADHD? This line of reasoning is based on several studies suggesting that lifelong bilingualism might similarly ameliorate EF disadvantages linked to lower socioeconomic status (SES) in children (Carlson & Meltzoff, 2008; Engel de Abreu, Cruz-Santos, Tourinho, Martin, & Bialystok, 2012) and adults (Prior & Gollan, 2011). Hence, the objective of the current study was to compare the performance of bilinguals and monolinguals, with and without ADHD in inhibition and shifting tasks. We hypothesized that the positive effect of bilingualism may mitigate the negative effect of ADHD, so that bilingual participants with ADHD will outperform monolingual participants with ADHD in EF tests.

Method

Participants

Eighty students aged 19 to 30 years, from the University of Haifa, the Technion and Emek Yezreel Academic College, were recruited through advertisements offering payment or course-credit for participating. Forty participants were previously diagnosed as having ADHD (20 females), and 40 were controls (20 females). ADHD participants had a valid diagnosis from the past 5 years, given by an MD authorized to diagnose ADHD (usually a neurologist or a psychiatrist). Of the ADHD participants, 21 met the criteria for the inattentive subtype, 2 met the criteria for the hyperactive/impulsive subtype, and 9 met the criteria for the combined subtype. The distribution of the subtypes did not differ across monolinguals and bilinguals.

In each group (ADHD and control), half of the participants were bilinguals and half were monolinguals. Bilingual participants were native speakers of Russian who were either born in Israel or immigrated to Israel from the Former Soviet Union before the age of 9 years, and had continuously used Russian and Hebrew since then. Monolinguals were native Hebrew speakers who had studied English as a foreign language in a school setting, beginning in the third grade, but were not proficient in any other language. All participants had normal or corrected to normal vision, without reported reading disability or language impairment. In addition, participants' diagnoses identified ADHD as their primary difficulty, and not as secondary to other psychiatric disorders.

Initially, 83 participants were recruited, but 1 participant was eliminated due to a low score in the Raven's Progressive Matrices test, 1 monolingual participant was eliminated because she reported speaking English as a native language, and 1 monolingual control was eliminated because of abnormally low performance in the *MATAL* battery, a computerized standardized battery for assessing learning diabilities in higher education (see Table 1 for participant characteristics).

Background Measures

Language proficiency

Language History Questionnaire. Participants completed a Hebrew translation (Prior & Beznos, 2009) of the Language Experience and Proficiency Questionnaire (LEAP-Q; Marian, Blumenfeld, & Kaushanskaya, 2007), which includes questions regarding language exposure and ratings of spoken language proficiency. The Hebrew and English scores (on a 1-10 scale) were analyzed using two-way ANOVA with language group (monolingual, bilingual) and attention group (control, ADHD) as between-subject variables. As expected, monolinguals had higher Hebrew exposure scores than bilinguals, $F(1, 76) = 15.09$, MSE = 4.17, $p < .001$, $\eta^2 = .16$. In addition, comparisons between Hebrew scores and English scores among monolingual participants revealed highly significant differences in both proficiency, $F(1, 39) = 114.37$, MSE = 0.547, $p < .001$, $\eta^2 = .75$, and exposure, $F(1, 39) = 257.02$, MSE = 2.66, $p < .001$, $\eta^2 = .87$, revealing much higher scores for proficiency and exposure in Hebrew than in English, as expected. There were no other significant differences between the groups and no interactions.

Category and letter fluency. Participants said as many words as they could from a specific semantic category or that start with a specific letter, within 1 min. All participants completed the tests in Hebrew (two categories and two letters); bilinguals also completed the tests in Russian (two categories different from those in Hebrew and two letters). Categories were *animals* and *vehicles* or *clothing* and *fruits and vegetables*. Hebrew letters were "bet" and "shin," and Russian letters were "be" and "sha." Hebrew categories and phonemes were based on Kave (2005). For Russian, we used the same semantic categories and phonemes, which are of similar frequency across the two languages. In each language, recorded instructions were presented orally and in writing simultaneously. The order of presentation for the languages and the categories was counterbalance across participants. Responses were recorded and coded offline. The score for each language was the mean of correct items, excluding repetitions. The only significant differences were that (a) bilinguals were able to produce more words in Hebrew than in Russian, $F(1, 39) = 41.33$, MSE = 10.75, $p < .001$, $\eta^2 = .52$, and (b) participants with ADHD produced fewer words in Hebrew categories in comparison with participants without ADHD, $F(1, 76) = 4.02$, MSE = 13.96, $p < .05$, $\eta^2 = .05$.

Hebrew and English scores in the University Entrance Exam. Participants who attended the University of Haifa were asked to sign a consent form that allowed us to receive their scores in the Hebrew and English sections of a national exam taken by all students wishing to enroll in higher education. Participants who attended other colleges reported

Table 1. Participant Characteristics.

	Monolinguals		Bilinguals	
	Control (*n* = 20, 10 females)	ADHD (*n* = 20, 10 females)	Control (*n* = 20, 10 females)	ADHD (*n* = 20, 10 females)
Age (years)	24.25 (2.45)	24.35 (2.37)	24.8 (2.09)	25.15 (2.16)
Raven	53.3 (2.92)	54.95 (3.62)	54.5 (3.12)	54.1 (3.66)
Parental education	14.56 (2.28)	14.23 (3.04)	14.13 (2.92)	15.53 (2.62)
Video games	2.31 (4.56)	3.44 (5.93)	3.08 (8.05)	5.22 (8.84)
LEAP-Q				
Hebrew oral prof.	9.76 (.43)	9.45 (1.03)	9.83 (.4)	9.06 (2.29)
Hebrew exposure	8.13 (1.57)	7.07 (1.13)	5.62 (2.57)	6.33 (2.6)
English oral prof.	7.9 (1.07)	7.78 (1.27)	7.75 (.87)	7.63 (1.31)
English exposure	1.51 (1.63)	2.05 (1.61)	1.82 (1.29)	2.06 (1.88)
Russian oral prof.	NA	NA	7.68 (1.73)	7.65 (1.9)
Russian exposure	NA	NA	4.2 (1.17)	4.75 (1.88)
Verbal fluency				
Hebrew categories	17.9 (4.12)	17.33 (4.2)	18.68 (4.01)	15.9 (2.28)
Hebrew letters	13.4 (3.89)	12.25 (3.14)	14.1 (3.77)	12.33 (4.57)
Russian categories	NA	NA	14.18 (3.9)	13 (3.17)
Russian letters	NA	NA	8.43 (3.52)	7.18 (3.27)
Hebrew psyc. score	126.57 (10.62)	123.15 (10.77)	121.13 (18.22)	118.43 (18.89)
English psyc. score	125.14 (10.98)	124.69 (15.71)	129 (12.57)	118.71 (14.3)
MATAL				
Mean standard score	0.02 (0.6)	−1.02 (0.52)	0.05 (0.29)	−1.01 (0.68)
Total percentile < 20	2.75 (1.97)	6.6 (1.57)	2.45 (1.91)	6.8 (2.61)
DSM-IV				
School inattention	2.65 (2.7)	7.15 (1.81)	1.5 (1.61)	6.1 (2)
School hyper/impuls	0.8 (1.06)	4.9 (2.9)	1.05 (1.23)	4.45 (2.54)
Present inattention	1.55 (1.61)	4.95 (2.9)	0.75 (0.85)	5.25 (2.45)
Present hyper/impuls	0.45 (0.51)	3.1 (2.53)	1.1 (1.38)	3.7 (2.36)

Note. LEAP-Q = Language Experience and Proficiency Questionnaire; Oral prof. = oral language proficiency; Psyc score = psychometric score; MATAL = a computerized standaradized battery for assessing learning disabilities in higher education. Total percentile < 20 = total number of percentile scores falling below 20th percentile; *DSM-IV* = *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.); School inattention = Inattention subscale score, referring to the high school period; School hyper/impuls = Hyperactivity/Impulsivity subscale score, referring to the high school period; Present inattention = Inattention subscale score, referring to the present; Present hyper/impuls = Hyperactivity/Impulsivity subscale score, referring to the present.

their scores or extracted them from the official website of the National Institute of Testing and Evaluation (NITE) that administers the exam. There were no significant group differences in these scores.

ADHD assessment

MATAL—A computerized battery of standard tests and questionnaires. The battery was developed by NITE to assess learning disabilities in higher education students who request test accommodations (Ben-Simon, 2005). Participants completed three subtests of attention performance: (a) a continuous performance task (CPT)—a measurement of sustained attention. Participants were asked to respond to a two dimensional target stimuli (shape and color); (b) an attention network task (ANT)—a combined measurement of alerting, orienting, executive attention, and sustained attention. Participants were asked to determine the direction (left or right) of a target symbol (arrow) presented with or without various cues and distractors; (c) a self-report questionnaire, referring to behavioral symptoms of attention difficulties, impulsivity, and hyperactivity in childhood and currently. Participants with ADHD who had been previously diagnosed using this battery delivered a copy of their diagnosis report and were not required to repeat the tests within the experiment. The MATAL battery is standardized on a representative sample of Israeli adults aged 16 to 30 years. The three subtests of attention performances yield 14 standard scores and 14 percentiles scores. For each participant, a mean standard score was calculated, as well as the total number of percentile score falling below the 20th percentile. As expected, we found a highly significant difference between participants with ADHD and control participants in both standard scores, $F(1, 76) = 75.27$, MSE = 0.29, $p < .001$, $\eta^2 = .5$, and percentiles, $F(1, 76) = 80.17$, MSE = 4.19, $p < .001$, $\eta^2 = .51$, but no differences between bilinguals and monolinguals or interactions (all *F*s < 1).

DSM-IV criteria for ADHD. This questionnaire consists of two subscales: Inattention and Hyperactivity/Impulsivity, referring to the high school period and to the present (APA, 1994). As expected, the difference between participants with ADHD and control participants was highly significant, in all four scores: inattention, $F(1, 76) = 96.56$, MSE = 4.29, $p < .001$, $\eta^2 = .56$, and Hyperactivity/Impulsivity during high school, $F(1, 76) = 64.21$, MSE = 4.38, $p < .001$, $\eta^2 = .46$, and inattention, $F(1, 76) = 70.71$, MSE = 4.41, $p < .001$, $\eta^2 = .48$, and Hyperactivity/Impulsivity, $F(1, 76) = 38.97$, MSE = 3.54, $p < .001$, $\eta^2 = .34$, at the present.

In addition, there were no significant differences between monolingual and bilingual participants regarding the present period. Monolinguals reported significantly more behavioral symptoms of inattention during high school than bilinguals, $F(1, 76) = 5.64$, MSE = 4.29, $p < .05$, $\eta^2 = .07$, but there were no significant differences in the Hyperactivity/Impulsivity subscale and no significant interactions between language group and attention group.

Additional background variables. Participants completed the Raven's progressive matrices (Raven, Court, & Raven, 1977) to assess general nonverbal intelligence. The task consists of 60 items, in which one segment of a larger pattern is missing, and participants are asked to identify the missing segment to complete the pattern. The score was the total number of correct items. There were no significant group differences. The SES of participants was assessed based on the average number of parental years of schooling, which was equivalent across all participant groups. Finally, we also asked participants to report the average number of weekly hours that they engage in video games, and found no differences across groups.

EF Measures

EFs were measured by four tasks, three of which were nonlinguistic and one involved letter knowledge. The nonlinguistic tasks were computerized and presented using E-prime (Version 2.0) software on a PC with a 19-inch color monitor. A response box (Psychological Software Tools, Inc., Pittsburgh, Pennsylvania) was affixed to the computer to ensure accurate RT measurement. Participants were seated approximately 50 cm from the monitor. The final task was a paper-and-pencil task.

Inhibition

Numeric Stroop. The implementation of the task was based on the study reported by Hernandez et al. (2010). In each trial, participants were instructed to indicate by button press, as quickly and accurately as possible, how many items appear on the screen (range from 1 to 3). There were three experimental conditions—neutral, congruent, and incongruent—presented in random fashion. In the neutral condition, the items were nonnumerical (Latin letters: G, M, or Z), while in the congruent and the incongruent conditions, the items were digits (1, 2, or 3). In congruent trails, the value and number of items matched (e.g., 333), and in incongruent trails they did not match (e.g., 111), therefore creating a conflict. The task consisted of two blocks of 90 trials each, with an equal number of trials for each condition. Participants were required to lay the index, middle, and ring fingers of their dominant hand on buttons on the response box marked with 1, 2, and 3, respectively. Before the first block, there were 9 training trials. Each training trial was followed by a feedback screen, indicating accuracy and RT. Experimental trials started with a fixation cross appearing in the middle of the screen for 1,000 ms, followed by the target stimuli presented for 2,000 ms or until a response was given. A rest screen including a repetition of instruction appeared between the blocks. The interference effect was calculated as differences in RT and accuracy between congruent and incongruent trials.

Simon arrows/Spatial Stroop. The implementation of the task was based on the study reported by Bialystok et al. (2008). Participants were requested to lay their right and left index fingers on the right and left buttons of a response box, respectively. In each trial, an arrow pointing either left or right appeared on the screen. There were three experimental blocks: basic, conflict, and reverse. In the basic block, the arrow appeared in the center of the screen, and participants were instructed to respond to the direction of the arrow, by pressing the corresponding response button (left or right). This condition served to establish response speed when no additional processing is required. There were 48 trials in this block, presented in random sequence. In the conflict block, the target arrows were presented on the left or right sides of the display, creating congruent trials when the direction and position corresponded, and incongruent trials when they were in conflict. Participants were instructed to press the button indicating the direction that the arrow is pointing irrespective of the position. There were 96 trials in this block (48 congruent and 48 incongruent trials), presented in random order. The interference effect was calculated as differences in RT and accuracy between congruent and incongruent trials. The reverse block was a measure of habitual response suppression: The display was identical to the display in the basic block with an arrow appearing in the center of the screen. However, the instruction was reversed—to press the response button in the direction opposite to the one indicated by the arrow. This block contained 48 trials.

The task consisted of six sub-blocks of trials (two sub-blocks for each type). The basic sub-blocks were always presented first and last, while the conflict and reverse blocks were administered in between in two presentation orders that were counterbalanced across participants; half of the participant saw the conflict block and then the reverse block (i.e., basic, conflict, reverse, basic), but the other half saw the reverse block first and then the conflict block (i.e., basic, reverse, conflict, basic). Before each block, an instruction screen appeared followed by four practice trials. Each practice trial was followed by feedback screen, indicating accuracy and RT, and incorrect responses were also signaled by a beep. Experimental trials began with a blank white screen presented for 850 ms. Then, a fixation cross appeared for 500 ms, immediately followed by the target, which was presented for 2,000 ms or until a response was given. Incorrect responses were signaled by a 400 ms beep, but no other feedback was given.

Shifting

TMT Hebrew version. This is a "connect-the-dots" test (Reitan & Davidson, 1974), in which English letters were replaced by Hebrew letters. In Part A, participants are requested to connect circles that contain numbers from 1 to 25 by ascending order. In Part B, participants are instructed to alternate between numbers and Hebrew letters and connect them by order (e.g., 1-"Alef," 2-"Bet," etc.). In this section, there are 13 numbers and 12 Hebrew letters. In both parts, participants must not lift their pencil until finishing the task. The tester drew the participant's attention to any errors committed. Both parts require the involvement of overlapping processes and abilities including visual perception, visual search and motor speed, but Part B additionally requires shifting between sequences. Part B is more demanding and is considered to be a test of EF (Bialystok, 2010). Outcome measures were accuracy and response time for each part separately.

Task-switching paradigm. The current procedure was based on Prior and MacWhinney (2010). Participants were presented with one of four targets, red or green triangles and circles, and had to make a shape or a color judgment (Figure 1). The experiment consisted of three parts. There were two single-task blocks, one for color and one for shape. The order of the initial single-task blocks was counterbalanced across participants. Next, three mixed-task blocks were presented, and finally two additional single-task blocks were presented.

The targets were red or green triangles (2.8° x 2.8°) and circles (2.3° x 2.3°). Task cues were graphic and not verbal to avoid any influence of the participants' language experience. The cue for the shape task was a row of small black shapes different from the shape targets, and the cue for the color task was a color gradient. Response mappings—the assignment of colors and shapes to the right and left hand—were counterbalanced across participants. Participants responded using the index fingers of both hands. Thus, in the mixed blocks there were two congruent targets, which received the same response regardless of the task, and two incongruent targets, which needed to be responded to with the right or the left index finger depending on the task cue (Figure 1). The response mappings for the two tasks remained constant in the pure and mixed blocks for each participant. Thus, each participant always needed to respond with the same hand to each target dimension.

Single-task blocks contained 8 practice trials, followed by 36 experimental trials. Mixed-task blocks included 50 trials each, preceded by 16 practice trials. Half of trials in the mixed blocks were switch trials, in which the task changed from the previous trials, and half were nonswitch trials, in which the task remained the same, of both the color and shape tasks. The order of trials was pseudorandom with a maximum of 4 consecutive trials of the same type. Participants had the opportunity to rest between the mixed blocks. The response mappings appeared on the bottom of the screen throughout the entire experimental block. Trials started with a fixation point that appeared in the middle of the screen for 350 ms. The task cue then appeared for 250 ms 2.8° above the fixation cross. Finally, the target was presented and remained on the screen until a response was given, or for a maximum of 4 s. The response mappings and the task cue remained on the screen until the response was given. Responses were followed by a 850 ms intertrial interval, in which only the response mappings appeared on the screen. Incorrect responses were signaled by a 400 ms beep.

Shifting abilities were measured by examining switching costs and mixing costs. The *switching cost* is the difference in performance between switch and nonswitch trials in the mixed blocks. This measure reflects the resources needed due to shifting from one task to another. The *mixing cost* is the difference in performance between trials in the single-task blocks and nonswitch trials in the mixed blocks. This measure reflects the resources needed for maintaining two competing tasks, deciding what is the relevant response on each trial and monitoring the task cue (Prior & MacWhinney, 2010). Costs were measured in RT and in accuracy.

Procedure

The study was approved by the ethics committee at University of Haifa and all participants gave informed consent. Participants were invited individually for a MATAL testing session lasting 45 min, and completed the tasks and other background measures in another session, lasting approximately 1.5 hr. Participants with ADHD who use stimulant medication as treatment were requested to refrain from taking the medication on the testing days. The tasks were administered in the following order: EF tests and verbal fluency tests were performed first, in counterbalanced

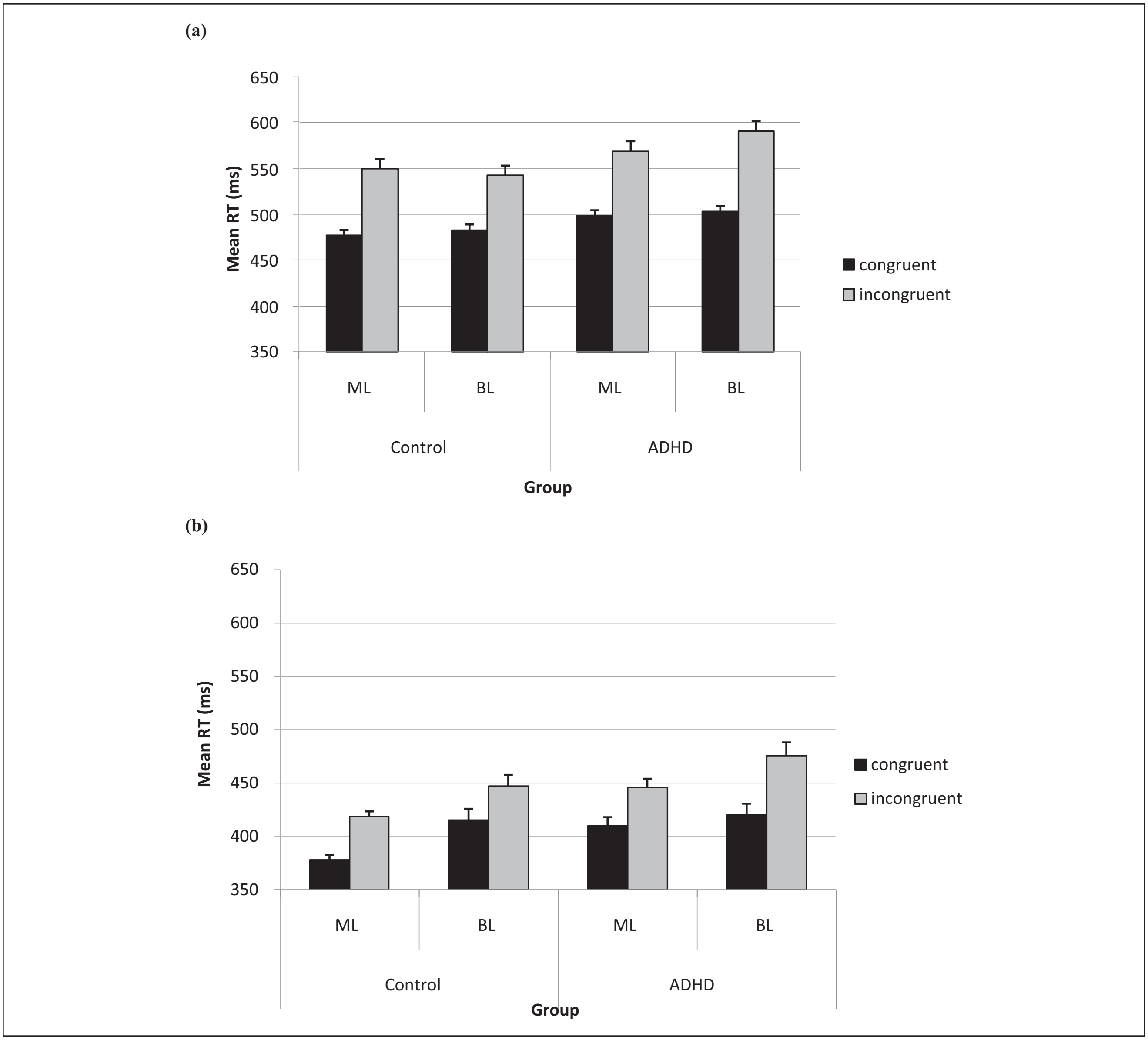

Figure 2. Mean RT in milliseconds and standard error for congruent and incongruent trials in (a) Numeric Stroop task and (b) Simon arrows task, by group.
Note. RT = reaction time. ML = monolinguals. BL = Bilinguals.

order. Afterward, participants completed the Raven task and answered the questionnaires.

Results

Inhibition

Conflict resolution

Numeric Stroop task. RT analyses were performed on accurate trials. In the accuracy analyses, responses faster than 150 ms were excluded (.07% of the trials). Performance was analyzed using a three-way repeated-measures ANOVA with language group (monolingual, bilingual) and attention group (control, ADHD) as between-subject variables, and congruency (congruent, incongruent) as a within-subject variable. The interference effect is defined as the difference in performance between congruent and incongruent trials.

In the RT analyses (Figure 2), the main effect of congruency was significant, $F(1, 76) = 364.62$, MSE = 578.86, $p < .001$, $\eta^2 = .83$, revealing faster responses for congruent trials than for incongruent trials. The main effects of language group and attention group were not significant (both $ps > .16$). However, there was a significant three-way interaction between language group, attention group, and congruency, $F(1, 76) = 4.08$, MSE = 578.86, $p < .05$, $\eta^2 = .05$. This interaction stems from the fact that attention group significantly interacted with congruency among bilinguals, $F(1, 38) = 8.42$, MSE = 486.92, $p < .01$, $\eta^2 = .18$, but not among monolinguals ($F < 1$). The interference effect was greater for bilingual participants with ADHD (88.06 ms) than for control participants (59.42 ms), but was similar for all monolingual participants (71 and 73 ms for controls and ADHD, respectively). There was no significant interaction between language group and congruency ($F < 1$) or between attention group and congruency, $F(1, 76) = 3.05$, MSE = 578.86, $p = .08$, $\eta^2 = .04$.

Participants were overall more accurate when responding to congruent than to incongruent trials, a main effect of congruency, $F(1, 76) = 131.78$, MSE = 0.002, $p < .001$, $\eta^2 = .63$. The main effect of language group was not significant ($p = .18$), but the main effect of attention group was significant, $F(1, 76) = 9.46$, MSE = 0.002, $p < .005$, $\eta^2 = .11$, revealing that participants with ADHD were less accurate than control participants. Attention group also significantly interacted with congruency, $F(1, 76) = 7.93$, MSE = 0.002, $p < .01$, $\eta^2 = .09$, because while the accuracy rate in congruent trials was almost identical for all participants (above 99%), participants with ADHD were far less accurate in incongruent trials (88.6%) than were controls (93.18%). There was no significant interaction between language group and congruency ($p = .2$) or between language group, attention group, and congruency ($F < 1$).

Simon arrows. RT analyses were performed only on accurate trials. In the accuracy analyses, responses faster than 200 ms were not included (.19% of the trials). Performance was analyzed using a repeated-measures three-way ANOVA with language group (monolingual, bilingual) and attention group (control, ADHD) as between-subject variables, and congruency (congruent, incongruent) as a within-subject variable. The RT analyses yielded a similar pattern to that found in the Numeric Stroop task (Figure 2). The main effect of congruency was significant, $F(1, 76) = 164.72$, MSE = 404.29, $p < .001$, $\eta^2 = .68$, because congruent trials received faster responses than incongruent trials. The main effects of language group and attention group were not significant (both ps > .13). However, this analysis revealed a significant three-way interaction between language group, attention group, and congruency, $F(1, 76) = 5.02$, MSE = 404.29, $p < .05$, $\eta^2 = .06$, which was driven by a significant two-way interaction between attention group and congruency among bilinguals, $F(1, 38) = 6.15$, MSE = 455.2, $p < .05$, $\eta^2 = .14$, but not among monolinguals ($F < 1$). The interference effect was greater for bilingual participants with ADHD (55 ms) than for control participants (32 ms), but was quite similar for all monolinguals (36 and 41 ms for participants with and without ADHD, respectively). All two-way interactions were not significant (all ps > .14).

Table 2. Reaction Time in Milliseconds (*SD*) in the Basic and Reverse Trials in the Simon Arrows Task, by Group.

	Basic	Reverse
Monolinguals		
Control	339 (39)	392 (56)
ADHD	346 (65)	393 (90)
Bilinguals		
Control	325 (32)	381 (65)
ADHD	354 (56)	413 (85)

The accuracy analyses also yielded a similar pattern to that found in the Numeric Stroop task. The main effect of congruency was significant, $F(1, 76) = 41.07$, MSE = 0.001, $p < .001$, $\eta^2 = .35$, indicating more accurate responses for congruent trials than for incongruent trials. The main effect of language group was not significant ($F < 1$), but the main effect of attention group was significant, $F(1, 76) = 6.16$, MSE = 0.002, $p < .05$, $\eta^2 = .08$, indicating lower accuracy rates for participants with ADHD than for controls. Furthermore, there was a significant interaction between attention group and congruency, $F(1, 76) = 7.02$, MSE = 0.001, $p < .05$, $\eta^2 = .09$, because whereas the accuracy rate in congruent trials was similar for all participants (above 98%), the accuracy rate in incongruent trials was lower for participants with ADHD (93.48%) than for controls (96.9%). No other interactions were significant (all Fs < 1).

Habitual response inhibition—Simon reverse block. RT analyses were performed only on accurate trials. In the accuracy analyses, responses faster than 200 ms were not included (.24% of the data). Performance was analyzed using a three-way repeated-measures ANOVA with language group (monolingual, bilingual) and attention group (control, ADHD) as between-subject variables, and type of instruction (basic, reverse) as a within-subject variable. The main effect of instruction type was significant for both RT and accuracy, $F(1, 76) = 100.82$, MSE = 1,221, $p < .001$, $\eta^2 = .57$; $F(1, 76) = 7.97$, MSE = 0.000, $p < .01$, $\eta^2 = .1$, respectively, revealing faster and more accurate responses in the basic blocks than in the reverse blocks. In the RT analysis (Table 2), there were no significant main effects for either language group or attention group ($F < 1$, $p = .28$, respectively) and no significant interactions (all Fs < 1). However, in the accuracy analysis (Figure 3), the main effect of attention group was significant, $F(1, 76) = 14.73$, MSE = 0.001, $p < .001$, $\eta^2 = .16$, revealing higher error rates for participants with ADHD than for controls. The main effect of language group was not significant, $F(1, 76) = 2.03$, MSE = 0.001, $p = .16$, $\eta^2 = .03$, and there were no significant interactions (all Fs < 1).

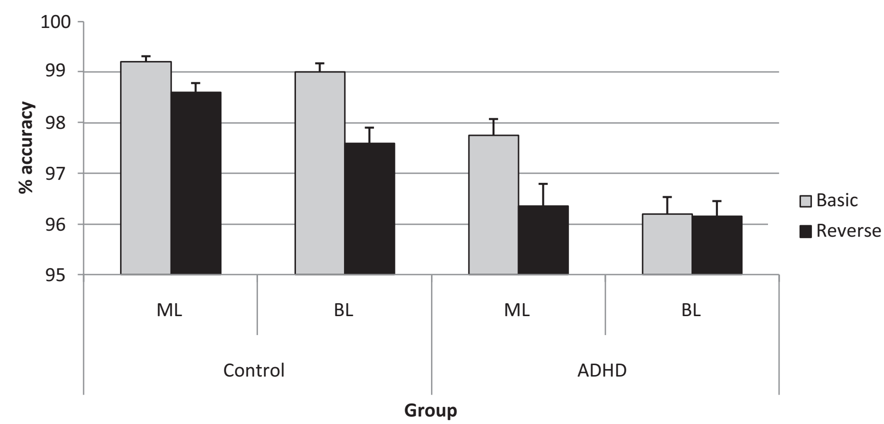

Figure 3. Percentage of accuracy and standard error for basic and reverse trials in Simon arrows task, by group. Note: ML = Monolingual, BL = Bilingual.

Table 3. Mean RT in Seconds (*SD*) and Mean Number of Errors (*SD*) for TMT Parts A and B, by Group.

	RT		Errors	
	Part A	Part B	Part A	Part B
Monolinguals				
Control	27.2 (9.3)	55.4 (17.8)	0.05 (0.30)	0.68 (1.5)
ADHD	31.2 (12.8)	62.4 (19.7)	0.40 (0.75)	0.35 (0.81)
Bilinguals				
Control	30.7 (8.9)	60.6 (22.5)	0.15 (0.36)	0.85 (1.7)
ADHD	30.6 (9.7)	69.4 (29.1)	0.05 (0.22)	0.60 (0.68)

Note. RT = reaction time.

Shifting

TMT. Differences in RT and accuracy between groups in the TMT were analyzed using a three-way repeated-measures analysis, with language group (monolingual, bilingual) and attention group (control, ADHD) as between-participant factors and TMT level as a within-participant factor (Part A, Part B) (Table 3). There was a significant effect of TMT level both in RT, $F(1, 75) = 221.93$, MSE = 40,401.46, $p < .001$, $\eta^2 = .74$, and in accuracy, $F(1, 75) = 9.23$, MSE = 8.28, $p < .01$, $\eta^2 = .11$, because all participants were slower and more error prone on Part B of the task. All remaining main effects and interactions were not significant (all *p*s > .17). Thus, there were no differences between the participant groups in their performance of the TMT.

Task switching

Switching costs. Switching costs in RT and accuracy were analyzed using a four-way repeated-measures ANOVA, with language group (monolingual, bilingual) and attention group (control, ADHD) as between-participant factors and trial type (repeat, switch) and congruency (congruent, incongruent) as within-participant factors (Table 4). Data from one control bilingual participant were eliminated from analysis because of accuracy rates below 50% across all trial types. RT analyses were performed on correct responses only.

There was a significant main effect of trial type for both RT and accuracy, $F(1, 75) = 68.03$, MSE = 5,466.50, $p < .001$, $\eta^2 = .48$; $F(1, 75) = 13.5$, MSE = 0.025, $p < .001$, $\eta^2 = .15$, respectively. Responses were faster and more accurate for repeat trials than for switch trials. The significant main effect of congruency was significant for both RT and accuracy, $F(1, 75) = 65.56$, MSE = 793,560.67, $p < .001$, $\eta^2 = .47$; $F(1, 75) = 62.24$, MSE = 0.47, $p < .001$, $\eta^2 = .44$, respectively, because responses were faster and more accurate for congruent trials than for incongruent trials. There was also a significant two-way interaction between trial type and congruency, which was driven by the fact that switching costs were larger in the incongruent than in the congruent condition, $F(1, 75) = 10.69$, MSE = 58,441.68, $p < .01$, $\eta^2 = .13$; $F(1, 75) = 15.80$, MSE = 0.019, $p < .001$, $\eta^2 = .18$; for RT and accuracy, respectively.

There were no significant differences between monolinguals and bilinguals in overall RT or accuracy (both *F*s < 1). Participants with ADHD were as fast as controls ($p > .16$), but were less accurate, as shown by a significant main effect of attention group, $F(1, 75) = 7.84$, MSE = 0.074, $p < .01$, $\eta^2 = .09$. The two-way interaction between language group and attention group was not significant, showing that the decline in performance associated with ADHD was stable across the populations (both *p*s > .26). Switching costs were similar for bilinguals and monolinguals, as there was no interaction between trial type and language group in either RT or accuracy (both *F*s < 1). Switching costs were also stable across control and ADHD participants in RT and accuracy (both *p*s > .19). Congruency effects did not

Table 4. Mean RT (*SD*) in Milliseconds in Single Task and Repeat and Switch Trials, by Congruency and Participant Group.

	Monolinguals		Bilinguals	
	Control	ADHD	Control	ADHD
Single	392 (50)	421 (116)	391 (69)	446 (102)
Repeat				
Congruent	759 (227)	888 (328)	886 (331)	879 (293)
Incongruent	836 (226)	976 (349)	914 (287)	978 (306)
Switch				
Congruent	820 (226)	932 (336)	941 (317)	979 (353)
Incongruent	900 (214)	1,117 (388)	1,044 (328)	1,121 (396)
Mixing cost	405 (185)	511 (253)	509 (262)	483 (225)
Switching cost				
Congruent	61 (79)	45 (103)	55 (118)	100 (126)
Incongruent	65 (81)	141 (148)	130 (153)	143 (153)

Note. RT = reaction time.

interact with language group (both *F*s < 1), but there was a significant interaction between congruency and attention group in RT, $F(1, 75) = 5.35$, MSE = 64,784.37, $p < .05$, $\eta^2 = .07$, and a marginal interaction in accuracy, $F(1, 75) = 3.65$, MSE = 0.028, $p = .06$, $\eta^2 = .05$, because participants with ADHD showed a larger disparity between congruent and incongruent trials than did controls. This pattern is similar to the findings with the interference tasks discussed above. The three-way interactions of language group and attention group with trial type and with congruency were not significant (all *p*s > .15).

Finally, the four-way interaction was significant for accuracy rates, $F(1, 75) = 4.99$, MSE = 0.006, $p < .05$, $\eta^2 = .06$, and marginal in RTs, $F(1, 75) = 3.52$, MSE = 19,212.54, $p = .065$, $\eta^2 = .05$. This interaction was driven by the fact that monolingual controls had similar switch costs for congruent and incongruent trials, whereas the three other participant groups showed larger switch costs in incongruent than in congruent trials. Specifically, incongruent trials reduced the accuracy of the bilingual controls to a greater degree than of the monolingual controls.

Mixing costs. Mixing costs are defined as the differences in RT between repeat trials in the mixed-task blocks and trials in the single-task blocks, and reflect the cognitive processes that are needed to maintain two different task sets in mind. Mixing costs in RT and accuracy were analyzed using a three-way repeated-measures ANOVA, with language group (monolingual, bilingual) and attention group (control, ADHD) as between-participant factors, and trial type (repeat, single) as a within-participant factor (Table 4). Because in the single-task blocks there is no distinction between congruent and incongruent trials (there is only one task mapping), the analysis of mixing costs did not include congruency as a factor.

There was a significant main effect of trial type in RT and accuracy, $F(1, 75) = 328.82$, MSE = 8,983,274.97, $p < .001$, $\eta^2 = .81$; $F(1, 75) = 31.0$, MSE = 0.03, $p < .001$, $\eta^2 = .29$, respectively. Responses were faster and more accurate for single trials than for repeat trials, as expected. In RTs, there was no significant main effect of language or attention group and no two-way interaction (all *p*s > .13). Moreover, the two-way interactions, including the language group and the attention group factors, were not significant (all *p*s > .22) demonstrating again that the effects of mixing were similar across all participant groups. In accuracy, there was no significant main effect of language ($p > .26$), but there was a significant main effect of attention group, $F(1, 75) = 14.06$, MSE = 0.02, $p < .001$, $\eta^2 = .16$, because participants with ADHD were less accurate overall than control participants. The two-way interaction and the three-way interaction were not significant (all *p*s > .14).

Discussion

The current study was conducted to examine the combined effect of bilingualism and ADHD on the EFs of inhibition and shifting. Based on previous literature describing bilingual advantages in these components of EF (e.g. Bialystok et al., 2008; Hernandez et al., 2010), we hypothesized that bilingualism might positively impact deficits associated with ADHD. Surprisingly, our results indicated the opposite pattern. Specifically, in several tasks, we found that bilinguals with ADHD showed larger decrements to performance than monolinguals with ADHD. Following a more detailed description of the EF components where this pattern was most prominent, we will consider two possible explanations for these findings.

Our findings largely corroborate previous reports of an EF deficit associated with ADHD. Participants with ADHD were less accurate than controls in performing tasks tapping various aspects of inhibitory control—both interference suppression and the habitual response suppression, as has been reported by others (e.g., Barkley, 1997; for review, see Hervey et al., 2004; Schoechlin & Engel, 2005). Furthermore, participants with ADHD were also less accurate than controls in the task-switching paradigm. Task-switching paradigms have been less extensively examined with ADHD, and previous studies have sometime also reported decrements in RT (King et al., 2007), which was not replicated in the current results.

In the interference suppression tasks, namely, the Numeric Stroop task and the conflict condition in the Simon arrows task, the two monolingual groups were equally fast, but the monolingual ADHD group showed lower accuracy rates. These results might indicate a speed accuracy trade-off among monolingual participants with ADHD, meaning that they managed to maintain adequate RT by extensive effort, which led to lower accuracy rates. Conversely, the bilingual ADHD group performed worse than the bilingual control group in both speed and accuracy. These findings might indicate that whereas monolinguals with ADHD were able to compensate for their difficulty by routing their efforts toward one aspect of performance, bilinguals with ADHD were not able to compensate for their poor ability in either aspect of performance, perhaps due to lower inhibitory function. However, in the incongruent trials in the task-switching paradigm, all participants with ADHD showed decrements in both speed and accuracy, possibly because of the higher cognitive demands of the paradigm, which also included task switches.

Specifically, the difficulty of the participants with ADHD was localized to the incongruent trials in all three paradigms (Stroop, Simon, and task switching). This finding is consist with previous studies using the Stroop task (Boonstra et al., 2010; King et al., 2007; Nigg et al., 2005) and the Simon task (Sebastian et al., 2012), indicating that the ADHD disadvantage is manifested most strongly in situations that demand conflict resolution by suppressing non-relevant responses. The results of the present study further suggest that the ADHD disadvantage in conflict resolution tasks might be more prominent among bilinguals. The fact that this pattern was found across three different conflict resolution paradigms supports the notion of a plausible combined effect for bilingualism and ADHD on interference suppression.

In contrast, we did not find any specific ADHD disadvantages in the habitual response suppression or in components of task switching and mixing, but rather a general increase in error rates. This overall decrease in accuracy might reflect the difficulty of participants with ADHD to maintain attention over the entire length of the tasks. Thus, these differences in performance between ADHD and control participants most likely reflect the difficulty of the former groups in sustaining attention over longer periods of time (e.g., Albrect et al., 2008; Sergeant, 2005; Tsal et al., 2005; Uebel et al., 2010).

As far as shifting abilities are concerned, a fairly clear pattern emerged. First, the TMT seemed not to be a sensitive measure in our population of adult University students. We did not replicate previous bilingual advantages that have been reported with this tool in younger children (Bialystok, 2010), nor previous reports of ADHD disadvantages on this measure (Boonstra et al., 2005; Nigg et al., 2005; Willcutt et al., 2005). The main findings from the task-switching paradigm, interestingly, again pointed toward disadvantages of adults with ADHD in inhibition, rather than in shifting and cognitive flexibility. In contrast to earlier studies that found increase switching costs for participants with ADHD over controls (Cepeda et al., 2000), we found only an overall increase in error rates, which was not specific to switch trials. The inclusion of both congruent and incongruent conditions within the mixed block shifted the focus of participants to competition at the response level, and thus the decrease in performance for participants with ADHD was most evident in the incongruent trials. Here again, we did not find any differences in performance between monolinguals and bilinguals. The results of the current study might suggest that the combined effect of bilingualism and ADHD is associated with the differentiation between subcomponents of inhibitory function, and specifically interference suppression. Thus, the findings from the current study support the notion of distinct inhibitory processes, and furthermore, suggest that language experience and ADHD have a joint effect on some but not all inhibitory subcomponents.

Importantly, bilinguals in the current study were not found to outperform monolinguals in any of the components of EF, in contrast to previous findings (e.g. Bialystok et al., 2008; Bialystok & DePape, 2009; ; Hernandez et al., 2010; Prior & Gollan, 2011; Prior & MacWhinney, 2010; for review, see Hilchey & Klein, 2011). However, as opposed to the robust and well-established relation between ADHD and deficits in EF (e.g. Boonstra et al., 2005), the available data from research on bilingual young adults suggest a more complex link between language experience and EF (Costa, Hernandez, Costa-Faidella, & Sebastian-Galles, 2009; Hilchey & Klein, 2011; Paap & Greenberg, 2013). One aspect of language experience relates to the level of language proficiency, suggesting that the bilingual advantage in EFs is more prominent among balanced bilinguals than in less balanced bilinguals who do not use both languages equally (Tao et al., 2011). The bilingual participants in the present sample were arguably less balanced because they demonstrated higher proficiency in Hebrew than in Russian. Likewise, the monolingual participants were not "pure monolinguals," who lack any knowledge of any language other than their native language. Ideally, the experimental groups would include highly balanced bilinguals, alongside pure monolinguals. However, it might be hard to fulfill this requirement, due to the rising prevalence of second language use (Cook, 2002). Therefore, the lack of a bilingual advantage in the current samples might be due to the specific proficiency characteristics of the bilingual and the monolingual participants.

Although a combined effect of bilingualism and ADHD was expected, the specific nature of this effect—suggesting that the decrease in EF associated with ADHD might be more prominent among bilinguals—was quite surprising. This is the case especially in light of the fact that the participant groups were very well matched in language variables and other background variables (see Table 1). We offer two possible explanations for this pattern of results. First, although the groups were well matched in attentional variables, it is possible that the ADHD screening assessment was not sensitive enough to detect latent differences between the ADHD groups, which still exerted their influence in the experimental EF measures. This assumption is based on previous findings that indicate heterogeneity in the combination of deficits among individuals with ADHD (Tsal et al., 2005), alongside a lack of reliable diagnostic criteria, especially for adults, which lead to heterogeneity in the diagnosed population (Barkley, 2006; Davidson, 2008). If the differences in attentional characteristics in the current sample were random, then a larger sample size might be helpful in overcoming this issue.

Alternatively, differences between the ADHD groups we studied might reflect differences between the Russian Hebrew bilingual population and the Hebrew monolingual population who were diagnosed as having ADHD. Such a biased difference might stem from under- or over-diagnosis in one population in comparison with the other, perhaps due to differences in cultural approaches (Timimi & Taylor, 2004). Specifically, monolinguals might be more aware of the disorder and more willing to make use of diagnosis to benefit from accommodations. Conversely, bilinguals might be more wary of a disorder that carries a negative stereotype with it, and thus not self-refer for diagnosis. In addition, because the bilingual participants in this study were from an immigrant population, they might have been less able to make use of available resources for diagnosis and support. Thus, although the ADHD screening measures did not reveal group differences, it still might be the case that bilinguals suffered from more severe ADHD than monolinguals, which then became apparent in the experimental EF tasks. Therefore, further research should survey the prevalence of individuals receiving a diagnosis of ADHD among immigrant populations in comparison with the general population, in Israel and elsewhere.

A second possible explanation for the larger deficits we observed for bilinguals with ADHD might be rooted in the ongoing burden of handling two language systems. Thus, bilinguals continuously need to overcome possible interference from the nontarget language (Kroll, Bobb, Misra, & Guo, 2008). This added burden may be especially detrimental to individuals with ADHD because of the inherent weakness of the attentional system. The fact that we found the specific interaction between bilingualism and ADHD in the interference suppression component of the inhibitory control system lends further support to this possibility. Along similar lines, according to socioconstructivist theories of development (e.g. Vygotsky, 1978), the cognitive demands of shifting between languages might have been outside the zone of proximal development for bilingual participants with ADHD, thus inhibiting their development along the dimensions of EF.

The current results do not presently allow us to prefer one of the alternatives we suggested over the other and they are not mutually exclusive. Further studies examining the prevalence and severity of ADHD in monolingual versus bilingual populations more carefully are necessary. Such studies will further our understanding whether the differences identified in the current study are a result of population differences in seeking diagnosis or rather reflect intrinsic changes to the attentional system itself as a combined result of ADHD and bilingualism. The current study included relatively small samples, and did not distinguish among the various ADHD subtypes. Thus, further research is necessary to ascertain whether the preliminary patterns identified in this study will hold for larger populations, and also for the various subtypes.

The consequences of ADHD and bilingualism have been treated separately until now, but the current study suggests that these factors might have interactive consequences for EF. Therefore, both language experience and attentional functioning should be considered in participant selection. Studies that investigated the relation between bilingualism and EF have to date excluded participants with ADHD, due to the robust evidence regarding the negative impact of ADHD on EF. However, the present study further suggests that language experience itself might be a confounding factor in studies that investigate the relation between ADHD and EF, and might enhance differences between ADHD and controls. Thus, future research into the adverse effects of ADHD on EF should carefully investigate the language background of participants, and this should also be a factor taken into account in clinical settings. Ultimately, epidemiological studies might be able to identify whether bilingualism might be considered a risk factor contributing to ADHD diagnoses. Given the preliminary nature of the current study, more research is necessary to answer these questions.

In conclusion, the current study suggests that bilingualism and ADHD might have a combined effect on EF. Specifically, the ADHD disadvantage in EFs might be more pronounced among bilinguals in comparison with monolinguals, and most prominently in interference suppression tasks. Due to the novelty of the subject in question, the findings from the current study should only serve as initial evidence. Clearly, this issue must be further investigated among varied bilingual populations, and perhaps in the long run will assist in shedding more light on the complex relation between bilingualism and EF.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study was supported by EU-FP7 Grant IRG-249163 to Anat Prior.

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