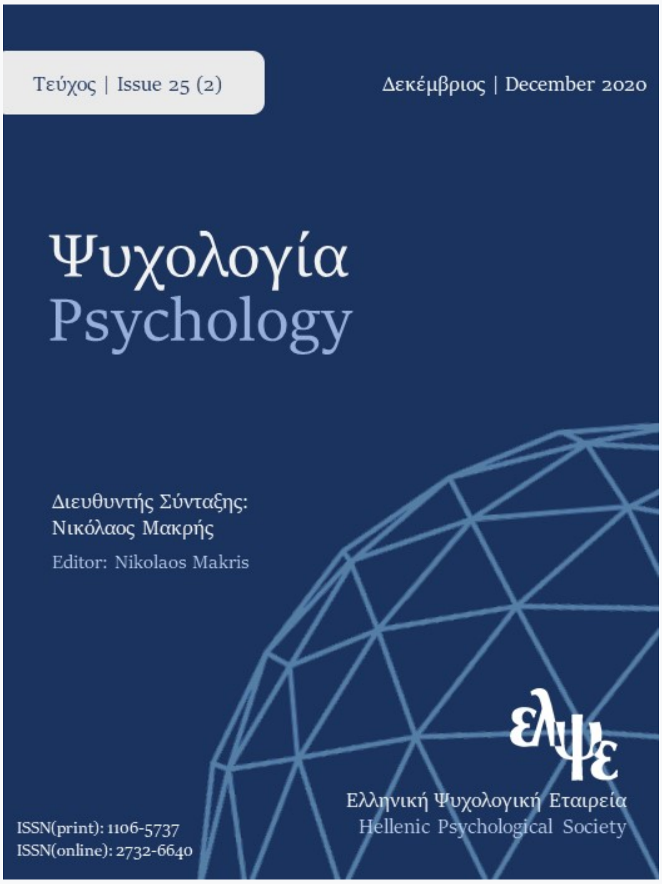
Psychology: the Journal of the Hellenic Psychological Society

Vol 25, No 2 (2020)

Special Section: Contemporary Issues in Neuropsychology



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doi: [10.12681/psy_hps.25588](https://doi.org/10.12681/psy_hps.25588)

To cite this article:

Chrysochoou, E., Kanaki, S., & Vivas, A. B. (2020). Executive functions in French-Greek early bilinguals: In search of the suggested bilingual advantage. *Psychology: The Journal of the Hellenic Psychological Society*, *25*(2), 76–92. https://doi.org/10.12681/psy_hps.25588

ΨΥΧΟΛΟΓΙΑ | PSYCHOLOGY, 25 (2), 76-92

Ελληνική Ψυχολογική Εταιρεία
Hellenic Psychological Society

ΕΜΠΕΙΡΙΚΗ ΕΡΓΑΣΙΑ | RESEARCH PAPER

Executive functions in French-Greek early bilinguals: In search of the suggested bilingual advantage

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KEYWORDS

early bilingualism,
executive functions,
inhibition,
switching,
updating

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ABSTRACT

Bilinguals must manage two languages on a daily basis, which requires, among other things, dealing with cross-linguistic interference. Such cognitive training is assumed to underlie better performance of bilinguals, relative to monolinguals, in non-verbal cognitive tasks. However, the suggested advantage has recently been questioned. The present study aimed at shedding light into this debate, focusing on French-Greek early bilingual adults. Exposure to two languages from the first few years of life has been suggested to favour the demonstration of an advantage. Bilinguals were compared to Greek-speaking monolingual adults (matched for age, gender, non-verbal intelligence, and SES) on executive function tasks, tapping switching, inhibition, and updating processes. Task demands were also manipulated. In line with the suggested advantage and as expected, in the switching paradigm, bilinguals performed faster overall and demonstrated a smaller mixing cost; this can be assumed to reflect better general monitoring and top-down processing for bilingual participants. In contrast, the groups did not differ on switching cost, neither on the inhibition and updating measures. Moreover, contrary to what was expected, the cognitive measures did not correlate with an index of how balanced bilingualism was. Findings do not support a general and robust cognitive advantage in a sample of early bilinguals. Factors that might influence its observation are discussed, along with lines of future research.

It is estimated that a significant percentage of people worldwide (see Bhatia & Ritchie, 2012) use or are exposed to more than one language in everyday life. In Europe, for example, among the 54% of the population that reported being able to hold a conversation in a second language, 24% reported using it every day or almost every day (European Commission, 2012, pp. 12, 41). Several individuals grow up in bilingual communities, others learn and frequently use a second language for carreer purposes, whereas an increasing number of individuals become bilingual due to migration. It thus comes as no surprise that bilingualism and its influences on both language and cognition have received a lot of attention over the last decade within the domains of psychology and psycholinguistics (Hilchey et al., 2015; Kroll & De Groot, 1997).

It has been proposed that bilingualism exerts a positive effect on cognitive performance, particularly on executive functions, in both children and adults (e.g., Abutalebi et al., 2015; Adesope et al., 2010; Bialystok & Craik, 2010; Bialystok et al., 2004; Festman et al., 2010; Hernández et al., 2010; Poulin-Dubois et al., 2011). For example, Costa, Hernández, and Sebastián-Gallés (2008) found that bilingual young adults were overall faster than monolingual peers in executive control tasks (e.g., the *Simon* and *Colour-Stroop* tasks), and experienced less interference from distractor stimuli. Moreover, Bialystok, Craik, and Luk (2008) found evidence for greater bilingualism effects in older adults.

Attempts to explain such a bilingual advantage in executive control have relied on the fundamental idea that life-long experience in managing two languages can be equalled with systematic cognitive training, which has spill over effects on non-linguistic, executive control functions. Existing evidence suggests co-activation of both languages in the bilingual mind (e.g., Costa et al., 2017; Thierry & Wu, 2007), irrespectively of the individual's intention to use one of them. Such linguistic competition is assumed to create demands for inhibitory control of the non-target language, so that fluency in the language that is currently used can be achieved (see Kroll et al., 2014 for a discussion). In a meta-analysis, Adesope and colleagues (2010) indeed concluded on an overall moderate effect of bilingualism on several cognitive outcomes, including enhanced attentional control, working memory, abstract and symbolic representation skills, and metalinguistic awareness. Adesope and colleagues noted, however, that effect sizes differed among studies, depending also on the cognitive tasks employed.

The locus and generality of the suggested bilingual advantage has been challenged further in more recent studies (see Laketa et al., in press). Several researchers have reported no differences between language groups when they were carefully matched on variables that may co-vary with cognitive performance, such as SES and general intelligence (Duñabeitia et al., 2014; Ladas et al., 2015; Vivas et al., 2017), or when homogeneous bilingual groups were involved (e.g., in terms of sociolinguistic background; Gathercole et al., 2014). Such potentially confounding factors have been overlooked in several previous studies. In line, Paap and colleagues have recently suggested that there is no compelling evidence for a bilingual advantage in inhibitory control (Paap, 2019; Paap et al., 2014), whereas in an earlier study, they had failed to replicate the suggested advantage on 15 indicators of cognitive processing (Paap & Greenberg, 2013). In line, a recent meta-analysis (Lehtonen et al., 2018), did not find systematic evidence for an inhibitory control advantage in bilingual adults, when correcting for publication bias. In Greece, after carefully matching Albanian-Greek bilinguals and Greek monolingual participants on age, gender, non-verbal intelligence, and SES (mostly low, characteristic of the specific bilingual population), researchers failed to replicate the suggested advantage in executive attention, alerting, and orienting , using the Attentional Network Test (ANT) with young adults (Vivas et al., 2017) or children (Ladas et al., 2015).

Several researchers have also investigated the possibility that bilingualism may lead to enhanced efficiency in shifting between mental sets. Prior and MacWhinney (2010), for example, employed a task-switching paradigm and found that the difference between mean reaction times for the switch versus non-switch trials in the mixed-task blocks (involving both types of trials) was smaller for the bilingual as compared to the monolingual participants. A smaller *switching cost* is assumed to reflect faster activation of a task set in response to a cue, as well as faster reconfiguration of action sets in overcoming any residual interference or activation from the task performed on the previous trial. On the other hand, Prior and MacWhinney observed no differences in a more *general, global* cost type, that of *mixing cost;* namely the relative cost of responding to the trials in single-task blocks, involving only non-switch trials, and the same type of trials in the mixed-task blocks of the task-switching paradigm. Thus, the authors concluded that bilingualism influences time-sensitive shifting of mental sets, as well as capacity to resist interference from previous trials, rather than the sustained control processes that are necessary to maintain two competing response sets, while monitoring the task and reaching a decision within a given trial (see also Koch et al., 2005; Rubin & Meiran, 2005).

These findings were replicated by Prior and Gollan (2011), who found no difference between English-speaking monolinguals and two bilingual groups (Spanish-English and Mandarin-English bilinguals) in mixing cost. A bilingual advantage in switching cost was once again observed, yet only in the group of Spanish-English bilinguals; that is, in the bilingual group that reported switching frequently between languages in daily life. In contrast, Wiseheart, Viswanathan, and Bialystok (2016) found benefits in monitoring (i.e., mixing cost), rather than switching capacity in bilinguals, relative to English-speaking monolinguals. However, since bilinguals spoke a variety of languages in combination with English, results might have been influenced by uncontrolled variables, such as linguistic similarity or cultural background. Moreover, Soveri, Rodriguez-Fornells, and Laine (2011) showed that a higher rate of everyday language switches was related to a smaller mixing, rather than switching cost in accuracy for Finnish-Swedish bilinguals. In summary, evidence for a bilingual advantage in this particular executive function remains scarce and has often been inconclusive (see also Paap, 2019 and Lehtonen et al., 2018).

Similarly, there is mixed evidence on the relationship between bilingualism and working memory. There are some studies in which bilinguals outperformed monolinguals in complex span tasks, assessing capacity for concurrent storage and manipulation of information in working memory, in accordance to a specific rule or task. For example, Bialystok and colleagues (2008) reported superior performance of younger relative to older participants, and of bilingual relative to monolingual participants in a backward Corsi block task. Based on relevant evidence with children and adults, Bialystok and colleagues concluded that this difference should not be attributed merely to working memory capacity, but to an effect of bilingualism on the executive control system more generally (Bialystok & Feng, 2009; see also Bialystok, 2009). It should be noted, however, that bilingual samples in several studies were characterized by significant heterogeneity. In the aforementioned study by Bialystok and colleagues (2008), for example, bilinguals spoke English and one of 24 different languages, whereas many among them were immigrants. Bilingual participants were moreover matched with monolinguals on an education index (rather than SES more generally), but not on intelligence.

Recent meta-analytic evidence regarding the effects of bilingualism on working memory capacity is also mixed (see Adesope et al., 2010 and Grundy & Timmer, 2017 for significant positive effects; see Lehtonen et al., 2018 for null findings). Moreover, the working memory tasks employed so far seem to tap on executive control in working memory, rather than updating per se (e.g., Rosselli et al., 2016; Morales et al., 2013). This research gap might be due to a less recognized relationship between updating and language acquisition and use in general (Dong & Li, 2015). Updating regards the ability to continuously monitor and rapidly revise the items held in working memory, and replacing older and no longer relevant information, with current and task-relevant information (see Miyake & Friedman, 2012; Morris & Jones, 1990). It could be that bilinguals rely on such a function to verify that the language used at a given moment is the one appropriate for the specific context.

To sum up, the evidence on the effects of bilingualism on executive functions is so far inconclusive. Among the factors put forward to explain contradictory findings are task impurity, variation in task complexity, as well as potentially confounding, yet uncontrolled variables (such as SES and general intelligence). Researchers have also pointed to variation in bilingual "profiles", regarding bilingualism type (e.g., early or simultaneous versus sequential bilingualism, or balanced versus dominant bilingualism), the similarity of the languages spoken, and cultural background (Coderre & van Heuven, 2014; De Houwer, 1998; Laketa et al., in press). The present study aimed at addressing these issues.

Specifically, we systematically examined the effect of bilingualism on three core executive functions (Miyake et al., 2000; see also Friedman & Miyake, 2004): switching, inhibition, and the least investigated function of updating. In doing so, we considered factors that might affect cognitive development and performance, as well as the precise sociolinguistic setting of the study. We formed a homogeneous bilingual group, consisting of early, mostly simultaneous bilinguals, living in Greece and speaking Greek and French on a daily basis. Bilingual participants were strictly matched to monolinguals on age, gender, non-verbal intelligence, and SES (taking into account educational level, as well as the type of occupation and position held).

It has recently been suggested that the modulating effects of bilingual experience on cognitive performance might depend on the task employed; specifically, its purity in terms of measuring the intended process, as well as the demands set by the task . Thus, we employed both a 2- and a 3-back task in measuring updating, and a Simon task that manipulated working memory demands regarding stimulus-response mapping (i.e., based on the number of colours corresponding to each response key). In addition, we employed a switching paradigm, which allowed for the calculation of both local and global costs (i.e., switching and mixing costs).

Finally, we took into account suggestions that the extent to which bilinguals switch between languages, and thus, the relative strength of each language and the control and monitoring demands set on bilingual speakers in everyday settings, might modulate the cognitive benefits of bilingualism (Green, 2011). Therefore, besides measuring vocabulary knowledge and perceived language use and proficiency, we also employed a *language switching task,* to more objectively measure bilingual experience (Meuter & Allport, 1999; see also Costa & Santesteban, 2004; Ladas et al., 2015; Philipp et al., 2007; Vivas et al., 2017). In this task, lower asymmetry in the speed of switching from Greek to French and vice versa (language switch cost asymmetry), would indicate more balanced bilingualism in terms of language dominance.

Based on the aforementioned theoretical suggestions and research findings, we stated the following hypotheses: If learning and monitoring the use of two languages in everyday life influences the development of executive functions, significant performance differences should be observed between matched samples of early French-Greek bilinguals and Greek-speaking monolinguals in the inhibition, switching, and updating tasks. In addition, performance differences should be more pronounced in the demanding conditions of the tasks employed; namely, the 3-back versus 2-back task version, and the high working memory demands condition in the Simon task. Finally, the more balanced bilinguals are (as indexed by language switch cost asymmetry), the better they should perform on the executive function tasks.

Method

Participants

Participants were 27 early French-Greek bilingual and 27 Greek-speaking monolingual adults, aged 18 to 56 years. Bilinguals were recruited from the French Institute of Greece in Athens and the French Institute of Thessaloniki, Greece, as well as from the French and Belgium embassies in Athens, via announcements that were either emailed or posted on relevant websites. Among them, 25 were exposed to both languages from birth (having one Greek and one French parent), whereas two bilinguals were exposed to the second language – French that is- as early as age three. Bilinguals were thus regarded early, mostly simultaneous, bilinguals (De Houwer, 1998; Grosjean, 1989; Klein et al., 2014). The monolingual participants were recruited in Thessaloniki and Athens. They were all born in Greece, had not lived abroad or used a second language on a daily/regular basis in the past, and reported very low levels of current exposure to and proficiency in a foreign language (mostly English, taught for no more than one or two hours per week during high-school years). Participants provided informed written consent to participate. The study was approved by the Ethics Committee of the University of Sheffield.

In order to carefully match and describe our bilingual and monolingual samples (see their characteristics in Table 1), we administered a non-verbal intelligence test, along with a demographics and language background questionnaire (Ladas et al., 2015; Vivas et al., 2017). Specifically, we assessed non-verbal intelligence, using the *Raven's Standard Progressive Matrices* (Raven, 2000). The SES of each participant was calculated by summing up the scores on three components: (a) *educational level* (from 0 *-did not finish elementary school-* to 5-*university or higher-level graduate*), (b) *type of occupation* (0 = *unemployed,* 1 = *blue-collar,* 2 = *white collar*), and (c) *position in occupation* (0 = *unemployed;* 1 = *unskilled worker;* 2 = *skilled-specialized professional;* 3 = *business owner;* 4 = *business owner with staff;* 5 = *executive member*). On that basis, we strictly matched the two groups, on a one-to-one basis, on age, gender, non-verbal intelligence, and the total SES score (see *t*-test results, confirming matching, in Table 1). With regard to SES level, specific cut-off scores were applied for inclusion in low SES (up to 7), middle status (8 to 12), and high SES (13 or greater) groups (see similar categorizations in Ladas et al., 2015; Vivas et al., 2017; see also Economou & Nikolaou, 2005, for a review). In each language group, there were 5 participants of low SES, 14 of middle status, and 9 participants of higher SES in each group.

Finally, we assessed vocabulary knowledge in both languages for the bilinguals and in Greek for the monolinguals using the WAIS III vocabulary test (Wechsler, 1997; see Koulakoglou, 1998, and Vivas et al., 2017 for the Greek, and Golay & Lecerf, 2011 for the French test versions). The test consists of 33 produce-the-definition items. The total score was the sum of a participant's item scores, with complete definitions given two points and incomplete definitions given a partial item score of one. The two groups were not found to differ on Greek vocabulary knowledge, but bilinguals performed better overall in the French as compared to the Greek vocabulary test (see Table 1).

Table 1

Demographics, Vocabulary, and Non-verbal Intelligence in the Monolingual and Bilingual groups

	Bilinguals	**Monolinguals**		
	M (SD), **range**	***M (SD),*** **range**	t	p
Age (years)	31.48 (8.58), 18-56	29.74 (8.05), 18-52	.769	.445
Raven's	54.26 (2.93), 48-58	55.26 (2.03), 52-59	- 1.458	.151
SES (total)	9.59 (3.78), 3-14	9.74 (3.73), 3-14	- .145	.885
Greek Vocabulary	50.70 (5.25), 41-58	52.81 (3.93), 47-59	- 1.672	.101
French Vocabulary	55.26 (3.52), 42-59	-		

Tasks and Procedure

The task-switching paradigm

We employed the task-switching paradigm developed by Prior and MacWhinney (2010; based on Rubin & Meiran's, 2005 assessment procedure). At the beginning of each trial, a fixation cross was presented in the centre of the computer screen for 350 ms. This was followed by a 150ms blank screen, and the task cue, presented 2.8° above the fixation cross, for 250ms. The target then appeared at the centre of the screen. To avoid using linguistic information, graphic cues were used: a colour gradient and a row of small black shapes (4.5° X 0.8°) for the colour and the shape tasks, respectively. Targets were red or green circles (2.8° X 2.8°) and triangles (2.3° X 2.3°). The cue and target remained on the screen until response or until four seconds had elapsed. Incorrect responses were followed by a 100ms beep. After an inter-trial interval of 850 ms (blank screen), the next target appeared. Participants were instructed to use the middle and index fingers of their right hand for one task, and the middle and index fingers of their left hand for the other task. The mapping task-hand response was counterbalanced across participants.

The task consisted of three parts (i.e., sandwich design). In the first part, participants performed two single-task blocks (colour and shape, counterbalanced in order across participants). Each block consisted of 8 practice trials, which were followed by 36 experimental trials. In the second part, there were 16 mixed-task practice trials, followed by 3 mixed-task blocks. Each Mixed-task block consisted of 48 trials of both the colour and the shape tasks; half were Switch trials and the other half were Non-switch trials, randomly ordered, with a maximum of four same task trials in a row. Two dummy trials were added at the beginning of each block to reduce the effects of time delay because of starting problems (they were not further analyzed). In the final, third part of the task, participants performed two Single-task blocks again, but in the opposite order from the one employed in the first part. In total, the Mixed-task blocks consisted of 72 Switch and 72 Non-switch trials, whereas participants were also given 144 trials in the four Single-task blocks (72 colour and 72 shape trials). Besides mean accuracy rates (%) and mean reaction times (ms) for correct trials per condition (Single-task trials, Mixed-task Switch trials, Mixed-task Non-switch trials), measures of switching cost (Mixed Switch RT – Mixed Non-switch RT) and mixing cost (Mixed-task Non-Switch RT – Single-task Non-switch RT) were additionally calculated for each participant.

The Simon task

The Simon Task version used was adopted by Bialystok et al. (2004, Exp. 2; see also Bialystok, 2006; Vivas et al., 2017; Morton & Harper, 2007) and was administered with the use of the e-prime software. Control and experimental blocks of trials corresponding to two working memory demand levels were included in the experiment. Specifically, in the lower working memory demand blocks (2-colours condition), a blue or brown circle appeared above or below fixation (control blocks with neutral trials) or on the left or right of the fixation point (experimental blocks with congruent and incongruent trials). Participants were instructed to press the left key (“A” on the keyboard) for the blue circle and the right key (“L”) for the brown circle. Trials were identified as congruent and incongruent depending on whether the position of the stimulus on the screen coincided with the position of the response key. In the higher working memory demand blocks (4-colours condition), a circle of one of four colours (pink, green, yellow, red) appeared again either above or below fixation in the control blocks, or on the left or right of the fixation point in the experimental blocks. Participants were instructed to press the left key (“A”) for pink and green circles, and the right key (“L”) for yellow and red circles. The colour-response mapping was counterbalanced across participants. Each trial began with a fixation point followed by a high tone sound.

The experiment consisted of two parts. Participants were first presented with the neutral and the experimental blocks of lower working memory demands, and then, with the higher demands’ neutral and experimental blocks. Block order was reversed in the second part, comprising a sandwich design. There were 192 experimental trials and 48 practice trials overall. Besides mean accuracy rates (%) and mean reaction times (ms) for correct trials per condition, a Simon effect measure was also calculated, by subtracting mean reaction time in the congruent from mean reaction time in the incongruent trials.

The n-back task

Updating was measured with a 2-back and a 3-back version of the n-back task (Kirchner, 1958; see also Jaeggi et al., 2010, and Pelegrina et al., 2015). In each version, participants were presented with a series of digits on the screen and were asked to press a specific key on the keyboard when the target digit matched the one presented *n* trials earlier (i.e., two trials earlier in the 2-back and three trials earlier in the 3-back task versions, respectively). Each digit was presented in black font on a white background for 500 ms and it was followed by a blank screen for 2,500 ms. Digits were presented in pseudorandom order, with the same digit, however, not presented twice in a row. Each task version started with a practice block of 22 digits for the 2-back task and 23 digits for the 3-back task. The first two and three trials, respectively, were dummy trials and were not analyzed further. Among them, seven digits were targets. The experimental block consisted of 62 digits in the 2-back and 63 digits in the 3-back task, among which two and three digits, respectively, were dummy trials, and 20 digits were targets. The number of targets recognized and mean reaction time (ms) for correct target hits were obtained for each participant.

The language switching task

A modified version of Meuter and Allport's (1999) language switching task was used with the French-Greek bilinguals of the present study. The task serves as a more objective measure of bilingual experience, tapping automaticity in switching between the two languages (see relevant measures in Ladas et al., 2015; Vivas et al., 2017). The target stimuli were orange Calibri digits (1-9), whereas the background font was either the Greek or the French flag, indicating each time the language in which participants were required to read the digit presented. Participants were instructed to read out loud each digit as quickly and accurately as possible. Response time was registered via a voice-key. Accuracy was registered by the experimenter via the keyboard.

There were two types of trials: *non-switch trials*, where the language of response was the same as in the previous trial (70% of the total trials), and *switch-trials* requiring a response in a different language from the one used in the previous trial (30% of the total trials). The switch and non-switch trials required a response in Greek and French in equal numbers of trials. The stimuli were presented in pseudorandom order, with no same digit presented in adjacent trials. Participants were presented with 10 practice trials and 150 testing trials in total. Each digit was presented on the screen until response. The inter-item interval was 400ms.

Each participant was assessed individually in a quiet room. In a first assessment session, the questionnaire, as well as the non-verbal intelligence, the vocabulary, and the language switching tasks were given. The four executive function tasks were given in counterbalanced order in a second assessment session. The procedure lasted approximately 100 minutes for the bilinguals and 80 minutes for the monolinguals. For the language switching task, a measure of absolute *Switch Cost Asymmetry* (SCA) was also calculated by subtracting the mean response time (ms) in the switch-to-Greek trials from mean response time in the switch-to-French task trials. An absolute SCA of zero would indicate balanced bilingualism in terms of language dominance.

Results

The switching task

Two pairs of participants were not included in the data analyses, because one bilingual participant had mean reaction time over 2,000ms and another participant had accuracy below 70%.

Reaction times. A 2 (Language group: Bilinguals, Monolinguals) x 3 (Trial type: Mixed-task Non-switch, Mixed-task Switch, and Single-task Non-switch) mixed ANOVA was applied on mean reaction times (ms) in the switching task (see Table 2). Results showed significant main effects of Language group: F (1, 48) = 7.124, p = .010, η^2_p = .129 and Trial type F(2, 96) = 98.823, p < .0001, η^2_p = .673. Overall, bilingual participants were faster (538ms) than monolingual participants (681ms). Bonferroni post-hoc comparisons, for the Trial type factor, showed significant differences between all conditions: Mixed-task Non-switch (608ms), Mixed-Switch (791ms, a Switching cost of 183ms), and Single-task Non-switch (431ms; a mixing cost of 422ms), all ps < .0001. In addition, the Language Group by Trial Type interaction reached statistical significance, F(2, 96) =

3.617, p = .031, η^2_p = .070. To analyze the interaction, we conducted independent sample t-tests to compare the language groups on the magnitude of the switching and mixing costs. Results showed that while bilingual (163ms of effect) and monolingual (202ms of effect) participants did not differ in terms of switching cost, $t(48)$ = -.950, p = .347, monolingual participants (202ms of effect) had a significantly greater mixing cost magnitude as compared to the bilinguals (163ms of effect), $t(48)$ = -2.407, p = .020.

Accuracy. A 2 (Language group: Bilinguals, Monolinguals) x 3 (Trial type: Mixed-task Non-switch, Mixed-task Switch, and Single-task Non-switch) mixed ANOVA was applied on mean accuracy rates (%) in the switching task. Results showed a significant main effect of Trial type, $F(2, 96)$ = 32.698, p < .0001, η^2_p = .405, but a non-significant effect of Language group $F(1, 48)$ = .946, p = .336, η^2_p = .019. Post-hoc Bonferroni comparisons showed significant differences between all conditions: Mixed-task Non-switch (93%), Mixed-task Switch (89%), and Single-task Non-switch (96%), all ps < .05. The Language group by Trial type interaction did not reach statistical significance, $F(2, 96)$ = 1.476, p = .234, η^2_p = .030.

Table 2
Mean Reaction Times and Standard Deviations for the Single-task Block Trials and the Non-switch and Switch Trials of the Mixed-task Blocks, by Language Group

	Mixed-task blocks		
	Non-switch trials	**Switch trials**	**Single-task blocks trials**
Language Group	***M (SD)***	***M (SD)***	***M (SD)***
Bilinguals	527 (171)	690 (261)	397 (80)
Monolinguals	689 (228)	891 (338)	464 (100)

The Simon task

Two pairs of participants (one of the pairs excluded above and a different pair) were not included in the data analyses; one bilingual participant had mean reaction time over 1000ms and another participant had accuracy below 70%.

Response times. A 2 (Language group: Bilinguals, Monolinguals) x 2 (Number of colours: 2- and 4-colours blocks) x 3 (Congruency: Congruent, Incongruent and Neutral) mixed ANOVA was applied on mean reaction times (ms) in the Simon task (see Table 3). Results showed significant main effects of Number of colours and Congruency; $F(1, 48)$ = 63.037, p < .0001, η^2_p = .568, and $F(2, 96)$ = 30.600, p < .0001, η^2_p = .389, respectively. More specifically, reaction times were overall slower for the 4-colours condition (515ms) than for the 2-colours condition (418ms). Bonferroni post-hoc comparisons also showed that mean reaction times in the Incongruent condition (488ms) differed significantly from mean reaction times in the Congruent condition (451ms; an overall Simon effect of 35ms), and the Neutral condition (461ms), p < .0001. The Number of colours by Congruency interaction also reached statistical significance, $F(2, 96)$ = 6.727, p = .002, η^2_p = .123. To analyze the interaction, we conducted a repeated measures ANOVA for each Number of colours condition with congruency as the within subject factor. For the 2-colours condition, there was a significant main effect of Congruency, $F(2, 98)$ = 48.498, p < .001, η^2_p = .497. Post-hoc Bonferroni comparisons showed significant differences between the Congruent (405ms) and Incongruent (446ms) conditions, and between the Incongruent and Neutral (404ms) conditions, all ps < .0001. For the 4-colours condition, there was also a significant main effect of congruency, $F(2, 106)$ = 9.079, p < .001, η^2_p = .156. Post-hoc Bonferroni comparisons showed significant differences between the Congruent (498ms) and Incongruent (530ms) conditions and between the Congruent and Neutral (525ms) conditions, all *ps* < .01. The language factor did not interact with any other factor; namely, Language by Number of Colours, F (1, 48) = 1.137, p = .292, η^2_p = .023, Language by Congruency, F(2, 96) = .169, p =.844, η^2_p = .004, and Language by Number of Colours by Congruency, F(2, 96) = .385, p =.681, η^2_p = .008.

Accuracy. A 2 (Language group: Bilinguals, Monolinguals) x 2 (Number of colours: 2- and 4-colours blocks) x 3 (Congruency: Congruent, Incongruent and Neutral) mixed ANOVA was applied on mean accuracy rates (%) in the Simon task. Results showed significant main effects of Number of colours and Congruency: F(1, 48) = 5.045, p = .029, η^2_p = .095, and F(2, 96) = 10.941, p < .0001, η^2_p = .082, respectively. Overall, accuracy was higher for the 2-colours condition (96%) relative to the 4-colours condition (94%). Post-hoc Bonferroni comparisons showed significant differences between the Congruent (97%) and Incongruent (94%) conditions, p = .001, the Congruent and Neutral conditions (95%), p = 0.018, and the Incongruent and Neutral conditions, p = .049. In addition, both the Language group by Number of colours and the Number of Colours by Congruency interactions reached statistical significance: F(1, 52) = 7.489, p = .009, η^2_p = 135, and F(2, 96) = 4.275, p = .017, η^2_p = .082, respectively. Planned t-tests showed that accuracy rates did not significantly differ between the 2-colours (95%) and the 4-colours (96%) conditions in the monolingual group, t(24) = .467, p = .645; however, accuracy was lower in the 4-colours condition (94%) relative to the 2-colours condition (96%) in the bilingual group, t(24) = 2.92, p = .007. Bilingual and monolingual participants did not significantly differ in any of the Number of colours conditions, *ps* > .05. To analyze the Number of colours by Congruency interaction, we conducted a repeated measures ANOVA for each colour-number condition with congruency as the within subject factor. For the 2-colour condition, there was a main effect of Congruency, F(2, 98) = 19.259, p < .0001, η^2_p = .282. Post-hoc Bonferroni comparisons showed significant differences between accuracy rates in all conditions: Congruent (98%), Incongruent (93%), and Neutral (96%), all *ps* < .01. However, the main effect of Congruency did not reach statistical significance in the 4-colours condition, F(2, 98) = 1.455, p = .238, η^2_p = .029. It is finally noted that neither the language group by congruency, nor the three way interaction reached statistical significance: F (2, 96) = .843, p = .433, η^2_p = .017 and F(2, 96) = .223, p = .800, η^2_p = .005, respectively.

Table 3
Mean Reaction Times and Standard Deviations as a Function of Language Group, and the Stimulus-Response Mapping and Congruency Conditions in the Simon Task

		Stimulus-Response Mapping	
		2-Colours	**4-Colours**
Congruency conditions	**Language Group**	***M (SD)***	***M (SD)***
Congruent	Bilinguals	396 (70)	478 (100)
	Monolinguals	414 (72)	518 (112)
Incongruent	Bilinguals	439 (66)	505 (102)
	Monolinguals	454 (69)	555 (154)
Neutral	Bilinguals	395 (56)	499 (119)
	Monolinguals	412 (74)	537 (135)

The n-back task

A 2 (Language group: Bilinguals, Monolinguals) x 2 (Task difficulty: 2-back and 3-back blocks) mixed ANOVA was applied on mean reaction times (ms) for correct target hits. Results showed a significant main effect of Task difficulty, $F(1, 52) = 5.708$, $p = .021$, $\eta^2_p = .099$. More specifically, mean reaction time was faster in the 2-back condition (569ms) relative to the 3-back condition (672ms). The Language group main effect and the Language group by Task difficulty interaction did not reach statistical significance: $F(1, 52) = 1.917$, $p = .172$, $\eta^2_p = .036$, and $F(1, 52) = .015$, $p = .904$, $\eta^2_p = .000$, respectively. Number of targets recognized was submitted to a 2 (Language group: Bilinguals, Monolinguals) x 2 (Task difficulty: 2-back and 3-back blocks) mixed ANOVA. Results showed a significant main effect of Task difficulty, $F(1, 52) = 74.038$, $p < .0001$, $\eta^2_p = .587$. More specifically, overall the number of target hits was greater for the 2-back condition (16 trials) relative to the 3-back condition (11 trials). Similarly to the RT analysis above, neither the main effect of Language group, nor the Language group by Task difficulty interaction reached statistical significance: $F(1, 52) = .168$, $p = .684$, $\eta^2_p = .003$, and $F(1, 52) = .195$, $p = .660$, $\eta^2_p = .004$, respectively.

The language switching task

A 2 (Language: French and Greek) x 2 (Trial type: Non-switch and Switch) repeated measures ANOVA was applied on bilingual participants' mean response times (ms) in the language switching task. Results showed a significant main effect of trial type, $F(1, 26) = 10.439$, $p = .003$, $\eta^2_p = .286$. As expected, response times were overall higher for the Switch trials (647ms) relative to the Non-switch trials (601ms, a switching cost of 46ms). The main effect of Language and the Language by Trial type interaction did not reach statistical significance: $F(1, 26) = .585$, $p = .451$, $\eta^2_p = .022$, and $F(1, 26) = 2.814$, $p = .105$, $\eta^2_p = .098$, respectively.

Finally, contrary to our hypothesis, Pearson r correlation coefficients did not demonstrate significant relationships between absolute language switch cost asymmetry ($M = 47.07$; $SD = 56.84$) and each cognitive measure; namely, the Simon effect in the 2-colours ($r = -.017$, $p = .736$) and the 4-colours ($r = -.016$, $p = .939$) conditions, the switching cost ($r = -.368$, $p = .070$) and the mixing cost ($r = -.293$, $p = .155$) measures, and the number of targets recognized ($r = .033$, $p = .870$; 3-back: $r = .133$, $p = .509$) and mean reaction times for targets recognized (2-back: $r = -.198$, $p = .322$; 3-back: $r = .002$, $p = .990$) in the n-back task.

Discussion

The aim of this study was to provide further insight into the potential effects of bilingualism on the capacity to resist interference (inhibition function), switch between tasks, and update information in working memory (see Miyake et al., 2000). In designing the present study, we took into account factors other than language experience, which were left uncontrolled in previous studies, but might possibly account for the inconsistent evidence produced so far. Specifically, we formed a homogeneous group of early, mostly simultaneous, bilinguals and attempted to isolate early bilingualism effects on executive functioning, controlling for age, gender, intelligence, and SES (strictly matching the language groups on a one-to-one basis). Exposure to two languages from the first few years of life has been suggested to favour the demonstration of an advantage (e.g., Yow & Li, 2015). The bilingual participants spoke French-Greek on a daily basis; namely, languages that differ in terms of lexical -orthographic and phonological- and grammatical characteristics, and could, thus, set significant demands for linguistic interference control and monitoring. We conducted a comprehensive cognitive assessment, involving participants in tasks tapping switching, inhibition, and updating functions, while manipulating task demands (i.e., we used 2-back versus 3-back task blocks, and a Simon task of two working memory load conditions). The tasks provided different types of measures, namely, accuracy, reaction times, as well as effect and cost measures (e.g., the Simon effect, and switching and mixing costs). We also employed a *language switching task* to more objectively measure bilingual experience and specifically, how balanced bilingual participants were in terms of language dominance.

In contrast to the first hypothesis and previous positive findings with early bilinguals (Bialystok et al., 2012; Luk et al., 2011), or late bilinguals (Antoniou et al., 2013; Pelham & Abrams, 2014; Tao et al., 2011; Vega-Mendoza et al., 2015), we did not observe significant differences between the language groups on switching cost, interference resistance, and updating. Differences were actually not observed in any demand condition of the inhibition task (low and high working memory load conditions) and the updating task (2- and 3-back blocks), in contrast to the second hypothesis.

However, in the colour-shape switching task, bilingual participants were overall faster and demonstrated a significantly smaller Mixing cost. This effect is assumed to reflect general monitoring and attentional control, which can support the maintenance of two competing response sets, while monitoring which task is cued; thus, enabling selection of the correct stimulus-response mapping (Prior & MacWhinney, 2010; Koch et al., 2005; Rubin & Meiran, 2005). Such demands can be considered analogous to those set on bilinguals in a given conversation, not only when selecting which language to use, but also when maintaining it and facilitating access to its lexicon or grammatical entries. On the other hand, the switching cost can be regarded as more analogous to topic changes in discourse, equally engaging bilinguals and monolinguals in everyday life contexts (see discussion in Wiseheart et al., 2016). Switching cost seems to reflect more transient and time-sensitive control processes that are important for updating goals and efficiently mapping responses with cues, while resisting proactive interference (Prior & MacWhinney, 2010; Braver et al., 2003; Mayr & Kliegl, 2000, 2003). We did not observe differences in this type of cost, in line with Wiseheart and colleagues (2016), but contrary to Prior and MacWhinney (2010). Actually, Prior and Gollan (2011) found that this benefit was only evident in bilinguals who were frequently switching between languages in daily life. Our participants were not asked to report on switching frequency, however. Whether the latter can influence the differences observed between bilinguals and monolinguals in task-switching paradigms merits further investigation. Relevant studies could ideally, also control for cross-linguistic interference as a function of language similarity.

The non-significant effects of bilingualism on the executive functions measured in the present study are in agreement with research that questions the generality and robustness of a bilingual cognitive advantage (Laketa et al., in press; Lehtonen et al., 2018; Paap et al., 2015; Paap, 2019; Vivas et al., 2017; von Bastian et al., 2017). That is, it has been proposed that bilingualism does not exert a strong influence on the development of executive functions, whereas observed effects almost completely disappear when confounding factors are controlled. Alternatively, as Gathercole et al. (2014) suggested, it could be that the language control mechanisms employed by simultaneous bilinguals who are fluent in both languages, differ from those employed by sequential or late bilinguals that are less fluent in the second language. As suggested, language control in simultaneous and fluent bilinguals might involve activation of links between and within language systems according to linguistic context, rather than inhibitory control. In line with this suggestion, most null findings have actually been reported in studies with such bilingual samples (e.g., Welsh-English in Gathercole et al., 2014, and Basque-Spanish in Duñabeitia et al., 2014); that is, simultaneous, fluent bilinguals, like our participants. Though in our study, bilinguals were not living in a bilingual community, as was the case in the North Wales and the Basque Country studies mentioned above. Future studies might further test this hypothesis by comparing bilingual samples involved in different sociolinguistic and interactional contexts (single versus dual-language contexts). Finally, in contrast to what was expected, we did not find significant correlations between cognitive performance and the switch cost asymmetry measure provided by the language switching task (see also Vivas et al., 2017). Lack of a significant correlations could be due to our adult bilingual sample being relatively balanced in terms of language dominance (characterized by a rather small switch cost asymmetry overall). Alternatively, it could be that the language switching task is not a valid index of inhibitory control in language production (Bobb & Wodniecka, 2013; Costa & Santesteban, 2004; Christoffels et al., 2007). Future research should aim for alternative objective measures of bilingual experience and language dominance.

In conclusion, the present study found little evidence in favour of a bilingual advantage in executive functions in a homogeneous group of French-Greek early bilingual adults, when controlling for age, gender, intelligence, and SES. Bilinguals had overall faster reaction times and smaller mixing costs in the colour-shape switching task, which is indicative of better general monitoring and sustained control mechanisms. Future studies, preferably longitudinal, should aim for thorough explorations of cognitive development and performance as a function of bilingualism, focusing on language use and switching patterns, and the interactional context.

Acknowledgments

We would like to express our gratitude to Dr Anat Prior for sharing with us an e-prime version of the task-switching paradigm used in the Prior and MacWhinney (2010) study.

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ΕΜΠΕΙΡΙΚΗ ΕΡΓΑΣΙΑ | RESEARCH PAPER

Εκτελεστικές λειτουργίες σε γαλλο-ελληνόφωνους πρώιμα δίγλωσσους: Σε αναζήτηση του προτεινόμενου πλεονεκτήματος

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αναστολή,
εκτελεστικές λειτουργίες,
εναλλαγή,
ενημέρωση,
πρώιμη διγλωσσία

ΣΤΟΙΧΕΙΑ ΕΠΙΚΟΙΝΩΝΙΑΣ

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ΠΕΡΙΛΗΨΗ

Η καθημερινή χρήση δύο γλωσσών απαιτεί, μεταξύ άλλων, από έναν δίγλωσσο ομιλητή τη διαχείριση διαγλωσσικών επιδράσεων και παρεμβολών. Αυτή η εξάσκηση θεωρείται πως αντανακλάται στις καλύτερες επιδόσεις τους έναντι των μονόγλωσσων σε μη λεκτικά γνωστικά έργα. Πρόσφατα ευρήματα, ωστόσο, θέτουν υπό αμφισβήτηση το προτεινόμενο πλεονέκτημα. Η παρούσα μελέτη διερευνά το ζήτημα σε πρώιμα δίγλωσσους ενήλικες (γαλλο-ελληνόφωνους). Η έκθεση στις δύο γλώσσες από τη βρεφική ηλικία θεωρείται πως ευνοεί την εκδήλωση πλεονεκτήματος. Οι επιδόσεις τους σε έργα εκτελεστικών λειτουργιών, συγκεκριμένα, σε έργα εναλλαγής, αναστολής και ενημέρωσης (διαβαθμισμένης δυσκολίας), συγκρίθηκαν με αυτές ελληνόφωνων μονόγλωσσων. Οι δύο ομάδες εξισώθηκαν ως προς το φύλο, την ηλικία, τη μη λεκτική νοημοσύνη και το κοινωνικοοικονομικό επίπεδο. Σε συμφωνία με το προτεινόμενο πλεονέκτημα και, όπως αναμενόταν, οι δίγλωσσοι ενήλικες ήταν ταχύτεροι στο έργο εναλλαγής. Επίσης, η απόκλιση της ταχύτητας απόκρισης στις δοκιμασίες των απλών συστοιχιών (σταθερό κριτήριο απόκρισης) από τις δοκιμασίες των σύνθετων συστοιχιών όπου δεν άλλαζε το κριτήριο (mixing cost), ήταν μικρότερη για τους δίγλωσσους συμμετέχοντες. Αντιθέτως, οι γλωσσικές ομάδες δεν διαφοροποιήθηκαν ως προς την απόκλιση της ταχύτητας απόκρισης στις δοκιμασίες των σύνθετων συστοιχιών όπου άλλαζε το κριτήριο, από αυτές στις οποίες παρέμενε σταθερό (switching cost). Διαφορές δεν παρατηρήθηκαν ούτε στις μετρήσεις αναστολής και ενημέρωσης, σε κανένα επίπεδο μνημονικών απαιτήσεων, αντίθετα από το αναμενόμενο. Αντίστοιχα, το πόσο ισορροπημένη ήταν η διγλωσσία δεν συσχετίστηκε με τις γνωστικές επιδόσεις των δίγλωσσων. Τα ευρήματα δεν επιβεβαιώνουν την ύπαρξη γενικευμένου γνωστικού πλεονεκτήματος σε πρώιμα δίγλωσσους ενήλικες. Συζητούνται παράγοντες που ενδέχεται να επηρεάζουν την εκδήλωσή του και διατυπώνονται προτάσεις για μελλοντική έρευνα.