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RESEARCH NOTE

The influence of bilingualism on working memory event-related potentials*

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Bilingualism has been found to enhance the ability to store and manipulate information in working memory (WM). However, previous studies of WM function in bilingualism have been limited to behavioural measures, leaving questions unanswered regarding the effects of bilingualism on neural mechanisms employed during WM tasks. We recorded brain activity (event-related potentials; ERPs) while participants (23 English-speaking and 21 English–French bilinguals) performed an n-back WM task. Accuracy and reaction time were similar across groups, but monolinguals exhibited smaller P300 amplitudes relative to bilinguals, suggesting that bilinguals have more cognitive resources available to complete cognitively demanding tasks.

Keywords: bilingualism, event-related potentials, working memory

1. Introduction

As early as the 1960s, research suggested that bilinguals may experience cognitive advantages over monolinguals, particularly in tasks involving problem solving and creativity (Bain, 1975; Kessler & Quinn, 1987; Peal & Lambert, 1962). However, recent research examining this bilingual advantage has yielded mixed findings, with some studies finding improved executive function (EF) in bilinguals (Badzakova-Trajkov, 2008; Bialystok, Craik, Klein & Viswanathan, 2004; Bialystok & Martin, 2004; Prior & Gollan, 2011), and others finding no such advantage (Duñabeitia, Hernández, Antón, Macizo, Estévez, Fuentes & Carreiras, 2013; Gathercole, Thomas, Kennedy, Prys, Young, Vinas Guasch, Roberts, Hughes & Jones, 2014; Goldman, Negen & Sarnecka, 2014).

While many previous studies have examined EF differences in bilingualism, few have studied working memory (WM) differences. WM is involved with temporarily storing and manipulating information that is no longer perceptually present (Baddeley, 2003; Diamond, 2013). Similar to EF studies, current findings have reported mixed results with respect to the effect of bilingualism on WM performance, with some reporting improved performance in bilinguals relative to monolinguals (Kudo & Swanson, 2014; Morales, Calvo & Bialystok, 2013), and others finding no cognitive advantage (Bialystok, 2009; Blom, Küntay, Messer, Verhagen & Leseman, 2014; Bonifacci, Giombini, Bellocchi & Contento, 2011; Engel de Abreu, 2011; Ratiu & Azuma, 2014). The present study aimed to determine whether WM differences between monolinguals and bilinguals are measurable through brain activity patterns (event-related potentials; ERPs).

Electroencephalography (EEG) is a technique that can be combined with cognitive, sensory, or motor tasks, to extract waveforms reflecting the brain's activity during specific mental processes (Luck, 2014). These waveforms, referred to as event-related potentials (ERPs), are associated with varying cognitive processes, and can be measured through latency (time to process the stimulus) and amplitude (intensity of the response) (Luck, 2014). Each component may be positive or negative, and has a typical latency range; for example, the P300 is a positive-going component occurring around 300ms after stimulus onset.

The components of interest in the current study are the P200, N200 and P300. The P200 normally occurs 150–300ms following stimulus presentation (Luck, 2014), and is thought to be associated with WM (Finnigan, O'Connell, Cummins, Broughton & Robertson, 2011; Lijffijt, Lane, Meier, Boutros, Burroughs, Steinberg, Moeller & Swann, 2009), with smaller amplitudes

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representing lower WM performance (Finnigan et al., 2011). The N200 occurs 200–350ms post-stimulus presentation (Folstein & Van Petten, 2008) and reflects attention and the ability to discriminate an incongruity between a current stimulus and the representation of a stimulus held in memory (Bennys, Portet, Touchon & Rondouin, 2007; Folstein & Van Petten, 2008; Patel & Azzam, 2005). The N200 occurs later in low performers, suggesting impairments in the processing of stimulus detection (Daffner, Chong, Sun, Tarbi, Riis, McGinnis & Holcomb, 2011). The P300 occurs 300–600ms post-stimulus and is involved with many cognitive processes such as cognitive control, attention, and memory processing (Mertens & Polich, 1997; Polich, 2007). The P300 can be divided into two subcomponents, the frontally maximal P3a and the parietally maximal P3b. The P3a, which occurs earlier than the P3b, is elicited only when the participant is not actively attending to a stimulus (response to a non-target stimulus), whereas the P3b requires active attention and detection of a target (Luck, 2014; Polich, 2007). P300 latency reflects information processing speed, and increases as processing time increases (Kok, 2001; Polich, 1996), while P300 amplitude reflects intensity of processing (Kok, 2001) and resource allocation (Polich, 1996).

WM can be studied by using the n-back task, where participants are required to determine whether a current stimulus matches a stimulus from *n* steps earlier. Previous research on the n-back task has shown that as WM load increases, the P300 decreases due to diminished WM capacity and fewer available resources to complete the task (Daffner et al., 2011; Gevins, Smith, Le, Leong, Bennett, Martin, McEvoy, Du & Whitfield, 1996). However, high performers exhibit increased P300s as task difficulty increases, due to the availability of more resources to allocate to task completion (Daffner et al., 2011).

ERP studies of executive control have found differences between monolinguals and bilinguals across a range of tasks. Barac and colleagues found that bilingual children exhibited larger amplitudes, shorter latencies, and better behavioural performance during complex response inhibition (Barac, Moreno & Bialystok, 2016) compared to monolinguals, indicating improved executive control in bilinguals. Electrophysiological differences between monolinguals and bilinguals have also been found in both cognitive monitoring and task switching (Barac et al., 2016; Grundy et al., 2017; Kousaie & Phillips, 2012), although in the latter two studies no behavioural differences were observed. These findings indicate that ERPs may offer additional insight into the difference in cognitive processing between monolinguals and bilinguals.

The present study aimed to examine the effect of bilingualism on WM. Monolingual and bilingual participants completed the n-back WM task while EEG was recorded. We expected bilinguals to have shorter RTs and improved accuracy, with larger P200s, reflecting improved WM performance and capacity. We also hypothesized that bilinguals would have smaller N200 amplitudes than monolinguals, reflecting heightened ability to discriminate between a current stimulus and the one held in memory. With respect to the P300[1], both monolinguals and bilinguals were expected to exhibit the typical amplitude reduction with increased WM load. Bilinguals were expected to have larger P300 amplitudes than monolinguals overall, reflecting higher WM capacity and enhanced ability to allocate their resources to complete the task.

2. Methods

2.1 Participants

Fifty young adults aged between 18 and 30 were recruited through word of mouth at the University of Ottawa. Of the fifty participants recruited, six were excluded for the following reasons: two scored less than 50% during the 2-back, two revealed after testing that they were fluent in a third language, and ERP data of two participants was very noisy, requiring exclusion of more than 25% of their trials. There were 23 English monolinguals (17 females) and 21 bilinguals (15 females) totalling forty-four participants remaining. The monolingual group had a mean age of 19.70(±2.32) and 14.61(±1.83) years of education, while the bilingual group had a mean age of 19.71(±1.65) and 14.71 (±1.52) years of education. Groups did not significantly differ in age or education (Table 1). Bilingual participants were native English speakers and highly proficient in French; all became fluent in French before the age of 13. Demographic information and neuropsychological test scores are provided in Table 1. The study was approved by the research ethics board at Bruyère Research Institute; participants provided informed written consent before starting the study and were compensated $10 an hour.

Participants completed a self-rated language proficiency scale for English and French, and bilinguals completed a language history and usage questionnaire to assess frequency of language use in different contexts (Table 2). If participants reported knowledge of another language rated above a 2 (“very little ability”) they were excluded. Participants had no neurological or psychiatric history, were not taking medications that influence the central nervous system, and had not suffered any major head injuries.

[1] Consistent with previous studies, we refer to the parietally-maximal P3b as the P300.

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Table 1. *Demographic and neuropsychological results by group (mean (SD)).*

	Group		
	Monolingual	Bilingual	t-test and *p*-values
N (females)	23 (17 females)	21 (15 females)	
Age	19.70 (2.32)	19.71 (1.65)	t(42) = –0.03, *p* = 0.98
Education	14.61 (1.83)	14.71 (1.52)	t(42) = –0.20, *p* = 0.84
Digit Span Forward	11.22 (2.19)	11.47 (2.48)	t(42) = –0.37, *p* = 0.72
Digit Span Backward	7.13 (1.98)	7.57 (2.29)	t(42) = –0.68, *p* = 0.50
Letter # Sequencing	11.34 (2.08)	12.23 (3.16)	t(42) = –1.11, *p* = 0.27
WCST	4.30 (0.97)	4.52 (0.98)	t(42) = –0.74, *p* = 0.46
Stroop1	112.57 (5.10)	111.81 (16.39)	t(42) = 0.17, *p* = 0.87
Stroop2	80.91 (7.89)	79.62 (10.68)	t(42) = 0.46, *p* = 0.65
Stroop3	52.35 (11.75)	54.52 (10.75)	t(42) = –0.64, *p* = 0.53
Digit Symbol-Written	66.39 (12.54)	64.52 (12.23)	t(42) = –0.74, *p* = 0.62
Digit Symbol-Oral	71.17 (11.88)	73.29 (15.60)	t(42) = 0.50, *p* = 0.61
BNT-English (/60)	53.21 (4.06)	50.38 (8.27)	t(42) = 0.37, *p* = 0.71
F Fluency- English	13.09 (4.36)	13.61 (4.25)	t(42) = –0.41, *p* = 0.68
A Fluency- English	11.74 (2.85)	12.00 (5.13)	t(42) = –0.21, *p* = 0.83
S Fluency- English	16.30 (5.10)	15.19 (5.18)	t(42) = 0.72, *p* = 0.47
F Fluency- French		8.90 (4.18)	
A Fluency- French		9.67 (4.41)	
S Fluency- French		8.29 (3.45)	
BNT-French (/60)		35.43 (11.36)	

Notes: BNT = Boston Naming Test, WCST = Wisconsin Card Sorting Test (categories completed). Stroop1 = requires participants to read the name of colors, Stroop2 = name the color of "X's", Stroop3 = name the ink color of color words printed in a different color (e.g., the word "RED" printed in green ink). Digit Symbol-Written = match the digit to corresponding symbol by writing the answer, Digit symbol-Oral = match the digit to corresponding symbol by reading the answer aloud.

2.2 Procedure

Participants completed a neuropsychological battery that included letter/number sequencing, forward and backward digit span (Wechsler Memory Scale, (Wechsler, 1997)), Wisconsin Card Sorting Test (WCST) (Grant & Berg, 1948), both the written and verbal Digit Symbol Substitution subtests of the Wechsler Adult Intelligence Scale-III (WAIS-III) (Wechsler, 1997), the Stroop task (Stroop, 1935), verbal fluency (FAS and animal fluency) and the Boston Naming Test (BNT) (Kaplan, Goodglass, Weintraub & Segal, 1983). Bilinguals completed the fluency tasks and BNT in both English and French to allow characterization of their language abilities in both languages.

Neuropsychological data were collected in one testing session. In a second testing session, participants completed the n-back task (and another task not reported in this paper)[2] while EEG was recorded. Each session lasted approximately 1.5 to 2 hours.

[2] The n-back was employed as a delay task after an emotional faces paradigm where participants were required to state if a picture was emotionally arousing.

2.3 N-back working memory task

Participants saw digits one at a time at the center of a computer screen for 1000ms with an inter-stimulus interval of 1700ms. The n-back task includes three different memory load conditions. In the 0-back condition, participants press the mouse key in response to the number 0, in the 1-back condition participants press the mouse key when the number matches the previous number seen (e.g., a 9 and then another 9), and in the 2-back condition participants press the mouse key when the digit matches the one presented two trials previously (e.g., a 9 followed by a 6 and then another 9). Each condition consists of 180 trials, with 60 requiring the participant to respond (by pressing the mouse key). Each condition lasted approximately 10 minutes, for a total of 30 minutes.

2.4 EEG data recording and analysis

The EEG was recorded from 32 active silver-silver chloride electrodes attached to an electrode cap (Brain Products, GmbH, Munich, Germany) placed according to the international 10–20 system. An EOG electrode

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Table 2. *Relative use of language and self-reported proficiency ratings.*

	Monolinguals	Bilinguals
French Age of Acquisition	6.13 (1.54)	4.05 (2.27)
French Age of Fluency	—	9.95 (3.28)
English Proficency Rating		
Listening	4.87 (0.34)	5 (0)
Reading	5 (0)	5 (0)
Speaking	5 (0)	5 (0)
Writing	4.96 (0.21)	4.95 (0.22)
French Proficency Rating		
Listening	1.94 (0.24)	4.48 (0.51)
Reading	1.88 (0.49)	4.33 (0.48)
Speaking	1.82 (0.39)	4.14 (0.48)
Writing	1.71 (0.47)	3.76 (0.70)
French use at home		
Speaking	—	28.57% (37.32)
Listening to speak	—	33.33% (32.91)
Reading	—	25% (32.60)
Writing	—	21.43% (31.90)
French use at school/work:		
Speaking	—	34.52% (25.59)
Listening to speak	—	40.47% (24.34)
Reading	—	29.76% (23.21)
Writing	—	32.14% (25.18)

Note: Values given are mean scores with standard deviations. Self rated profiency was rated on a five point scale: 1-no ability at all, 2-Very little ability, 3-Moderate ability, 4-Very good ability, 5-Native-Like abilties. Language use was rated on a 5 point scale: 0%, 25%, 50%, 75%, and 100% of the time. Age of acquisition is reported for monolingual speakers because many received French instruction in school but never achieved fluency.

was placed on the infraorbital ridge of the left eye to record vertical eye movements. An average of the mastoids was used as a reference for all channels. Inter-electrode impedances varied from 0–20kΩ and the EEG was digitized at rate of 500Hz.

EEG data was processed offline using Brain Vision Analyser 2.1 (Brain Products, GmbH, Munich, Germany). The EEG was down-sampled to 250Hz with a time constant of 2s, and digitally filtered using a low pass filter of 30Hz. The EEG was visually inspected for channels containing high levels of noise, and high noise channels were replaced by interpolating the data of surrounding electrode sites (Perrin, Pernier, Bertrand & Echallier, 1989). Independent Components Analysis was used to identify eye movements and blinks that were independent of the EEG activity. The continuous EEG was reconstructed into 1200ms epochs starting 200ms before stimulus onset. The 200ms pre-stimulus period served as a zero-voltage baseline period, and epochs were baseline-corrected. Any epochs containing EEG activity exceeding $\pm 100\mu V$ were rejected from the averaging, with correct trials for both target and non-target trials included in averages.

3. Statistical analysis and results

3.1 Neuropsychological data

Neuropsychological test scores from monolingual and bilingual groups were compared using independent sample t-tests, with Bonferroni correction for multiple comparisons. There were no significant differences between monolinguals and bilinguals on any of the neuropsychological test scores. Bilingual participants' verbal fluency and BNT task performance in English and French was compared using a repeated-measures ANOVA. Their performance was better in English than French on all measures except F fluency, indicating that our bilingual participants were English-dominant.

3.2 N-back behavioural performance

Trials with RTs exceeding ±2.5 standard deviations from the mean by participant and condition were excluded as outliers. Accuracy and RT were analyzed with two separate 3x2 mixed ANOVAs with Condition (0-, 1-, and 2-back) as a within-subject factor and Group (Monolingual vs Bilingual) as a between-subject factor. Outliers constituted less than 1% of the trials in all conditions and groups. Average accuracy and RTs by group are shown in Table 3.

A repeated-measures ANOVA revealed decreasing accuracy with increasing task difficulty overall (main effect of Condition F (2, 84) = 113.22, $p<0.001$, $n_p{}^2$ = 0.73). No other effects reached significance (Group: F (1,42) = 1.24, $p = 0.271$, Condition X Group: F (2, 84) = 1.44, $p = 0.244$). Similarly, longer RTs were observed as task difficulty increased (main effect of Condition F (2, 84) = 63.98, $p<0.001$, $n_p{}^2$ = 0.60), but no other effects reached significance (Group: F (1,42) = .72, $p = 0.402$, Condition X Group: F (2,84) = 1.33, $p = 0.268$).

3.3 ERP analyses

Three components were selected for analysis: the P200, N200, and P300. For all three components, four midline sites were chosen for analysis (Fz, FCz, Cz, and Pz). A Greenhouse-Geisser correction procedure was used for all ERP analyses when sphericity was violated (Greenhouse & Geisser, 1959). Bonferroni-corrected pairwise comparisons were performed when comparing groups at the four sites of measurement.

The P200 was scored as the most positive peak from 100–200ms and the N200 was scored as the most negative peak from 200–350ms. Two separate 4x3x2

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Table 3. *Behavioural performance on the n-back task for each condition and group.*

Measures for N-back Mean (Standard Deviation)	Group		
	Monolinguals (n = 23)	Bilinguals (n = 21)	t-test and *p*-values
0-back			
RT(ms)	391.02 (41.04)	382.32 (56.40)	t(42) = 0.59, *p* = .56
Accuracy to Targets	97.30 (1.57)	96.98 (1.86)	t(42) = 0.63, *p* = .53
Omission Errors (%)	0.13 (0.46)	0.14 (0.48)	t(42) = –0.88, *p* = .93
Commission errors (%)	0.35 (0.57)	0.19 (0.57)	t(42) = 0.96, *p* = .34
Outliers (/180)	1.48 (0.85)	1.67 (0.91)	t(42) = –0.71, *p* = .48
1-back			
RT(ms)	456.96 (60.05)	455.28 (82.25)	t(42) = .09, *p* = .93
Accuracy to Targets	91.23 (9.40)	93.17 (5.70)	t(42) = –0.70, *p* = .48
Omission Errors (%)	3.96 (5.94)	2.76 (3.70)	t(42) = 0.79, *p* = .43
Commission errors (%)	0.39 (0.67)	1.00 (1.38)	t(42) = –1.84, *p* = .08
Outliers (/180)	1.30 (0.93)	1.33 (0.91)	t(42) = –1.04, *p* = .92
2-back			
RT(ms)	500.67 (58.79)	471.15 (73.54)	t(42) = 1.49, *p* = .14
Accuracy to Targets	68.84 (18.38)	74.68 (10.89)	t(42) = –1.26 *p* = .20
Omission Errors (%)	18.17 (11.01)	13.90 (7.01)	t(42) = 1.52, *p* = .13
Commission errors (%)	6.48 (3.09)	6.05 (2.46)	t(42) = 0.51, *p* = .61
Outliers (/180)	0.52 (0.67)	1.28 (1.06)	t(42) = –2.90, *p* = .006*

Notes: The differences between groups showed only that monolinguals had fewer outliers than bilinguals in the 2-back condition. However, when a repeated measures ANOVA was conducted the difference was not significant.

mixed ANOVAs (one for latency and one for amplitude) were conducted with the within-subject factors Site (Fz, FCz, Cz, and Pz) and Condition (0-, 1-, and 2-back), and the between-subject factor of Group (monolingual vs. bilingual) for both the P200 and N200. Visual inspection of the P300 showed no distinctive peak in either the monolingual or bilingual group. Thus, mean amplitudes were calculated at all midline regions with a time window of 300–500ms. One 4x3x2 mixed ANOVA was conducted for mean amplitude analysis, with the within-subject factors of Site (Fz, FCz, Cz, and Pz) and Condition (0-, 1-, 2-back), and the between-subject factor of Group (monolingual vs. bilingual).

P200 latency analysis revealed a main effect of Condition, F (2, 84) = 7.99, p = 0.003, n_p^2 = 0.16, with post hoc comparison indicating that the 0-back had a shorter latency (166.05ms) than the 1-back (174.67ms, p = 0.006) and 2-back (172.86ms, p = 0.035) conditions, which did not differ from each other (Figure 1). P200 amplitude analysis revealed a main effect of Condition, F (3,126) = 8.19, p = 0.001, n_p^2 = 0.16, with post hoc tests revealing smaller peak amplitudes for the 0-back (5.56μV, p = 0.002,) and 1-back (5.75μV, p = 0.010) conditions compared to the 2-back condition (6.39μV). No effects of Group (monolingual versus bilingual) nor other effects of interest were found (Figure 2).

N200 latency analysis revealed no significant main effects or interactions (p > 0.05 in all analyses). Significant differences in N200 amplitude were observed: a main effect of Condition F (2, 84) = 24.09, p <0.001 n_p^2 = 0.36 was due to larger amplitudes in the 0-back condition (-3.10μV) compared to the 1-back (-2.09μV) and 2-back (-1.44μV), p <0.001, and a larger amplitude in the 1-back compared to the 2-back (p = 0.006). That is, the amplitude became less negative (smaller) as task difficulty increased (Figure 1).

The P300 analysis showed a significant effect of Group, F (1, 42) = 5.43, p = 0.025, n_p^2 = 0.11. Bilinguals had a mean amplitude of 2.22μV whereas the mean amplitude for monolinguals was 0.73μV (Figure 2). P300 amplitude also revealed a main effect of condition, F (2, 84) = 8.85, p<0.001, n_p^2 = 0.17 (Figure 1). Bonferroni corrected post-hoc analyses revealed that the 0-back task elicited smaller amplitudes (0.986μV) than both the 1-back (1.511μV), p = 0.02 and 2-back (1.930μV), p <0.001. There was a significant Site X Group interaction, F (3, 126) = 5.78, p = 0.004, n_p^2 = 0.12. Pairwise comparisons identified differences between monolinguals and bilinguals at Fz (-0.13μV for monolinguals vs. 1.31μV for bilinguals, p = 0.024); FCz (0.34μV vs. 2.2μV, p = 0.016), and Cz (0.86μV vs. 2.70μV, p = 0.017). That is, monolinguals exhibited smaller P300

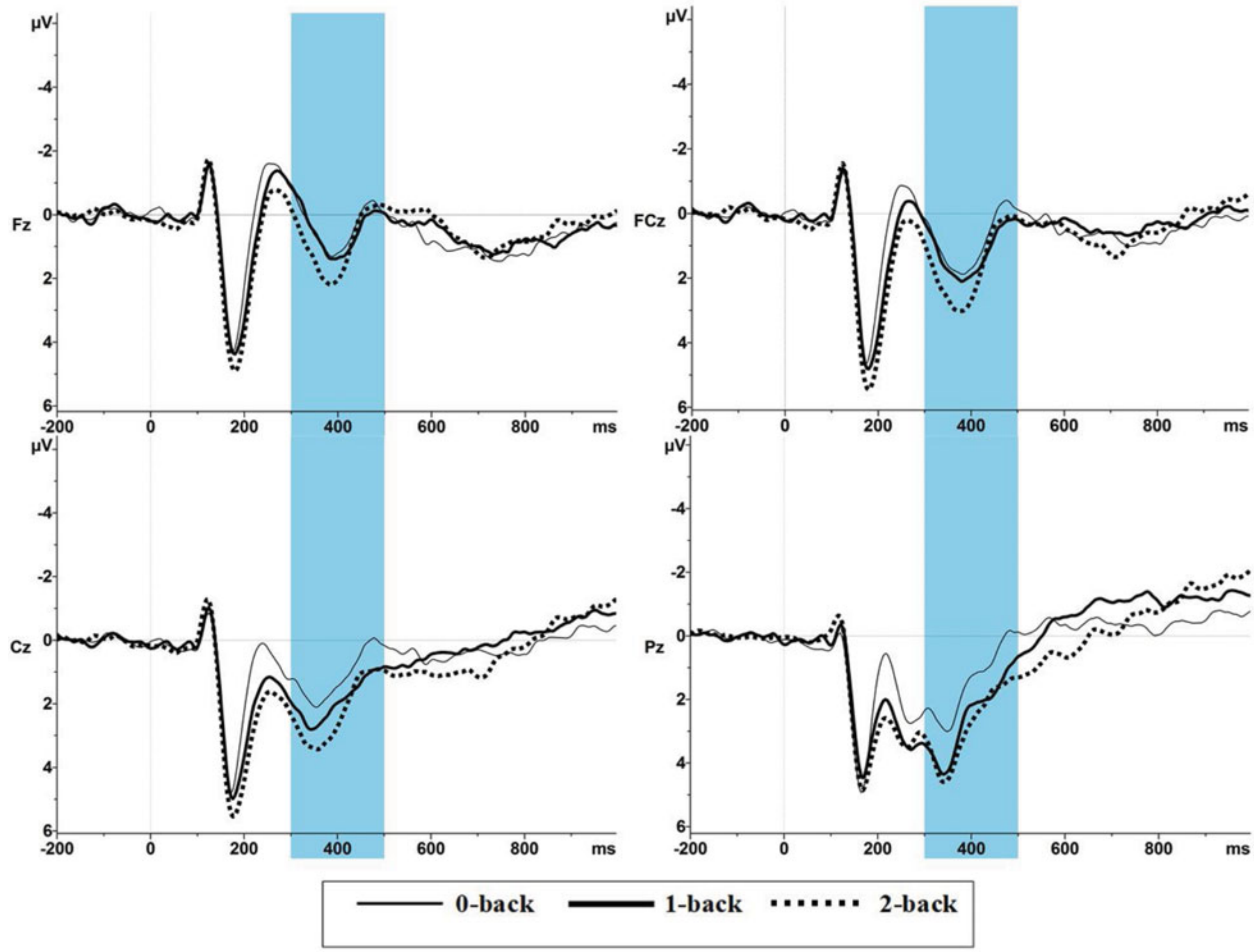

Figure 1. (Colour online) Grand Averaged ERP waveforms combining both groups to show the effect of condition. Negative is plotted upwards.

amplitudes compared to bilinguals at Fz, FCz, and Cz across all conditions.

4. Discussion

While numerous studies have employed neuroimaging techniques such as ERPs, magnetoencephalography (MEG), and functional magnetic resonance imaging (fMRI), to examine EF differences between bilinguals and monolinguals (Abutalebi, Della Rosa, Green, Hernandez, Scifo, Keim, Cappa & Costa, 2012; Bialystok, Craik, Grady, Chau, Ishii, Gunji & Pantev, 2005; Gigi, Anderson, Craik, Grady & Bialystok, 2010; Green & Abutalebi, 2015; Kousaie & Phillips, 2012), to our knowledge the present study is the first to examine the effect of bilingualism on WM performance using ERPs.

In line with previous research (Bialystok, 2009; Blom et al., 2014; Bonifacci et al., 2011; Engel de Abreu, 2011; Ratiu & Azuma, 2014), no differences were observed between monolingual and bilingual participants in standardized neuropsychological tasks tapping WM (digit span forward, digit span backward, and letter/number sequencing). Behaviourally, monolinguals and bilinguals responded with similar accuracy and RT in all conditions of the experimental task (0-, 1-, and 2-back). As predicted, longer RTs and lower accuracy were observed in both groups as task difficulty increased.

The P200 and N200 are believed to be involved with early processing for allocation of attention and inhibitory processing (Bennys et al., 2007; Lijffijt et al., 2009) as well as the ability to discriminate between a current stimulus and the representation of one held in memory (Folstein & Van Petten, 2008). Similar P200 latency and amplitude between groups demonstrates that the allocation of attention during a WM task does not differ between monolinguals and bilinguals. Although it was expected that monolinguals would have diminished N200s, the similarity between groups suggests that both groups have similar ability to focus attention and discriminate between the target stimulus and the one held in memory.

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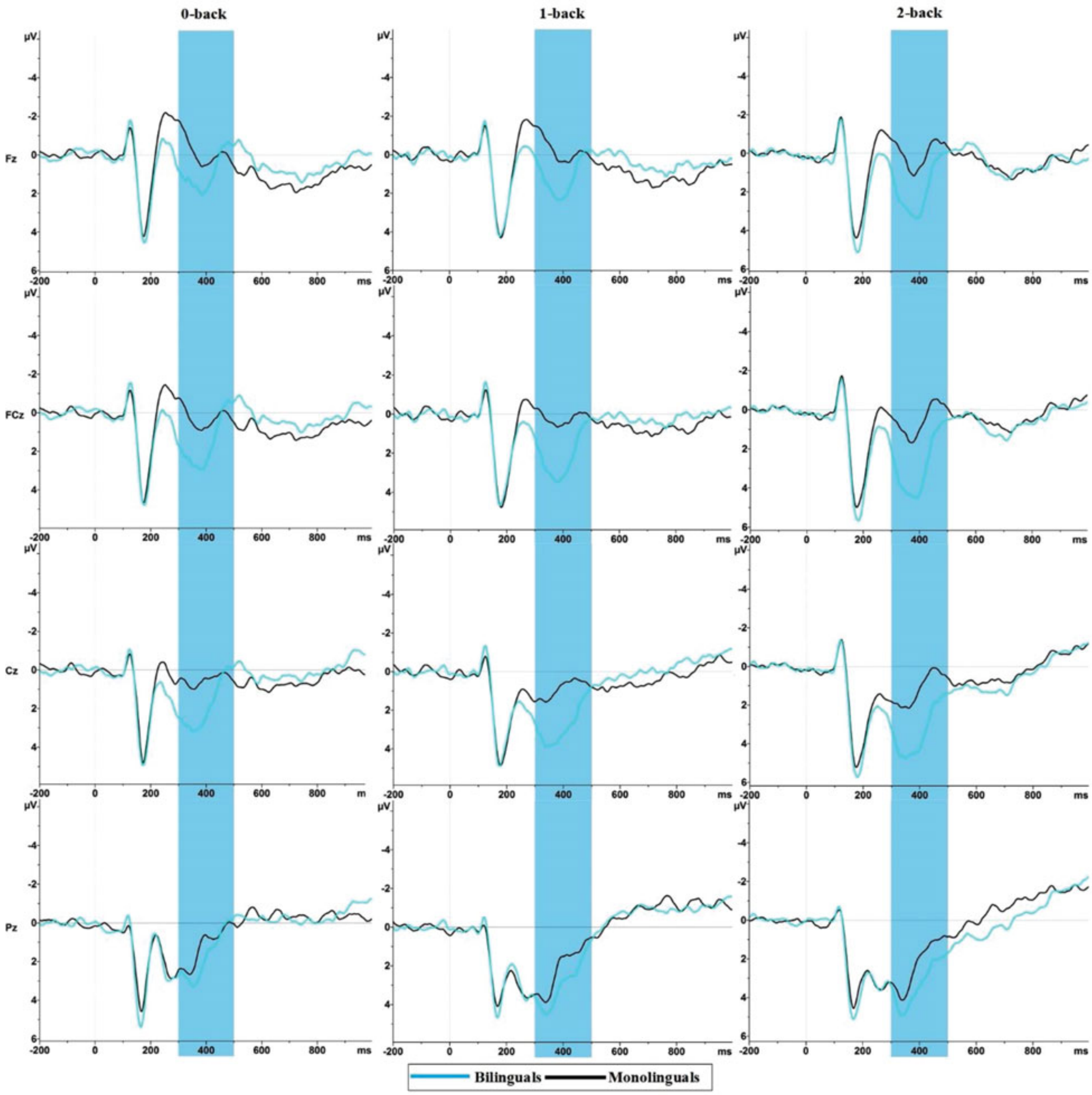

Figure 2. (Colour online) Grand averaged ERP waveforms for bilingual and monolingual young adults during each of the n-back conditions. Negative is plotted upwards.

While previous research has indicated that P300 amplitude declines as WM load increases, due to the availability of fewer cognitive resources (Daffner et al., 2011; Gevins et al., 1996; Kok, 2001), here we found that P300 amplitude increased with increasing WM load. This finding may reflect participants' near-ceiling accuracy. High accuracy suggests that participants had sufficient cognitive resources available to complete the task with little difficulty. Bilinguals also exhibited larger P300 amplitudes relative to monolinguals, reflecting differences in cognitive processing. Based on previous research on high and low performers (Daffner et al., 2011), we posit that larger P300 amplitudes in bilinguals demonstrate that they have more cognitive resources available for allocation towards task completion (Kok, 2001) compared to monolinguals, suggesting that bilinguals can complete more difficult tasks with less effort and higher efficiency.

In the absence of behavioural differences, electrophysiological differences between monolinguals and bilinguals during WM processing were found. Future research should replicate this study with a 3-back task to determine if more challenging tasks can elicit both behavioural

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and neural group differences. To determine whether electrophysiological differences between groups translate into a behavioural cognitive advantage, it would also be beneficial to test bilingual and monolingual older adults. Language group differences are more difficult to detect in young adults because they are at the peak of their cognitive functioning, whereas effects of bilingualism on WM may be easier to detect in older adults due to age-related cognitive declines.

5. Conclusion

While monolinguals and bilinguals performed with similar accuracy and response time in both low and high load WM conditions, group differences were observed in electrophysiological response. Specifically, bilinguals showed significantly larger P300 amplitudes relative to monolinguals, indicating that bilinguals have more resources available to allocate to task completion as WM load increases. These findings indicate that ERPs may be sensitive to cognitive differences that are not revealed by behavioural measures.

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