Is there an effect of diglossia on cognition? An investigation of the relationship between diglossia and Executive Functions in young adults.

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Abstract:

Recent studies investigating whether bilingualism has effects on cognitive abilities beyond language have produced mixed results, with evidence from young adults typically showing no effects. These inconclusive patterns have been attributed to many uncontrolled factors, including linguistic similarity and the conversational contexts the bilinguals find themselves in, including the opportunities they get to switch between their languages. In this study, we focus on the effects on cognition of diglossia, a linguistic situation where two varieties of the same language are spoken in different and clearly separable contexts. We used linear mixed models to compare 32 Arabic diglossic young adults, and 38 English monolinguals on cognitive tasks assessing the Executive Functions domains of inhibition, switching and working memory. Results revealed that, despite both groups performing as expected on all tasks, there were no effects of diglossia on their performance in any of these domains. These results are discussed in relation to the Adaptive Control Hypothesis. Considering that this is the first study to investigate the diglossic advantages in Arabic, we propose that any effects on Executive Functions that may be attributed to the use of more than one language or language variety should not be expected when the two are used in exclusive contexts with limited opportunity to switch between them.

Keywords

Diglossia, bilingualism, cognition, Executive Functions.

1. Introduction:

The effects of using two languages on cognition have been widely discussed in the psycholinguistic literature on bilingualism. It is widely accepted that the two languages of a bilingual are constantly active and, in order to select the language that is appropriate to a given context, a bilingual must access domain general mechanisms that are not restricted to language processing (Green & Abutalebi, 2013). These mechanisms are thought to include Executive Functions such as inhibition, switching and working memory (Miyake et al., 2000). Significantly better performance for bilinguals compared to monolinguals in non-linguistic tasks tapping into these functions have led several researchers to claim cognitive advantages in bilinguals, which stem from their long-term greater reliance on these Executive Functions; however, this claim remains controversial, especially as far as young bilinguals are concerned (for a comprehensive review, see Valian, 2015). Much less is known about the effects on cognition of speaking two *varieties* of a single language, in linguistic situations such as bidialectalism and diglossia; indeed, the limited available evidence has only added to the controversy in the field. Many explanations have been put forward to explain the contradictions in the evidence, including some relating to the type and frequency of opportunities for switching between languages/varieties. One of the most prominent proposals is the Adaptive Control Hypothesis (Green & Abutalebi, 2013), which predicts that different bilingual conversational contexts require different degrees of reliance on Executive Functions, and as a result, modulate the extent of the relevant effects on cognition (see also; Bialystok, Craik, & Ryan, 2006; Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009). One of the contexts that the Adaptive Control Hypothesis describes is the Single Language Context, where limited opportunities for language switching occur, and as a result minimal, if any, effects on cognition should be expected compared to the Dual Language Context which allows for more switching. In the present

study, we focus on Arabic diglossia as a case for studying the effects of using two varieties of the same language on cognition. Arabic diglossia offers a good example of a Single Language Context which provides limited opportunities for switching between the two varieties, allowing to test the predictions of the Adaptive Control Hypothesis for Single Language Contexts. The remaining sections of this introduction define diglossia, summaries the evidence on the effects of two languages, or two varieties of a single language, on cognition in young adults, before outlining the aims of the present study.

1.2. Defining diglossia

According to Ferguson (1959), diglossia refers to the coexistence of two or more related varieties of the same language in one community. Ferguson described four linguistic situations as prototypes of diglossia, including Standard/Colloquial Arabic (in the Arab world), Katharevousa/ Dhimotiki (in Greece), Standard/Swiss German (in German), and Standard /Creole French (in Haiti); in such situations one variety functions as the “standard” formal language, while the other is typically a regional dialect. The two varieties are very divergent: the standard or “high” (H) variety is highly codified, more grammatically complex, often the language used for written literature or for educational or religious reasons, and learned through formal education. As a result, a person speaking the high variety is often seen as more educated or of higher status. The “low” (L) variety tends to be less grammatically complex, used for everyday conversation in informal settings, and is learnt at home.

As already mentioned, one of the prototypical diglossic situations is diglossia in Arabic-speaking countries. Modern Standard Arabic (MSA) is the common high variety

which is used across Arabic-speaking nations in formal contexts and found in literature, governance, religious discourse and formal speeches. Low varieties of Arabic, known as colloquial dialects, vary between countries and are used in informal communication in music, films, sport and everyday conversation (Albirini, 2016). In contrast to the disappearing diglossic situations of other countries (e.g. Greece) (Frangoudaki, 1992), diglossia remains a defining characteristic of the Arab world. This serves to maintain the Islamic heritage and the language of the Qura'an (Amara & Mar'I, 2002), enforces a sense of nationalism and functions as a unifying force amongst Arab countries (Palmer, 2008). Diglossia in the Arab world, therefore, constitutes an ideal candidate for studying the effects of using two varieties of a language on cognition, a phenomenon that remains under-researched (Alrwaita, Houston-Price & Pliatsikas, 2020).

1.3. The effects of bilingualism on Executive Functions

Before considering the effects of diglossia on cognition, it is useful to review the evidence relating to bilingualism, which has received greater attention from researchers. As discussed earlier, the juggling of two languages in the bilingual mind is thought to activate domain general cognitive mechanisms that support Executive Functions (EFs). Thus, bilinguals are “trained” to prevent interference from the non-target language in order to use the target language (Bialystok et al. 2012; Carlson & Meltzoff 2008). The need to constantly inhibit interference is thought to be the origin of the reported enhanced inhibition abilities in bilinguals compared to monolinguals, which are seen even in non-linguistic tasks (Calvo & Bialystok, 2014; Costa, Hernández, & Sebastián-Gallés, 2008; Kroll & Bialystok, 2013; Ross & Melinger, 2017). Inhibition, the ability to suppress attention to, or ignore, misleading

information in order to attend to an appropriate target, along with switching, the ability to switch from one task to another, and working memory/updating, the ability to temporarily hold information in mind for processing, are fundamental to Executive Functions (Miyake et al., 2000) and the most commonly investigated domains in bilingual studies.

While the bilingual ability to manage two languages is considered to enhance executive control abilities (Kroll & Bialystok, 2013), only a small number of studies have replicated findings of advantages in young adults (Costa et al., 2009; Emmorey, Luk, Pyers, & Bialystok, 2008). The advantage is found most commonly in older bilinguals (Hilchey & Klein, 2011). For instance, Kousaie and Phillips (2012) reported no bilingual advantages in tasks requiring inhibitory control amongst young adults (see also; Paap & Greenberg, 2013; Scaltritti, Peressotti, & Miozzo, 2017). Similar null findings were reported in studies investigating bilingual advantages in switching tasks (Hernández, Martin, Barceló, & Costa, 2013; Paap & Greenberg, 2013), and working memory tasks (Bialystok, Craik, & Luk, 2012; Paap & Greenberg, 2013). The lack of a consistent advantage for young adults was explained in terms of the peak performance hypothesis, which states that, in contrast to children and older adults, young adults are at the peak of their cognitive performance (Bialystok, Martin, & Viswanathan, 2005), making it difficult to find evidence of advantages in one group over another (Paap, Johnson, & Sawi, 2015).

Given that bilingual advantages have been closely linked to language use (Yang, Hartanto, & Yang, 2016), it is perhaps surprising that the inconsistent findings in the literature have not previously been linked to differences in linguistic context or amount of language switching of the bilingual participants studied. It has recently been suggested that the extent to which bilinguals engage their Executive Functions to resolve conflict between their two languages are spoken. According to the Adaptive Control Hypothesis (ACH) (Green & Abutalebi, 2013), there are three conversational contexts that vary in the amount

of switching between a bilingual's two languages, each impacting on Executive Functions differently: (a) the Single Language Context, where speakers use each language in a different context (e.g., one language at home and another at work); (b) the Dual Language Context, where speakers use the two languages in the same context, and switching occurs between sentences but not within sentences; (c) the Dense Code-Switching context, where speakers freely switch between the two languages within the same sentence. According to the ACH, Dual Language Contexts require the most inhibitory control, followed by Single Language Contexts and the Dense Code-Switching contexts, and Dual Language Contexts should therefore result in particularly enhanced Executive Functions (Green & Abutalebi, 2013). Following the Adaptive Control Hypothesis categorization, diglossia, and Arabic diglossia in particular, is closest to the bilingual Single Language Context, considering the exclusive contexts in which the varieties are used and the minimal switching between the two varieties. Diglossia therefore provides a test case to study the effects on cognition of linguistic contexts where proficient speakers of two language varieties have only minimal need to switch between them.

1.4. The effects of speaking two varieties of one language on Executive Functions.

Only a few studies have investigated the effects of speaking two varieties of a single language on Executive Functions of young adults. We first review the evidence from bidialectalism, a linguistic situation that is very similar to diglossia but where the typical H and L varieties of diglossia are better represented as a standard variety and a local dialect (Papapavlou & Pavlou, 1998). Scaltritti and colleagues (2017) investigated whether the amount of exposure to the two varieties of a language relates to bidialectals' performance in

inhibitory control tasks. In two experiments, Scaltritti et al. reported no significant correlation between exposure to the two varieties and performance in the Flanker and Simon tasks; moreover, they reported no advantages for bidialectals compared to Italian monolinguals, in line with studies that report no bilingual advantage in young adults (Kousaie & Phillips, 2012; Paap & Greenberg, 2013). Scaltritti et al. (2017) argued that the lack of switching between dialects in the Italian-Venetian context explains the lack of the bidialectal advantage in this study. Poarch and colleagues (2019) investigated whether balanced usage of the Swabian-German dialect and standard German enhances bidialectals' performance in Simon and Flanker tasks. Poarch and colleagues compared balanced Swabian-German and Swabian-dominant bidialectals aged 18- 26 and reported smaller Flanker and Simon effects in the Swabian-dominant group, which they interpreted as an advantage. Poarch et al. suggested that using the non-standard dialect more than the standard language dialect enhances inhibitory control over equal use of the two dialects. This conclusion contradicts the findings of Scaltritti et al., (2017), and others; for example, Bosma and colleagues have suggested that Frisian-Dutch children who are more balanced in proficiency, perform better in Executive Functions tasks than unbalanced children (Bosma, Hoekstra, Versloot, & Blom, 2017).

To date, only one study has investigated the effects of diglossia on Executive Functions in young adults (Antoniou & Spanoudis, 2020). This study was conducted in Cyprus, where Modern Standard Greek functions as the high variety and Cypriot Greek the low variety (Antoniou, Kambanaros, Grohmann, & Katsos, 2016). Diglossic and multilingual advantages were explored across the Executive Functions domains of inhibition, switching and updating (Miyake, 2000) by comparing diglossics (speakers of Cypriot Greek & Modern Standard Greek), multilingual participants (speakers of Cypriot Greek, Modern Standard Greek & another language) and monolingual speakers of Modern

standard Greek on the Stroop, Flankers, Color-Shape, N-back and Corsi block tasks. Antoniou and Spanoudis reported both multilingual and diglossic advantages across all Executive Functions components. Notably, while these findings contradict the results of studies in bilinguals and bidialectals of a similar age, they corroborate those of Antoniou et al., (2016), who found diglossic advantages in Cypriot-Greek children.

The discrepancy between the evidence from diglossia and bidialectalism, two very similar linguistic situations, is intriguing, and potentially related to the different usage of the two language varieties in bidialectal and diglossic settings. Most importantly, Antoniou & Spanoudis's findings (2020) contradict the prediction that executive control demands should be low in diglossic environments, given the clear separation between the contexts in which each variety is used (high variety for writing, low variety for speaking).

1.5. The Role of Context and Switching

As mentioned, both diglossia and bidialectalism constitute Single Language Contexts in the Adaptive Control Hypothesis terms (Paap & Greenberg, 2013); both offer limited opportunities for switching between the two varieties, which are used in a specific context. For these reasons, the Adaptive Control Hypothesis predicts that Single Language Contexts have minimal effects on Executive Functions compared to dual language contexts with their greater language switching requirements. The predictions of the Adaptive Control Hypothesis are supported by studies highlighting the role of language switching in modulating performances in Executive Functions tasks (Bialystok et al., 2006; Costa et al., 2009) and by the observation that the bilingual advantage is more likely to be found in tasks that require more switching (Bialystok et al., 2006; Costa et al., 2009). It is therefore important to consider why, in conditions where we would expect to see minimal or no

advantages (diglossic and bidialectal environments), contradictory results have been found in the only available study of diglossia (Antoniou & Spanoudis, 2020).

While the bidialectal and diglossic situations appear to be similar, it is worthwhile considering the differences in how the H and L varieties function in each case, and how often speakers switch between them. First, bidialectalism develops in diglossic situations when H takes over L, meaning that the high variety is used for both formal and informal purposes (Grahmann, 2013). Second, diglossic native speakers are raised in homes where only L is used (Keller, 1982). Finally, in bidialectalism H is seen as the more prestigious variety and learning it is considered more important than learning L, while in diglossia both variety are expected to be learned (Rowe & Grohmann, 2013). Linguistically, in bidialectalism H and L are similar in complexity, while in diglossia H is syntactically and grammatically more complex than L (Ferguson, 1959).

There are also some differences in the functional uses of bidialectalism and diglossia, which suggest that diglossia better corresponds to the Single Language Context than bidialectalism. In diglossia, switching between the two dialects depends entirely on the activity, as all users understand both varieties, although the level of understating of the H variety can vary with education. However, in bidialectalism the use of the two varieties is overlapping (Masica & Sinha, 1986); which means that both H and L can be used for formal purposes. It follows that we should be less likely to observe cognitive advantages in diglossia than in bidialectalism. As described above, the limited available evidence points in the opposite direction, suggesting that broad brush categorizations of environments as diglossic or bidialectal might not necessarily describe the important characteristics of those environments. For example, in diglossia, exposure to and usage of the two varieties might vary considerably across different languages (Kaye, 2001). Given that lower exposure to

one variety results in less switching between the two varieties, and therefore to less enhancement of executive control abilities (Kirk, Fiala, Scott-Brown, & Kempe, 2014; Scaltritti et al., 2017), relative use of the two varieties in diglossia is likely an important factor to consider. Interestingly, the diglossic situation in Cyprus has been recently characterized as diglossic transitioning into type B diglossia or “*diaglossia*”, where the use of the standard or H dialect is no longer restricted to written purposes, but also extends to oral communication. In such cases, and the extent of code-switching depends more on the situation than on the activity (speaking/ writing) (Auer, 2005; Rowe & Grohmann, 2013), a situation that is more similar to bidialectalism than true diglossia. This issue highlights the need for studies of diglossia in environments other than Cyprus.

Arabic offers the ideal test case for investigating the effects of diglossia on Executive Functions. First, in typical diglossia there is a clear separation between the contexts in which each dialect is used, which should limit enhancements to Executive Functions (Costa et al., 2009). This separation is strongly enforced in Arabic diglossia, where there is rigid use of the high variety for formal purposes and the low variety for informal purposes (Albirini, 2016), ruling out the possibility of an overlap in their use (Kaye, 2001). According to Albirini (2016), even the most educated Arabs do not use the formal dialect (H) for informal purposes, or vice versa; doing so would be a clear violation of sociolinguistic norms (Albirini, 2016). In contrast, switching between the high and the low dialects is very frequent in Cyprus, even when the speaker does not intend to switch (Pavlou, 2004). Second, some Arabic speakers are rarely exposed to the high variety; even educated Arabs would find it difficult to hold conversations entirely in the high variety, and understanding it is even more difficult for uneducated Arabs (Kaye, 2001). Again, this implies less switching between the two dialects and, as a result, less enhanced Executive Functions. Arabic therefore offers an

example of diglossia that in which two language varieties are used in a Single Language Context.

2. This study

To investigate whether Arabic diglossia has an effect on Executive Functions abilities, we compared young Arab diglossics to English-speaking monolinguals of the same age in a series of tasks tapping into the three domains of Executive Functions (Miyake et al., 2000), namely Flanker, Stroop, Color-shape Switching and Nback. If our results replicate the findings by Antoniou & Spanoudis (2020), this would suggest that diglossic situations, in general, enhance performances in Executive Functions tasks, irrespective of the amount of language switching (which, as discussed, differs between Cyprus and the Arab world). If we fail to report a diglossic advantage, this could be attributed to the specific properties of diglossic Arabic and its rigid correspondence to a Single Language Context as defined by the Adaptive Control Hypothesis.

3. Methods:

3.1. Participants:

70 young adults participated, 32 Arabic speaking diglossic young adults (22 females, mean age= 29.6 (5.6)), and 38 English speaking monolinguals (34 females, mean age= 21.6 (5.6)). Arabic speaking adults were recruited from Prince Sultan University in Riyadh, Saudi Arabia. English speaking adults were recruited from the School of Psychology and Clinical Language Sciences at the University of Reading. One English-speaking individual was excluded for having bilingual parents and scoring significantly higher than other

monolinguals in the Language and Social Background Questionnaire (LSBQ) (Anderson, Mak, Keyvani Chahi, & Bialystok, 2018) (see below). Table 1 presents demographic information for our sample.

3.2. Language background and proficiency measures:

Prior to the study, our monolingual participants were assessed using the Language and Social Background Questionnaire (LSBQ)(Anderson et al., 2018). The LSBQ examines the degree to which, and the domains in which, participants use English, and other languages (if applicable), in their daily lives. To measure proficiency, the questionnaire includes self-rating questions about reading, writing and listening skills in English/other languages. Factor scores were calculated for each participant for three domains: English proficiency, non-English social use, non-English home use. A composite ‘bilingualism score’ was computed by summing the factor scores weighted by the variance in each factor. According to Anderson et al., (2018), those with composite scores below -3.13 should be classified as monolinguals, while composite scores above 1.23 indicate bilinguals. Our monolingual young adults had an average composite score of -8.18 with a standard deviation of 1.2.

To ensure that our diglossic group were indeed diglossics (knowing both the standard and the spoken dialect), we adapted the LSBQ to investigate the degree of dialect use, and the domains in which each dialect was used (Appendix A). Arabic-speaking diglossics were asked to complete the adapted version of the LSBQ on which they achieved an average composite score of -0.21 with a standard deviation of 2.6. According to Anderson et al., (2018), this score lies in the gray area between bilingualism and monolingualism.

Because the level of knowledge of Standard Arabic differs according to the level of education and exposure to the standard dialect (Kaye, 2001), proficiency in Standard Arabic was measured using a vocabulary test designed by Masri and Milton (2017). This test is administered using a pen and a paper and it comprises a checklist of the most common Arabic words (generated by Kilgariff et al., (2014) from the web-based corpus of Arabic (Sharoff, Umanskaya, & Wilson, 2014). The test is divided into two parts, each including 20 words and 20 non-words intermixed. Participants indicated if they recognized each word by responding either yes or no to each word. The duration of the test is between 10-15 minutes. According to Masri and Milton (2017) a native Arabic speaker around the age of 20 would acquire 2,000 words and this would increase with age. Based on performances in the vocabulary test, no one was excluded from the diglossic group (see Table 1).

3.3. Executive Functions tasks:

The battery of executive function tasks included tasks measuring inhibition, switching and working memory. Flanker and Stroop tasks were administered to measure inhibition, the Color-shape task was administered to measure switching, and finally the Nback task was administered to measure working memory. Tasks were delivered using E-prime 2.0 software (Psychology Software Tools, PA; for more information on the tasks see Kendrick, Robson, & Meteyard, 2019). All tasks were presented in a 15.6-inch computer screen, and all participants were tested in private rooms.

3.3.1. Inhibition

3.3.1.1. Flanker:

This task had three conditions: Congruent, Incongruent and Neutral. In all conditions, a central arrow appeared on the screen and participants were asked to indicate if the arrow pointed to the right or left by pressing either (<) or (>) buttons on the keyboard. Participants were instructed to respond as fast and accurately as possible. In the congruent condition, there were surrounding (flanking) arrows, which pointed in the same direction as the target central arrow (<<<<<). In the Neutral condition, the target central arrow appeared with dashes on the left and the right sides (--< --). In the Incongruent condition, there were surrounding arrows pointing in the opposite direction to the target central arrow (>><>>). 44 trials of each type were distributed across four blocks, each including 33 trials, 11 per condition, presented in a random order. Each trial began with a 250 ms fixation cross, followed by a stimulus lasting for 5000 ms, or until a response was provided. Trials were separated by a blank screen which appeared for 250 ms.

3.3.1.2. Stroop:

In this task, a single word appeared on the screen and participants were asked to decide the Color in which a word was written. The task consisted of three conditions: Congruent, Incongruent and Neutral. In the Congruent trial, the target word was consistent with the ink Color; for example the word “green” was presented in green ink. In Neutral trials, Neutral words were written in different ink Colors (red, green or blue). In Incongruent trials, names of Colors were presented that were inconsistent with the ink Color; for example; the words “green” in red ink. The three different Colors (red, green and blue) were assigned to three adjacent keyboard buttons and participants responded by clicking the corresponding button (see Fig 1).

48 trials of each type were distributed across three blocks, each consisting of 48 trials in random order, with a total of 144 trials. Each trial began with a 250 ms fixation

cross, followed by the presentation of the word for a maximum of 5000 ms, or until a response was provided.

For Arabic-speaking participants, the same task was administrated translated in Arabic.

3.3.2. Switching

3.3.2.1. Color-Shape Switching:

In this task, participants were presented with three possible patterns in either blue, green or red. There were three blocks. First, in the blocked Color task, two patterns appeared on the screen and participants had to decide if the patterns were the same or different Colors. Second, in the blocked pattern task participants were presented with two patterns and were asked to decide if the pattern was the same or different. Third, in the switching task participants had to switch between attending to the Color or the pattern. In each trial, a word (Color/ pattern) was presented at the top of the screen, indicating whether Color or pattern should be responded to. To respond, participants had to press the S button on the keyboard for “same”, or the D button for “different” (see Fig 1).

There was a total of 124 trials. The blocked Color task and blocked pattern task each included 31 trials. The switching block included 62 randomized trials consisting of 31 ‘Stay’ trials, where participants were asked to attend to the same property (Color/pattern) as the previous trial, and 31 Change trials, where participants had to switch to attending to the other property. Each trial began with a 100 ms central fixation cross, followed by a stimulus presentation until a response was detected. There was a 250 ms blank screen between trials.

3.3.3. Working memory

3.3.3.1. Nback:

This task included two versions with increasing working memory load: 1-back and 2-back. In both, a single number between 1 to 9 appeared on the screen. In the 1-back version, participants were asked to decide if the number they saw on the screen was the same as the number that had appeared one trial before. In the 2-back version, participants were asked to decide if the number they saw on the screen is the same as the number that appeared two trials before. If the answer was yes, participants were asked to press a key; if the answer was no, participants were asked not to respond (see Fig 1).

The task included 117 trials, of which 36 were target ('yes') trials. These trials were distributed across four blocks, each containing 9 targets. The paradigm for this task was similar to other Nback tasks, with a ratio of trial to target of 31% for the 1-back condition and 32% for the 2-back. Each stimulus was presented for 500 ms, after which a black screen appeared for 1500ms, to allow the participant to make a decision and respond before the next number appeared. In each task, no more than two target trials appeared consecutively.

Figure 1: Stroop task, Color-shape task, Nback task (Kendrick et al., 2019).

4. Results:

Analyses of accuracy and reaction time (RT) data were run using generalized linear mixed-effects models from the statistical package *lme4* (Kendrick et al., 2019), in R studio version (4.0.3). Because reaction times were not normally distributed, they were log-transformed prior to the analysis.

4.1. Flanker:

The RTs from both groups we screened for extreme values defined as anything that exceeded 2500 ms, or was less than 200 ms. These values were excluded, affecting 1.7% of the Diglossics (DI) data, and 3.7 % of the Monolinguals (MONO) data.

4.1.1. Accuracy:

Accuracy results are provided in the supplementary materials. As the optimization requires more than 10000 iterations, and to avoid convergence errors, we increased the

amount of iterations to 100000. A maximal model with random intercepts and slopes for both subject and condition, and interaction between group and condition did not converge. We then simplified the structure by removing the interaction between group and condition for the slope; however, the model did not converge. Finally, we removed the random slope for condition and the model converged. Model comparison revealed that the model with random intercept for subject, and random slope for condition provided a better fit than the model without a random slope despite convergence issues. Results for the model without slopes is provided in (Appendix B). To get values for the missing comparison (Incongruent vs Neutral), we have used the contrast function from the *emmeans* package (Lenth et al., 2021) which allows for a contrast between all variables.

To measure the contribution of group, condition and interaction between group and condition to the overall fit, we have compared models with and without these factors. The inclusion of condition contributed significantly to the overall model fit ($\chi^2(4)=26.939, p=0.001$). The results revealed that Incongruent (M correct responses= 95%, $SD(21)$) was significantly less accurate than both Congruent (M correct responses= 98%, $SD(12)$) ($\beta=-1.334, SE=0.570, t(.)=-2.340, p=0.019$), and Neutral (M correct responses= 98%, $SD(14)$) ($\beta=-0.960, SE=0.321, t(.)=-2.988, p=0.007$). There was no significant difference between Congruent and Neutral. However, the inclusion of group did not contribute significantly to the overall model fit ($\chi^2(3)=6.6608, p=0.083$). Further analysis showed no significant difference between Diglossics (M correct responses=97%, $SD(14)$) and Monolinguals (M correct responses=96%, $SD(17)$). The interaction between group and condition did not significantly contribute to the overall model fit ($\chi^2(2)=1.7473, p=0.4174$). Further analysis showed no significant interaction between group and condition.

4.1.2. Reaction Times:

For the RTs analysis, all incorrect trials were removed. For the Diglossics incorrect trials are 86 out of 3689 trials (7%), for the Monolinguals incorrect trials are 150 out of 4434 trials (4%).

Figure 2: Reaction times for Diglossics and Monolinguals across conditions for Flanker, Stroop, Color-shape and Nback.

Figure 2a illustrates RTs data for the Flanker task. The maximal model with random intercepts and slopes for both subject and condition, and interaction between group and condition yielded a singular error. We then simplified the structure by removing the interaction term in the slope; however, the model did not converge again. Finally, we removed the random slope for condition and the model converged. Model comparison revealed that the model with a random intercept for subject, and a random slope for condition provided a better fit than a model without a random slope despite singular error warning (for results see Table 1). Results for the model without slopes is provided in (Appendix C). To

get values for the missing comparison (Incongruent vs Neutral), we have used the contrast function from the *emmeans* package (Lenth et al., 2021)

<insert table 1 here>

To measure the contribution of group, condition and interaction between group and condition to the overall fit, we have compared models with and without these factors. The inclusion of Condition did contribute significantly to the overall model fit ($\chi^2(4)=95.255, p<0.001$). Further analysis revealed a significant difference between Congruent and Incongruent trials, with Incongruent (M RTs =2.77 ms, SD(0.10)) being significantly slower than Congruent (M RTs =2.70, SD(0.18)) ($\beta=-0.080, SE=0.008, t(68.080)=9.78, p<0.001$). There was also a significant difference between Congruent and Neutral trials, with Neutral (M RTs =2.69 ms, SD(0.175)) being faster than Congruent(M RTs =2.70 ms, SD(0.18)) ($\beta=-0.171, SE= 0.020, t(231.3)=-2.523, p=0.0123$). There was also a significant difference between Neutral and Incongruent trials, with Neutral trials being faster; ($\beta=-0.082, SE=0.0060, t(.)=13.64, p<0.001$). The inclusion of group contributed significantly to the overall model fit ($\chi^2(3)=30.344, p<0.0001$). Further analysis revealed a significant difference between Diglossics and Monolinguals, where Diglossics (M RTs =2.8 ms, SD(0.20)) were significantly slower than Monolinguals (M RTs =2.63 ms, SD(0.11)) ($\beta=-0.17, SE=0.029, t(65.79)=-5.74, p<0.001$). However, The interaction between group and condition did not significantly contribute to the overall model fit ($\chi^2(2)=3.34, p=0.1882$). There was a significant interaction between group and condition when comparing Incongruent and Neutral, where Monolinguals showed a smaller difference between the two conditions ($\beta=0.022, SE=0.003, t(782.9)=-5.74, p=0.0001$). There was no other group and condition interaction.

4.2.Stroop:

The RTs from both groups were screened for extreme values defined as anything exceeding 2500 ms, or was less than 200 ms. These values were excluded, affecting 1.4% of the Diglossics data, and 3% of the Monolinguals data.

4.2.1. Accuracy:

Accuracy results are provided in the supplementary materials. As the optimization requires more than 10000 iterations, and to avoid convergence errors, we have increased the amount of iterations to 100000. The maximal model with random intercepts and slopes for both subject and condition, and interaction between group and condition did not converge. We have then simplified the structure by removing interaction between group and condition in the slope; however, the model did not converge. Finally, we removed the random slope (condition) and the model converged. Comparing models with and without random slopes revealed that the model without slopes and without convergence errors is a better fit. To get values for the missing comparison (Incongruent vs Neutral), we have used the contrast function from the *emmeans* package (Lenth et al., 2021)

The inclusion of condition contributed significantly to the overall model fit $\chi^2(4)=21.03, p=0.0003$. Results revealed that Incongruent (M correct responses= 97%(16)), was significantly less accurate than both Congruent (M correct responses=98%, SD(16)) ($\beta=-0.789, SE=0.0343, t(.)=7.384, p=0.0214$), and Neutral (M correct responses=97%, SD(14)) ($\beta=0.029, SE=0.004, t(.)=6.837, p<0.001$). There was no significant difference between Neutral and Congruent.

Also, the inclusion of group contributed significantly to the overall model fit ($\beta = -0.385$, $SE = 0.182$, $\chi^2(3) = 14.642$, $p = 0.00215$). Further analysis showed a significant difference between Monolinguals and Diglossics, with the Diglossics (M correct responses = 98%, $SD(10)$) being more accurate than Monolinguals (M correct responses = 97%, $SD(16)$) ($\beta = -0.807$, $SE = 0.385$, $t(.) = -2.094$, $p = 0.0363$). The interaction between group and condition did not significantly contribute to the overall model fit ($\chi^2(2) = 0.539$, $p = 0.7635$). Results revealed that there was no significant interaction between groups and conditions.

4.2.2. Reaction Times:

All incorrect trials were removed. This affected 56 out of 4600 trials (2%) of the Diglossic group, 152 out of 5614 trials (3%) of the Monolingual group.

Figure 2b illustrates RTs data for the Stroop task which suggests that Monolinguals were faster. The maximal model with random intercepts and slopes for both subject and condition, and interaction between group and condition functioned without errors (for results see Table 2). To get values for the missing comparison (Incongruent vs Neutral), we have used the contrast function from the *emmeans* package (Lenth et al., 2021).

<insert table 2 here>

To measure the contribution of group, condition and interaction between group and condition to the overall fit, we have compared models with and without these factors. The inclusion of condition contributed significantly to the overall model fit ($\chi^2(4) = 68.535$, $p < 0.0001$). Results showed that Incongruent trials (M RTs = 2.82 ms, $SD(0.15)$) were significantly slower than both Congruent trials, (M RTs = 2.789 ms, $SD(0.141)$) ($\beta = -0.03792$, $SE = 0.0053$, $t(67.28) = 7.384$, $p < 0.001$), and Neutral trials (M RTs = 2.79 ms, $SD(0.13)$) ($\beta = 0.02950$, $SE = 0.0043$, $t(.) = 6.431$, $p < 0.001$). There was also a

significant difference between Congruent and Neutral, with Neutral being significantly slower ($\beta=0.013, SE=0.0047, t(-67.69)=2.740, p<0.01$). The inclusion of group contributed significantly to the overall model fit ($\chi^2(3)=42.63, p<0.0001$). Analysis revealed that there was a significant difference between Diglossics and Monolinguals, where Diglossics ($M RTs=2.86$ ms, $SD(0.137)$) were significantly slower than Monolinguals ($M RTs=2.75$ ms, $SD(0.13)$) ($\beta=-0.10721, SE=0.0172, t(67,97)=-6.232, p<0.001$). The interaction between group and condition did not significantly contribute to the overall model fit ($\chi^2(2)=2.0959, p=0.3507$). There was no significant interaction between group and conditions.

4.3. Switching:

The RTs from both groups were screened for extreme values defined as anything that exceeded 6000 ms, or was less than 300ms. Extreme values were excluded, affecting 2.3 % of the Diglossics data and 0.1 % of the Monolinguals data.

4.3.1. Accuracy:

Accuracy results are provided in the supplementary materials. As the optimization requires more than 10000 iteration, and to avoid convergence errors, we have increased the amount of iterations to 100000. The maximal model with random intercepts and slopes for both subject and condition, and interaction between group and condition did not converge. We have then simplified the structure by removing interaction between group and condition in the slope; however, the model did not converge. Finally, we removed the random slope (condition) and the model converged. Comparing models with and without random slopes revealed that the model without slopes and without convergence errors is a better fit.

To measure the contribution of group, condition and interaction between group and condition to the overall fit, we have compared models with and without these factors. The inclusion of Condition contributed significantly to the overall model fit ($\chi^2(2)=19.817, p<0.001$). Further analysis showed a significant effect of condition, where Change (*M correct responses*=94%, *SD*(23)), is less accurate than Stay (*M correct responses*=96%, *SD*(17)) ($\beta=0.835, SE=0.261, t(.)=-3.197, p=0.0013$). The inclusion of group significantly contributed to the overall model fit ($\chi^2(2)=10.883, p<0.01$). Results reveal a significant difference between Diglossics and Monolinguals, where Diglossics (*M correct responses*=97%, *SD*(0.166)) were more accurate than Monolinguals (*M correct response*=94%, *SD*(0.233)) ($\beta=-0.602, SE=0.244, t(.)=-2.467, p=0.0136$). The interaction between group and condition did not significantly contribute to the overall model fit ($\chi^2(1)=1.0522, p=0.305$). There was no significant contribution between group and condition.

4.3.2. Reaction times:

Along with extreme values, all incorrect trials were removed, for the Diglossics incorrect trials are 65 out of 2298 trials, for the Monolinguals incorrect trials are 180 out of 2037 trials. Removing incorrect trials affected 3% of the Diglossic group, and 6% of the Monolingual group.

Figure 2c illustrates RTs data for the Switching task which suggests that Monolinguals were faster. The maximal model with random intercepts and slopes for both subject and condition, and interaction between group and condition had a singular error. We have then simplified the structure by removing interaction between group and condition in the slope; however, the model did not converge. Finally, we removed the random slope

(condition) and the model converged. Model comparison revealed that the model without slopes and without errors is a better fit than the maximal model (for results see Table 3).

<insert table 3 here>

To measure the contribution of group, condition and interaction between group and condition to the overall fit, we have compared models with and without these factors. The inclusion of condition contributed significantly to the overall model fit ($\chi^2(2)=23.525, p<0.001$). Results revealed that there was a significant difference between conditions, where Change ($M RTs=3.05$ ms, $SD(0.17)$) is slower than Stay ($M RTs=3.03$ ms, $SD(0.18)$) ($\beta=-0.0128, SE=0.0052, t(0.0048)=-2.459, p=0.014$). Also, the inclusion of group contributed significantly to the overall model fit ($\chi^2(2)=30.344, p<0.001$). Further analysis showed a significant difference between Diglossics and Monolinguals, where Diglossics ($M RTs=3.124$ ms, $SD(0.180)$) were significantly slower than Monolinguals ($M RTs=2.969$ ms, $SD(0.147)$) ($\beta=-0.1466, SE=0.2570, t(7.083)=-5.702, p<0.001$). However, the interaction between Group and Condition did not significantly contribute to the overall model fit ($\chi^2(1)=1.1892, p=0.2755$). There is no significant interaction between group and condition.

4.4. Nback:

For the one-back task, the RTs from both groups we screened for extreme values defined as anything that exceeded 1200 ms, or was less than 250ms. Extremes values were excluded, affecting 1% of the Diglossics data and 1.3% of the Monolinguals data.

For the two-back task the RTs from both groups we screened for extreme values defined as anything that exceeded 1500 ms, or was less than 250ms. Extreme values were excluded, affecting 2% of the Diglossics data and 4% of the Monolinguals data.

4.4.1. Accuracy:

Removing upper cut off and lower cut off points results in no inaccurate results. Therefore, we did not run an accuracy analysis for this task, as all our participants were at ceiling.

4.4.2. Reaction Times:

Figure 2d illustrates RTs data for the Nback task which suggests that Monolinguals were faster. The maximal model with random intercepts and slopes for both subject and condition, and interaction between group and condition worked without errors (for results see Table 4).

<insert table 4 here>

To measure the contribution of group, condition and interaction between group and condition to the overall fit, we have compared models with and without these factors. The inclusion of condition contributed significantly to the overall model fit ($\chi^2(2)=19.177, p<0.001$). Analysis revealed that there was a significant effect of condition, where Two back (M RTs=2.697 ms, SD(0.174)) is significantly slower than One back (M RTs=2.661 ms, SD(0.151); $\beta=-0.06136, SE=0.02563, t(51.61)=2.394, p=0.020$). The inclusion of group also contributed significantly to the overall model fit ($\chi^2(2)=8.75, p=0.0125$). There is a significant difference between Diglossics and Monolinguals, where Diglossics (M RTs= 2.70 ms, SD(0.167)) were significantly slower than Monolinguals (M RTs=2.657 ms,

SD(0.15)) ($\beta=-0.07050, SE=0.02483, t(66.818)=-2.839, p=0.005$). The interaction between group and condition did not significantly contribute to the overall model fit ($\chi^2(1)=0.027, p=0.8688$). There was no significant interaction between group and condition.

5. Discussion:

Following suggestions that conversational contexts requiring different levels of switching affect Executive Functions differently (Green & Abutalebi 2013), this study examined whether diglossic participants (who with minimal opportunities for code-switching between their two language varieties correspond to Green & Abutalebi's Single Language Context) perform similarly to monolinguals. We compared the performance of Arabic speaking young adults to English speaking monolinguals of a similar age on four tasks, Flanker, Stroop, Color-shape and Nback, that cover Miyake's (2000) three domains of Executive Functions: inhibition, working memory and switching. In each task we compared performance between cognitively challenging and control conditions, namely between Congruent and Incongruent trials for the Flanker and Stroop tasks, between Stay and Change trials for the Color-shape switching task, and between One back and Two back trials for the for the Nback task. While all of our tasks yielded the expected pattern (i.e. lower accuracy and slower RTs for the more cognitively challenging conditions), the difference in performance across task levels did not differ between our diglossic and monolingual groups in any task. Specifically, our results did not reveal smaller cognitive costs for diglossics compared to monolinguals, a finding that has been typically interpreted as an advantages for bilingual groups when compared to monolinguals (Valian, 2015); in other words, our results suggest no diglossic advantages in any Executive Functions task.

These findings will be discussed with reference to previous studies and theoretical proposals for the effect of using two languages on cognition.

Despite the fact that the monolingual group had fewer males than the diglossic group, and that diglossics (M age=29.6) were slightly older than monolinguals (M age=21.6), we have not included either gender or age as covariates. First, to our knowledge gender was not discussed in the bilingual literature as modulator for Executive Functions. Second, both groups still lie within the young group category; mostly defined between 18-40 (Donnelly, Brooks, & Homer, 2019).

It is worth noting that the monolingual group had shorter RTs than the diglossic group across all tasks (all p s<0.001). While a bilingual advantage in global RTs have been often linked to the high monitoring skills of bilinguals compared to monolinguals (Hilchey & Klein, 2011), our study fails to replicate these effects in a diglossic population; rather, our findings point toward a global disadvantage for the diglossic group. It is important to note that bilingual advantages in overall reaction times have not been replicated in all studies (Antón, Carreiras, & Duñabeitia, 2019; Kirk et al., 2014). In order to explain this discrepancy, some have rejected bilingualism as a factor leading to faster RTs, and attributed the faster RTs sometimes found in this group to unmatched external factors such as socioeconomic status (Antón et al., 2019). Since monolinguals in our study demonstrated faster RTs than diglossics, we can't readily attribute this seeming diglossic disadvantage to the two groups' language experiences; indeed, we had no grounds to predict it, nor has it been reported previously. As suggested by Anton et al., (2019), this finding might be related to external factors which warrant further investigation. One candidate is task familiarity; our monolingual group were psychology students recruited for course credit who may have been familiar with the classic cognitive tasks we employed. In contrast, our diglossics were not recruited from a psychology department. Prior training has been shown to result in better

performance in inhibition, switching and working memory tasks (Chevalier et al., 2012; Hughes, Ensor, Wilson, & Graham, 2009; Salminen, Strobach, & Schubert, 2012) and to increased processing speed (Dux et al., 2009), and this suggestion might explain our overall RTs patterns. Another possible reason that could explain the longest reaction times by diglossics is that while both groups still lie within the gray area of young adults as defined by bilingual studies (Donnelly et al., 2019), diglossics were slightly older than monolinguals, and it has been suggested that processing speed and reaction times decline with age (Ferreira, Correia, & Nieto, 2015). Moreover, in a follow up analysis, we compared the maximal model with and without age. This showed no significant contribution of age in any of the tasks ($p>0.05$).

With respect to overall accuracy, there was no significant difference between the two groups except in the Color-shape switching task, where diglossics demonstrated significantly greater accuracy than monolinguals (although the monolingual group showed shorter reaction times on the same task). In other words, the diglossic group were slower but more accurate than the monolingual group in deploying their switching abilities, possibly suggesting that their language experiences have made them more successful in suppressing irrelevant information, albeit at a cost in terms of speed. However, this remains an uncommon finding, so we interpret it with caution.

To our knowledge, this is the first study that reports no Executive Functions advantages across the board in diglossics. Our study contradicts previous studies by Antoniou et al., (2016), who found a diglossic advantage in children, and Antoniou and Spanoudis (2020), who found a diglossic advantage in young adults. The contradiction between our and previous results might be explained in light of the amount of switching

required by our diglossic group. In Arabic the standard dialect and regional varieties are clearly separated by context, and orally switching between the two varieties is very unlikely (Albirini, 2016). In this respect Arabic is a good example of a Single Language Context as described by the Adaptive Control Hypothesis (Green & Abutalebi, 2013), where each language/dialect is used in a specific context and switching between them rarely occurs. This contrasts with the diglossic situation in Cyprus, where switching between the two varieties occurs frequently (Pavlou, 2004), as the two varieties are not restricted to a specific context (Rowe & Grohmann, 2013). Therefore, we suggest that the diglossic advantage found in other studies (Antoniou & Spanoudis, 2020; Antoniou et al., 2016) is due to the diglossic situation in Cyprus allowing for switching between the two varieties. Importantly, our results are in line with Scaltritti et al., (2017) who reported no bidialectal advantage in Executive Functions amongst young adults. This pattern of findings across studies calls for careful attention to the context in which each language is used in each environment, whether the case at hand is diglossia, bidialectalism and bilingualism. As discussed previously, the type and amount of code-switching cannot be assumed to be constant in each of these situations. Together, these findings suggest that it is overly simplistic to label a diglossic environment as a Single Language Context, or a bilingual environment as a Dual Language Context, based on narrow linguistic criteria. Strong predictions about the effects of multiple language use on cognition should not be drawn based on these crude categories alone; instead, the everyday linguistic experiences of the user should be central to the formulation of predictions.

Indeed, careful examination of the context of each bilingual/bidialectal/diglossic situation may be key in solving the long-running debate regarding the existence of a bilingual advantage. The mixed results reported in the literature have led some to conclude that bilingualism does not facilitate Executive Functions and that other factors such as

cultural differences or the statistical methods used explain reports of a bilingual advantage (Paap et al., 2015). Others have investigated potential alternative moderators of Executive Functions, such as socioeconomic status (Morton & Harper, 2007) and the age of second language acquisition (Kapa & Colombo, 2013; Pelham & Abrams, 2014). To date, the role of context as defined by the Adaptive Control Hypothesis as a mediator remains underexamined despite studies showing the impact of the dual language context in facilitating Executive Functions relative to the Single Language Context (Wu & Thierry, 2013; Yang et al., 2016). Similar conclusions have been drawn from bidialectal studies (Kirk et al., 2014; Scaltritti et al., 2017). The relationship between language and cognition is a complex one, involving heterogeneous populations, sociocultural contexts and individual experiences. While it has been suggested that rejecting the bilingual/bidialectal or diglossic advantage altogether may be premature, researchers are also encouraged to avoid overgeneralizing any discovered advantages to new populations in differing social contexts (Yang et al., 2016).

Finally, it is worth mentioning that the existence of a bilingual advantage is typically contested in the age group tested in this study. Unlike children and older adults, a bilingual advantage in Executive Functions has rarely been reported in young adults. Thus, it is possible that the lack of diglossic advantage in our study is attributed to the age group studied. However, Antoniou and Spanoudis's (2020) discovery of a diglossic advantage in the same age group gives more strengths to our arguments for the importance of considering the context of language use. Nevertheless, future studies might seek evidence from older diglossics to establish whether the age differences seen in studies of bilingualism also apply to diglossia.

6. Conclusion:

Despite the wealth of studies into the effect of speaking two or more languages on Executive Functions, little research has investigated the effects of speaking two language varieties on Executive Functions. In this study we assessed diglossic and monolingual young adults on the three components of Executive Functions: inhibition, working memory and switching (Miyake, 2000). Our study found no diglossic advantage on these tasks, in contrast with previous findings (Antoniou & Spanoudis, 2020). Our findings support the Adaptive Control Hypothesis proposed by Green and Abutalebi (2013), which hypothesizes that conversational contexts vary in the amount of code-switching between the two languages/varieties, which modulates Executive Functions differently. We argue that examining the language context, in terms of the amount of code-switching employed, is essential to understanding the relationship between languages/ language variations and cognition. Further, we argue that no contextual assumptions should be ascribed to all bilingual or diglossic situations. Rather, careful attention should be paid to the specific code-switching requirements of each language environment.

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Tables:

Table 1: *Linear mixed effects effect model results for the Flanker reaction times.*

Fixed Effects				
	Est/Beta	SE	t value	p value
Intercept	2.78	0.021	128.525	p<0.001*
Condition				
Congruent vs Incongruent	-0.080	0.008	9.78	p<0.001*
Congruent vs Neutral	-0.171	0.020	-2.52	p=0.0123*
Incongruent vs Neutral	-0.082	0.0060	-13.64	P<0.001*
Group	-0.171	0.029	-5.740	p<0.001*
Group interaction:				
Congruent X Incongruent	-0.010	0.0112	-0.898	p=0.372
Congruent X Neutral	0.009	0.006	1.452	p=0.147
Incongruent X Neutral	0.022	0.003	-5.74	p=0.0001*
Random Effects				
	Variance		S.D.	Correlation
Subject (Intercept)	0.0147449		0.12143	
Condition (Slope)				
Congruent vs Incongruent	0.0015378		0.03922	-0.12
Congruent vs Neutral	0.0001027		0.01013	-0.92 -0.27
Incongruent vs Neutral	0.001858		0.04310	-0.42 0.97
Residual	0.0115086		0.10728	
Model fit				
R ²	Marginal		Conditional	
	0.43			

Key: p-values for fixed effects calculated using Satterthwaites approximations, and tukey method.

Calculating random effect variance for Incongruent vs Neutral was calculated using a maximal model that includes a releval of the missing factor”Incongruent”.

Model equation:

lmer(logRT ~ Condition * Group +(1+Condition|Subject), data= Flanker)

Table 2: *Linear mixed effects effect model results for the Stroop reaction times.*

Fixed Effects				
	Est/Beta	SE	t value	P value
Intercept	2.846	0.01267	224.603	p<0.001*
Condition:				
Congruent vs incongruent	-0.037	0.005	7.384	p<0.001*
Congruent vs Neutral	-0.013	0.004	2.740	p<0.01*
Incongruent vs Neutral	0.029	0.0043	6.837	p<0.001*
Group:	-0.107	0.0172	-6.232	p<0.001*
Group interaction:				
congruent X Incongruent	-0.003	0.007	-0.459	p=0.647
congruent X Neutral	-0.009	0.006	-1.430	p=0.157
incongruent X Neutral.	-0.005	0.008	-0.686	p=0.495
Random Effects				
	Variance		S.D.	Correlation
Subject (Intercept)	0.0048668		0.06976	
Condition (Slope)				
Congruent vs Incongruent	0.0003716		0.01928	0.62
Congruent vs Neutral	0.0001802		0.01342	-0.33 -0.36
Incongruent vs Neutral	0.0005706		0.02389	-0.76
Residual	0.0129235		0.11368	
Model fit				
R ²	Marginal		Conditional	
	0.15		0.40	

Key: p-values for fixed effects calculated using Satterthwaites approximations, and tukey method.

Calculating random effect variance for Incongruent vs Neutral was calculated using a maximal model that includes a relevel of the missing factor "Incongruent".

Model equation:

lmer(logRT ~ Condition * Group +(1+Condition|Subject), data= Stroop)

Table 3: *Linear mixed effects effect model results for the switching reaction times.*

Fixed Effects				
	Est/Beta	SE	z value	p value
Intercept	312.5	0.018	70.67	p<0.001*
Condition: Stay vs Change	-0.0128	0.0052	-2.459	p=0.014*
Group:	-0.1466	0.0257	-5.702	p<0.001*
Group X Condition interaction:	-0.007	0.007	-1.090	p=0.2755
Random Effects				
	Variance		S.D.	
Subject (Intercept)	0.01102		0.1050	
Residual	0.01569		0.1253	
Model fit				
R ²	Marginal		Conditional	
	0.07		0.17	

Key: p-values for fixed effects calculated using Satterthwaites approximations.

Model equation:

`lmer(logRT ~ Condition * Group + (1|Subject), data= Switch)`

Table 4: *Linear mixed effects effect model results for the Nback reaction times.*

Fixed Effects				
	Est/Beta	SE	t value	p value
Intercept	2.709	0.018	184.65	p<0.001*
Condition: One back vs Two back	-0.061	0.0256	2.394	p=0.020*
Group:	-0.070	0.0248	-2.839	p=0.005*
Group X Condition interaction:	-0.004	0.029	-0.162	p=0.8721
Random Effects				
		Variance	S.D.	Correlation
Subject (Intercept)		0.010130	0.10065	
Condition (Slope)		0.005953	0.07716	-0.38
Residual		0.015288	0.12365	
Model fit				
R ²		Marginal	Conditional	
		0.05	0.40	

Key: p-values for fixed effects calculated using Satterthwaites approximations.

Model equation:

`lmer(logRT ~ Condition * Group +(1+Condition|Subject), data=Nback)`

Supplementary materials:

Table1: *Generalized Linear mixed effects model results for Flanker accuracy.*

Fixed Effects				
	Est/Beta	SE	z value	p value
Intercept	5.508	0.577	9.535	p<0.001*
Condition				
Congruent vs Incongruent	-1.334	0.57	-2.34	p=0.019*
Congruent vs Neutral	-0.631	0.547	-1.153	p=0.249
Incongruent vs Neutral	-0.96	0.321	-2.988	p=0.007*
Group	-0.3001	0.608	-0.493	p=0.6221
Group interactions:				
Congruent x Incongruent	-0.665	0.546	-1.217	p=0.223
Congruent x Neutral	-0.151	0.546	-0.319	p=0.749
Incongruent x Neutral	-0.514	0.443	1.161	p=0.245
Random Effects				
		Variance	S.D.	Correlation
Subject (Intercept)		2.9841	1.7274	
Condition (Slope):				
Congruent vs Incongruent		1.1552	1.0748	-0.70
Congruent vs Neutral		0.1753	0.4187	- 0.97 0.84
Incongruent vs Neutral		0.5702	0.7551	-0.20. 0.95
Model fit		Marginal	Conditional	
R2		0.43		

Key: p-values for fixed effects calculated using Satterthwaites approximations, and tukey method.

Model equation: `glmer(Accuracy ~ Condition * Group +(1+Condition|Subject), data= Flanker, family="binomial")`

Table 2: *Generalized Linear mixed effects model results for Stroop accuracy.*

Fixed Effects				
	Est/Beta	SE	z value	p value
Intercept	5.117	0.324	15.776	p<0.001*
Condition:				
Congruent vs Incongruent	-0.789	0.343	-2.300	p=0.021*
Congruent vs Neutral	-0.288	0.374	0.769	p=0.442
Incongruent vs Neutral	0.029	0.0043	6.837	P<0.001*
Group:	-0.807	0.385	-2.094	p=0.891
Group interaction:				
Congruent X Incongruent	-0.055	0.408	0.136	p=0.891
Incongruent X Neutral	-0.288	0.440	-0.655	p=0.512
Incongruent X Neutral.	-0.232	0.364	-0.639	p=0.522
Random Effects				
			Variance	S.D.
Subject (Intercept)			0.4957	0.7041
Model fit				
R ²			Marginal	Conditional
			0.08	0.20

Key: p-values for fixed effects calculated using Satterthwaites approximations, and tukey method. Confidence Intervals have been calculated manually.
Calculating random effect variance for Incongruent vs Neutral was calculated using a maximal model that includes a relevel of the missing factor”Incongruent”.

Model equation:

glmer(Accuracy ~ Condition * Group +(1|Subject), data=Stroop, family="binomial")

Table 3: *Generalized Linear mixed effects model results for switching accuracy.*

Fixed Effects				
	Est/Beta	SE	z value	p value
Intercept	3.366	0.195	17.261	p<0.001*
Condition	0.835	0.261	3.197	p=0.0013*
Group	-0.602	0.244	-2.467	p=0.013*
Group X Condition interaction	-0.322	0.3106	-1.038	p=0.2991
Random Effects				
	Variance		S.D.	
Subject (Intercept)	0.4209		0.6487	
Model fit				
R ²	Marginal		Conditional	
	0.07		0.17	

Key: p-values for fixed effects calculated using Satterthwaites approximations.

Model equation:

glmer(Accuracy ~ Condition * Group +(1|Subject), data=Switch, family="binomial")

Appendices:

Appendix A: Language and Social Background Questionnaire (Translated to Arabic)

Arabic Language and Social Background Questionnaire (Arabic translated version)

استبيان عن الخلفية اللغوية والاجتماعية

- تاريخ اليوم _____
- الجنس: ذكر _____ انثى _____
 - الوظيفة / الحالة الدراسية (مثال: منظم / غير منظم / المرحلة الدراسية) _____
 - تستخدم اليد اليمنى _____ اليسرى _____
 - تاريخ الميلاد _____
 - هل تمارس ألعاب الفيديو الاكشن والتي تتضمن ألعاب الطلق
 - الالكترونية من منظور الشخص الاول؟
نعم لا
 - اذا كان الجواب نعم، فكم ساعة في الأسبوع تمارس فيها هذه النوعية من ألعاب الفيديو؟ _____
 - هل تعاني من أي مشاكل سمعية؟
نعم لا
 - اذا كان الجواب نعم، فهل تستخدم أي سماعات خاصة؟
نعم لا
 - هل تعاني من أي مشاكل في النظر؟
نعم لا
 - اذا كان الجواب نعم، هل تستخدم نظارات طبية او عدسات؟
نعم لا
 - هل تم تصحيح نظرك الى الحد الطبيعي بالنظارات او العدسات؟
نعم لا
 - هل لديك عمى الوان؟
نعم لا
 - اذا كان الجواب نعم، فأى نوع؟ _____
 - هل تعرضت الى إصابة في الرأس؟
نعم لا
 - اذا كان الجواب نعم، هل من الممكن ان تشرح لنا _____
 - هل تعاني من أي مشاكل عصبية؟ (مثال، الصرع)
نعم لا
 - اذا كان الجواب نعم، الرجاء تسميتها _____
 - هل تتعاطى حاليا أي علاجات نفسية؟
نعم لا

الرجاء تحديد أعلى مرحلة دراسية ووظيفية لكل من الاب والام:

الأب:	الأم:
بدون شهادة ثانوية _____	بدون شهادة ثانوية _____
شهادة ثانوية _____	شهادة ثانوية _____
شهادة ما بعد المرحلة الثانوية _____	شهادة ما بعد المرحلة الثانوية _____
دبلوم _____	دبلوم _____
شهادة دراسات عليا _____	شهادة دراسات عليا _____
الوظيفة: _____	الوظيفة: _____
اللغة الاولى: _____	اللغة الاولى: _____
اللغة الثانية: _____	اللغة الثانية: _____
لغات أخرى: _____	لغات أخرى: _____

- هل ولدت في السعودية؟
- اذا كان الجواب لا، اين ولدت؟ _____
- متى قدمت للسعودية؟ _____

- هل عشت مسبقا في أي دولة لا تستخدم اللغة العربية كلغة سائدة؟ نعم لا

الى:	من:	١/ _____	اذا كان الجواب نعم، اين وكم كانت المدة؟
الى:	من:	٢/ _____	
الى:	من:	٣/ _____	

الخلفية اللغوية

- الرجاء ذكر جميع اللغات واللهجات التي تتحدثها وتفهمها مع ترتيبها حسب إتقانك لها، مع ذكر اللغة العربية.

اللغة:	أين تعلمتها:	العمر عند التعلم (ضع • اذا كنت تعلمتها منذ الولادة)	هل توقفت عن استخدام هذه اللغة في أي مرحلة؟ الرجاء ذكر المدة.
١/_____	المنزل المدرسة المجتمع مكان اخر: _____		
٢/_____	المنزل المدرسة المجتمع مكان اخر: _____		
٣/_____	المنزل المدرسة المجتمع مكان اخر: _____		
٤/_____	المنزل المدرسة المجتمع مكان اخر: _____		

الرجاء تقييم درجة مهارتك اللغوية من ٠ الى ١٠ في اللغة العربية واللغات الأخرى التي تتقنها.

العربية الفصحى: ٠ غير متقن ١٠ متقن ٥

التحدث

الفهم

القراءة

الكتابة

عند قيامك بالنشاطات التالية، كم من الوقت تستخدم فيه اللغة العربية الفصحى:

اطلاقا	قليلا	بعض الوقت	غالبا	جميع الوقت	
☐	☐	☐	☐	☐	التحدث
☐	☐	☐	☐	☐	الاستماع
☐	☐	☐	☐	☐	الكتابة
☐	☐	☐	☐	☐	القراءة

اللهجة العربية العامية: ٠ غير متقن ١٠ متقن ٥

التحدث

الفهم

القراءة

الكتابة

عند قيامك بالنشاطات التالية، كم من الوقت تستخدم فيه اللهجة العامية:

اطلاقا	قليلا	بعض الوقت	غالبا	جميع الوقت	
☐	☐	☐	☐	☐	التحدث

☐	☐	☐	☐	☐	الاستماع
☐	☐	☐	☐	☐	الكتابة
☐	☐	☐	☐	☐	القراءة

• اللغة الانجليزية: ٥
 • غير متقن ١٠ متقن

●	●	●	●	●	التحدث
●	●	●	●	●	الفهم
●	●	●	●	●	القراءة
●	●	●	●	●	الكتابة

• عند قيامك بالنشاطات التالية، كم من الوقت تستخدم فيه اللغة الانجليزية:

اطلاقا	قليلًا	بعض الوقت	غالبا	جميع الوقت	
☐	☐	☐	☐	☐	التحدث
☐	☐	☐	☐	☐	الاستماع
☐	☐	☐	☐	☐	الكتابة
☐	☐	☐	☐	☐	القراءة

اللغة المستخدمة في المجتمع

الرجاء تحديد أي لغة كنت تسمعها أو تستخدمها بشكل متكرر داخل أو خارج المنزل في المراحل العمرية الآتية:

اللغة الأخرى فقط	معظمها لغة أخرى	نصفها عربي ونصفها لغة أخرى	معظمها عربي	جميعها عربي	
					رضيع
					الروضة
					المرحلة الابتدائية
					المرحلة الثانوية

الرجاء تحديد اللغة المستخدمة بشكل عام عند التحدث مع الأشخاص التاليين:

اللغة الأخرى فقط	معظمها لغة أخرى	نصفها فصحي ونصفها لغة أخرى	نصفها عامي ونصفها لغة أخرى	جميعها لغة عربية فصحي	جميعها اللغة العربية العامة	
						الابوين
						الأخوة
						الاجداد
						الأقارب الآخرون
						الزوج/الزوجة
						الزملاء
						الجيران
						الاصدقاء

الرجاء تحديد أي اللغات تستخدم بشكل عام في الاوضاع التالية:

اللغة الأخرى فقط	معظمها لغة أخرى	نصفها فصحي ونصفها لغة أخرى	نصفها عامي ونصفها لغة أخرى	جميعها لغة عربية فصحي	جميعها اللغة العربية العامة	
						المنزل
						المدرسة
						العمل
						النشاطات الاجتماعية (الخروج مع الأصدقاء مثلاً)
						النشاطات الدينية
						النشاطات الغير روتينية (الرياضة، الهوايات، الألعاب)
						التسوق، المطاعم
						الرافق الصحية، المرافق الحكومية، المكاتب، البنوك.

الرجاء تحديد أي اللغات تستخدم بشكل عام في النشاطات التالية:

اللغة الأخرى فقط	معظمها لغة أخرى	نصفها فصحي ونصفها لغة أخرى	نصفها عامي ونصفها لغة أخرى	جميعها لغة عربية فصحي	جميعها اللغة العربية العامة	
						القراءة
						البريد الإلكتروني
						الرسائل النصية
						التواصل الاجتماعي (فيس بوك، تويتر، ..)
						كتابة لائحة المشتريات، اخذ ملاحظات
						مشاهدة الأفلام

						تصفح الانترنت
						الصلاة

في بعض من الاوقات نقوم بالتحويل من لغة/ لهجة الى أخرى، مثلا نتحدث اللغة العربية العامية ثم نحول الكلام الى اللغة العربية الفصحى، تعرف هذه الظاهرة بـ "التحويل اللغوي".
الرجاء تحديد مقدار تحويلك بين اللغات في الحالات التالية:

التحويل بين اللغة العربية الفصحى والعربية العامية:

دائما	غالبا	احيانا	قليلًا	ابدا	
					مع الابوين والعائلة
					مع الاصدقاء
					في مواقع التواصل الاجتماعي(فيس بوك، تويتر...)

التحويل بين اللغة العربية والإنجليزية:

دائما	غالبا	احيانا	قليلًا	ابدا	
					مع الابوين والعائلة
					مع الاصدقاء
					في مواقع التواصل الاجتماعي(فيس بوك، تويتر...)

Appendix B: Flanker Accuracy

This appendix includes an additional model we ran with the exclusion of the random slopes (for results see Table 2). The original maximal model was a better fit despite convergence issues.

Table1: *Mean accuracy (SD) per group and per condition for the Flanker task.*

	Congruent	Incongruent	Neutral
Diglossics	99% (12)	97% (18)	98% (13)
Monolinguals	98% (12)	94%(24)	98%(15)

To measure the contribution of group, condition and interaction between group and condition to the overall fit, we have compared models with and without these factors. The inclusion of condition did not contribute significantly to the overall model fit $\chi^2(2)=3.66$, $p=0.1604$. The results revealed that Incongruent (M correct responses= 95%, $SD=(21)$) was significantly less accurate than both Congruent (M correct responses= 98%, $SD=(12)$) ($\beta=-0.839$, $SE=0.2884$, $t(.)= -2.910$, $p=0.003$), and Neutral (M correct responses= 98%, $SD=(14)$) ($\beta=-0.916$, $SE=0.176$, $t(.)= -5.219$, $p<0.0001$). There was no significant difference between Congruent and Neutral. There was no significant difference between Congruent and Neutral. However, the inclusion of group did not contribute significantly to the overall model fit ($\chi^2(3)=7.4718$, $p=0.0582$). Further analysis showed no significant difference between Diglossics (M correct responses=97%, SD (14)) and Monolinguals (M correct responses=96%, SD (17)). The interaction between group and condition did not significantly contribute to the overall model fit ($\chi^2(2)=3.66$, $p=0.1604$). Further analysis showed no significant interaction between group and condition.

Table 2: *Generalized Linear mixed effects model results for Flanker accuracy*

Fixed Effects				
	Est/Beta	SE	t	p
Intercept	5.014	0.3722	13.473	p<0.001
Condition				
Congruent vs Incongruent	0.839	0.2884	-2.910	p=0.003
Congruent vs Neutral	0.145	0.322	0.459	p=0.652
Incongruent vs Neutral	-0.916	0.176	-5.219	p<0.001
Group	-0.299	0.4776	-0.627	p=0.530
Group interaction				
Congruent x Incongruent	-0.663	0.378	-1.753	p=0.0795
Congruent x Neutral	-0.219	0.4302	-0.510	p=0.609
Incongruent x Neutral	0.444	0.350	1.266	p=0.205
Random Effects				
	Variance		S.D.	
Subject (Intercept)			1.636	1.7274
	Model fit			
R ²			Marginal	Conditional
			0.07	0.38
Key: p-values for fixed effects calculated using Satterthwaites approximations, and tukey method. Confidence Intervals have been calculated using the asymptotic.				
Model equation: glmer(Accuracy ~ Condition * Group +(1 Subject), data=Flanker, family="binomial")				

Appendix C: Flanker Reaction Times.

This appendix includes an additional model we ran with the exclusion of the random slopes (for results see Table 1). The original maximal model was a better fit despite convergence issues.

To measure the contribution of group, condition and interaction between group and condition to the overall fit, we have compared models with and without these factors. The inclusion of Condition did contribute significantly to the overall model fit $\chi^2(4)=885.18, p<0.001$. Further analysis revealed a significant difference between Congruent and Incongruent trials, with Incongruent (M RTs =2.77 ms, SD(0.10)) being significantly slower than both Congruent (M RTs =2.70 ms, SD(0.18)) ($\beta=0.0820$, SE=0.0043, $t(7829)= 18.714$, $p<0.001$), and Neutral (M RTs =2.69 ms, SD(0.175)) ($\beta=-0.083$, SE=0.003, $t(.)= 27.67$, $p<0.0001$). There was also a significant difference between Congruent and Neutral trials, with Neutral (M RTs =2.69 ms, SD(0.175)) being faster than Congruent (M RTs =2.70 ms, SD(0.18)) ($\beta=-0.0129$, SE=0.00434, $t(7829)= -2.976$, $p<0.01$).

The inclusion of group contributed significantly to the overall model fit ($\chi^2(3)=42.63, p<0.001$). Further analysis revealed a significant difference between Diglossics and Monolinguals, where Diglossics (M RTs =2.8 ms, SD(0.20)) were significantly slower than Monolinguals (M RTs =2.63 ms, SD(0.11)) ($\beta=-0.1710$, SE=0.0287, $t(67.78)= -5.946$, $p<0.001$). Also, The interaction between group and condition did not significantly contribute to the overall model fit ($\chi^2(2)=14.041, p<0.001$). There is was a significant group and condition interaction where Monolinguals showed smaller difference than Diglossics in Congruent and Incongruent than the Diglossics group ($\beta=-0.0121$, SE=0.0039, $t(7829)= -2.004$, $p=0.045$), and in Incongruent and

Neutral than ($\beta=0.0222$, $SE=0.00604$, $t(7829)= 3.746$, $p=0.0008$), and also in Congruent and Neutral ($\beta=0.0105$, $SE=0.0059$, $t(7829)= 1.765$, $p=0.007$).

Table 1: *Linear mixed effects effect model results for the flanker reaction times.*

Fixed Effects				
	Est/Beta	SE	t	p
Intercept:	2788	0.020	133.196	p<0.001
Condition:				
Congruent vs Incongruent	0.082	0.0043	18.714	p<0.001
Congruent vs Neutral	-0.012	0.0043	-2.976	p<0.01
Incongruent vs Neutral	-0.083	0.003	27.67	p<0.0001
Group	-0.171	0.028	5.946	p<0.001
Group interactions:				
congruent x Incongruent	-0.012	0.003	2	p=0.045
Congruent x Neutral	0.010	0.005	1.76	p=0.007
Incongruent x Neutral	0.022	0.006	3.74	p=0.0008
Random Effects				
			Variance	S.D.
Subject (Intercept)			0.01370	0.117

Key: p-values for fixed effects calculated using Satterthwaites approximations, and tukey method. Confidence Intervals have been calculated using the asymptotic.
 $\text{lmer}(\log RT \sim \text{Condition} * \text{Group} + (1|\text{Subject}), \text{data}=\text{Flanker})$