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Prospective memory in bilinguals and monolinguals: ERP and behavioural correlates of prospective processing in bilinguals

Cristina López-Rojas [a,c,*], Eleonora Rossi [b], Alejandra Marful [a,c], Mª Teresa Bajo [a,c]

[a] Mind, Brain and Behavior Research Center (CIMCYC), University of Granada, Granada, Spain
[b] Department of Linguistics, University of Florida, USA
[c] Department of Experimental Psychology, University of Granada, Granada, Spain

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ABSTRACT

Prospective memory (PM) allows us to form intentions and execute them in the future. Successful retrieval of prospective intentions depends on adequate context monitoring and disengagement from the ongoing task. These processes are also central in predicting incoming language information and guiding language production in bilinguals. We investigated if different bilingual experiences (early/late bilinguals, monolinguals) modulate performance in PM tasks that varied in attentional requirements (focal vs. non-focal). Behavioural and event-related potential (ERP) results indicated that early bilinguals differed from late bilinguals and monolinguals in how they performed the prospective task. Specifically, they showed larger differences between the ongoing activity and the prospective task in the N300 and P3b components when performing the more difficult non-focal PM task, indicating that they engaged in monitoring/updating to adapt to the task's demands. These differences were not observed in late bilinguals and monolinguals, suggesting that prospective processing is dependent on the bilingual experience.

1. Introduction

Planning and remembering future events are essential processes in everyday activities. Prospective memory (PM) allows us to create intentions and execute them in the future. Although there are different approaches on how PM tasks are performed (Hohwy, 2013; Vecchi & Gatti, 2020), executing the intention in the right moment involves monitoring the context for the time or the target cue that indicates when the intention should be implemented and switching from the ongoing task to the prospective task to execute the prospective action in the appropriate moment (Scullin et al., 2015). Therefore, PM requires the successful involvement of executive functions such as monitoring and switching to prepare for a given task and to avoid incoming interference. In PM literature, monitoring processes reflect the strategic allocation of attentional resources required to detect a target cue (Ballhausen et al., 2017), whereas switching processes refer to the disengagement from the ongoing activity to remember the intention in a PM task (Cona et al., 2015). Thus, PM is usually assumed to be composed by prospective components including context monitoring, cue detection and switching and a retrospective component which includes actual remembering of the intention (McDaniel & Einstein, 2007). These prospective processes are used daily to remember intended critical actions such as taking medication, getting to an appointment, or giving a message to a friend at the proper time (PM). However, prospective processing occurs in very different contexts and over different cognitive operations and types of intentions. This prospective processing refers to proactive cognitive control strategies involving monitoring the context and preparing for an incoming event (Lamichhane et al., 2018).

For example, in the language context, prospective processing has been proposed as central in predicting incoming language information and in directing language production. In the context of bilingual language comprehension and production, prospective processing has also been proposed as a mechanism that facilitates language selection in bilinguals (Wu & Thierry, 2017). This prospective processing is especially important because many studies have shown that bilinguals coactivate their two languages, even if only one language is required (Blumenfeld & Marian, 2007; Dijkstra & Kroll, 2005; Hoshino & Thierry, 2011; Kroll & Stewart, 1994; Macizo et al., 2010). As a result, bilinguals need to negotiate their languages to avoid competition and select the more appropriate language for a given context (Morales et al., 2013, 2015). Recent research has shown that bilingual language selection is, in part, subserved by prospective processing of the environment for

* Corresponding author.
E-mail address: lopezrojas@ugr.es (C. López-Rojas).

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contextual cues to use the appropriate language. For example, visual cues such as the sociocultural identity of a face (Asian facial features versus occidental features; Li et al., 2013) or previous face-language associations (Woumans et al., 2015) have been shown to facilitate processing of the more expected language in the presence of the contextual facial cue. Similarly, bilinguals seem to adapt more easily to between-language switching when the presence of a bilingual person cues a bilingual context than when the presence of a monolingual person cues the use of a single language. For example, in a recent experiment by Kaan et al. (2020), Spanish-English bilinguals were asked to read sentences with and without between-language switches when they were in the presence of another Spanish-English bilingual or of an English monolingual. Their electroencephalograms (EEGs) were recorded while reading, and event-related potentials (ERPs) were locked to the critical point where language switched. Results showed that the early fronto-central positivity elicited by language switching was attenuated when a bilingual was present at the start of the study compared to when a monolingual was present. Hence, bilinguals monitored the context in a prospective manner to prepare for the appropriate language.

The concept that bilinguals activate their two languages and use executive control mechanisms, including monitoring and prospective preparation for language use, raises interesting questions regarding their performance in other prospective tasks. Context monitoring for bilingual language selection should be similar to monitoring in PM, and thus, one might expect that bilingualism would modulate the cognitive processes that emerge during prospective remembering. Hence, one might hypothesize that bilinguals might be better at monitoring the context to detect the appropriate cue to perform the prospective intention (Jiao et al., 2019).

A factor that can affect monitoring in bilinguals is the environment in which they are immersed (i.e., their recurrent pattern of conversational exchanges). Thus, for example, monitoring demands may vary greatly depending on the interactional language context in which bilinguals are immersed (Green & Abutalebi, 2013). From this perspective, bilinguals immersed in a context where two languages are at competition (e.g., talking to some persons in L1 and to others in L2) will need to monitor the context to a greater extent and will be more vulnerable to conflict than bilinguals that recurrently and freely switch between languages within the same utterance, who would use their languages in a more cooperative way. Consequently, it is possible that, due to the differences in language control demands, bilinguals that interact in language settings with different monitoring requirements will also adjust their monitoring capacities in a PM task. Similarly, if the age at which the bilinguals acquired their second language (L2) modulates how they control their languages, it might also influence the strategies that bilinguals use to monitor the context in a PM task (Luk et al., 2011). Age of acquisition of L2 has been demonstrated to play a critical role in the cognitive effects associated with bilingualism with longer active bilingual practice promoting adaptive transfer from language control to domain-general cognitive control (Bonfieni et al., 2019; Hartanto & Yang, 2019). For example, D'Souza et al. (2021) found that early age of acquisition was related with higher ability in change detection in adults. In addition, neuroimaging studies indicate that the age of acquisition of L2 affects the temporal and topological properties of the language network (Liu et al., 2020). Although the processes which support these cognitive differences are not clear, and they might be task dependent (De Bruin, 2019), the effect of bilingual experience over prospective memory seems to be more evident in early than late bilinguals.

Thereby, the goal of this study was to investigate how monitoring skills during a PM task are modulated by differences in the bilingual experience. Towards that goal, performance during a PM task was compared between a group of early English-Spanish bilinguals from Southern California (USA) who acquired their two languages during childhood (early bilingual group) and a group of late Spanish-English bilinguals from Granada (Spain) who acquired their L2 (English) during adolescence/adulthood (late bilingual group). This group of speakers was immersed in a Spanish context but used English daily in certain contexts. We compared these two extreme groups of bilinguals differing in interactional context and language experience to maximise between group differences. Hence, the two groups not only differed in age of acquisition, but also frequency of language use, switching behaviour and context, etc., although all participants were selected to have native-like language scores in their weaker language (see Table 1). We termed the two groups as early and late bilinguals to stress one of the main features in which they differed.

Critically, the nature of the PM task was also manipulated to increase or decrease the monitoring demands. Recent research suggests that the monitoring demands of the PM task depend on the focality of the cue signalling the prospective task. Importantly, focal and non-focal cues differ to the extent to which the processing of the cue engages the main features of the ongoing activity (Kliegel et al., 2008). An example of a focal PM task would be the following: participants receive instructions to name famous faces out loud when presented on a screen (ongoing task), while they are also instructed to stop naming out loud when the name starts with a given letter (e.g., the letter "B") and instead, press a key. For example, the face of Brad Pitt (the name starts with "B") is considered a focal cue because naming this face is involved in both the ongoing activity and processing of the prospective cue (start with "B"). In contrast, during a non-focal PM task, the cues in the main features of the PM cue are different than those of the ongoing activity. Taking the previous example: if participants are asked to stop naming out loud when the face on the screen wears glasses, the glasses represent a non-focal cue, since the identification of a face with glasses differs from the ongoing activity (naming faces), and since this critical feature differs from the operations needed to perform the ongoing activity (wearing glasses is not important for face naming). The manipulation of the focality is theoretically important since it has been proposed that the focality of the PM cues might induce different types of prospective processes. According to the multiprocess framework (McDaniel & Einstein, 2000) very salient or focal cues elicit a "spontaneous retrieval of the intention" without costly monitoring or retrieval (Einstein & McDaniel, 2005; Scullin et al., 2015). As such, non-focal cues, compared to focal cues, require more attentional prospective processing resulting in more difficulty and lower accuracy rates (Cona et al., 2013; McDaniel et al., 2015). We therefore predict that differences in language control

Table 1
Background information for the monolingual, late and early bilingual groups. Asterisks (*) means differences ($p < .05$) between the three groups. When the asterisk is located in a specific mean of a group indicate that the difference is significant ($p < .05$) only for these groups with respect to the others.

	Monolinguals	Late bilinguals	Early bilinguals
Exposure to English*	10% (7.76)	18% (9.57)	60% (13.66)
Exposure to Spanish*	86% (9.79)	76% (15.23)	40% (13.11)
Preference to speak in English*	8% (12.27)	36% (21.15)	62% (18.88)
Preference to speak in Spanish*	82% (22.63)	51% (26.03)	38% (18.72)
Predominant language during instruction	Spanish	Spanish	English
Age (years)	22.6 (3.04)	21.4 (2.52)	21.1 (1.85)
Level of education	University	University	University
Years of education	19.63 (3.31)	18.24 (2.13)	15.9 (1.39)*
Age of English Acquisition (years)*		6.47 (2.76)	3.64 (1.39)
Age of English fluency (years)*		15.35 (4.13)	6.54 (3.24)
Self-competence in English (from 0 to 10)*		8.05 (0.97)	9.21 (0.77)
Frequency of failures remembering English words (from 0 to 10)		5.15 (2.15)	4.14 (3.14)
Frequency of language switching (from 0 to 10)*		4.35 (2.43)	6.78 (3.12)

due to differential bilingual experience will interact with the focality effect in a PM task, since non-focal cues are more demanding on context monitoring than focal cues, and bilinguals will have to adapt to the monitoring requirements of the task. This focality manipulation is important because recent research suggests that processing differences between bilinguals and monolinguals usually arise in more demanding conditions (Jiao et al., 2019).

The neurocognitive mechanisms of PM have also been explored by looking at different ERP components (West, 2011). Specifically, the detection of the prospective cue has been associated with the N300 component, a negative deflection that is observed in a 250–500 ms time period after presentation of the prospective cue, detected mostly in parietal-medial and parieto-occipital scalp regions. This negative deflection is elicited by the PM cue in correct PM trials and differs from the relatively less negative response in correct ongoing trials (Cona et al., 2013). In addition, this component is usually accompanied by a positive deflection (P3b) to correct PM trials in central-parietal electrodes, with an onset of 300–400 ms and up to 600–800 ms after presentation of the PM cue and relative to ongoing trials. Studies suggest that the P3b is elicited by stimuli that work as targets or PM cues, reflecting the activity of processes related to working memory and context updating (Polich, 2007; West et al., 2003), and therefore, it is also considered as signalling monitoring within the PM context. We focused on the N300 and P3b ERP components because previous PM studies have related them to cue detection and monitoring, the prospective processes underlying PM (West, 2011). Other ERP components such as the frontal positivity (FN400, a positive deflection occurring between 300 and 500 ms after PM cue onset), the later parietal positivity (400–800 ms after PM cue presentation) or the prospective positivity (sustained parietal positivity between 400 and 1200 ms after PM cue onset) have been linked to the retrospective components linked to the noticing of the cue and retrieval of the intention (FN400 and parietal positivity), or to task reconfiguration (prospective positivity) (e.g., West & Krompinger, 2005; West et al., 2006; West, 2011), and therefore, they were not the focus of our research. The N300 and P3b, on the other hand, have been shown to be sensitive to the distinctiveness, salience and focality of the PM cue (Donchin & Fabiani, 1991; Zhang et al., 2021), and this feature is especially relevant in this study where we manipulated the focality of the PM cues.

Thus, in this study, we aimed at observing whether different bilingual experiences had an effect on the performance of a PM task that varied in monitoring demands (focal or non-focal tasks). To this end, monolinguals, late and early bilinguals performed an event-based task in which the nature of the PM cue (focal vs. non-focal) was manipulated. The neural activity was recorded to investigate the ERP components associated with prospective processing in PM tasks, and bilingual and monolingual brain activity as a function of the cue conditions (focal and non-focal) were compared (Cona et al., 2013, 2015).

Overall, we expected to observe better behavioural performance in focal compared to non-focal cues due to the more demanding monitoring conditions of the latter (McDaniel & Einstein, 2000). In addition, as other studies have shown (Cona et al., 2013; West et al., 2003; West, 2011), we also expected non-focal cues to elicit greater EEG amplitude differences between PM and Ongoing trials for the N300 and P3b components since they have been associated with prospective cue detection and monitoring processes. Hence, they would reflect the different prospective processing associated with both types of cues (McDaniel et al., 2015). The focus on these components will allow us to observe whether early and late bilinguals and monolinguals differ in the way they confront the monitoring demands of the PM task. In general, we expected the language experience of the participants to modulate PM performance such that bilinguals would better adjust to the monitoring demands of the task (focality of the cue) and adjust their strategies to the focality of the cue to a greater extent than monolinguals. This prediction will be in agreement with theoretical positions suggesting that the locus of differences in executive control between monolinguals and bilinguals lies in their capacity to regulate processing across a variety of task demands (Hilchey & Klein, 2011; Morales et al., 2013). Hence, we expected that bilinguals would adjust their monitoring strategies to the contextual demands, and that possible differences between monolinguals and bilinguals might be more evident in the more demanding non-focal condition (Jiao et al., 2019). In addition, we also expected this adjustment to vary depending on the bilingual language experiences (early and late bilinguals). Previous research has shown that early active bilingualism promotes greater transfer to domain-general cognitive control (Bonfieni et al., 2019; D'Souza et al., 2021; Hartanto & Yang, 2019), and therefore, we expected that the effects of bilingual experience over PM performance would be more evident in early than late bilinguals.

Furthermore, we expected that these differences would be reflected on differences in amplitudes for N300 and P3b between the type of trials and cue focality. Thus, we expected that N300 and P3b differences in amplitude between Ongoing and PM trials would be larger in monolinguals than bilinguals, indicating more efficient prospective processing in the bilinguals. Moreover, we expected that these processing differences would be more evident in the non-focal condition. Thus, for both, N300 and P3b components, our monolingual group should show greater amplitude differences between PM and Ongoing trials for the non-focal than focal cues due to the more demanding monitoring processes engaged to detect non-focal cues. More importantly, we predicted that these differences might be reduced for bilinguals and more so for the early than late bilingual groups.

2. Methods

2.1. Participants

This study has been approved by the Research Ethics Commission of the University of Granada (registration number, 84/CEIH72015). A sample size of 78 was required to obtain 95% power to detect a Cohen's effect of f = 0.40. This value is considered a large effect size in Cohen (1969) and it corresponds to $\eta^2 = 0.14$. based on the G*power analysis program (Faul et al., 2007) of a 3 × 2 × 2 mixed ANOVA. A total of 80 right-handed adults participated in this study (19 men; mean age = 21.9, SD = 2.6), and 30 were in the monolingual group, 29 in the late bilingual group, and 21 in the early bilingual group. Table 1 reports sociodemographic characteristics and language competences in this sample. The participants from the monolingual and late bilingual groups were recruited from the University of Granada. The participants in the early bilingual group were recruited from California State Polytechnic University (California). Participants in the two bilingual groups had Spanish as their mother-tongue first language (L1) and English as their secondly acquired language (L2). Early bilinguals were those who had acquired English fluency during childhood, whereas late bilinguals acquired fluency in English during adolescence or adulthood. The monolingual participants were native Spanish speakers who were not proficient in any other second language. Participants completed a sociodemographic questionnaire, from which basic personal information (gender, date of birth, illnesses, etc.) was obtained. Participants also completed the LEAP-Q (Marian et al., 2007) to obtain the history of language use of the bilinguals, including age of acquisition of the different languages, linguistic experiences with them, their self-evaluation of their proficiency in their L1 and L2, the frequency of use, and the frequency of language exposure and language switching. In addition, to assess the participants' proficiency in their less frequently used language we included objective measures: The Michigan English Language Institute College Entrance Test (MELICET) for the monolinguals an late bilinguals, and the Diploma of Spanish as a Foreign Language (DELE) for the early bilinguals. Only participants who obtained direct scores of 35 or more out of 50 in the questionnaire were selected into the bilingual groups. Previous studies indicate that native speakers usually obtain scores in the 36–49 range (Kaan et al., 2020), and therefore, our participants were selected to have

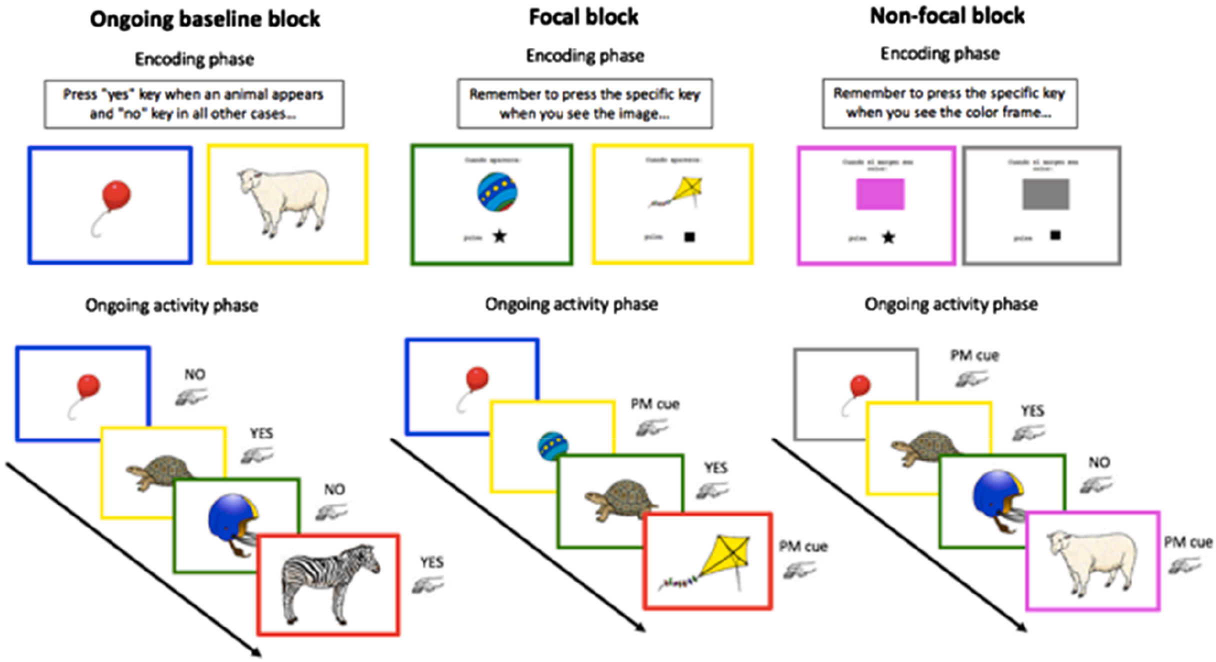

Fig. 1. Example of a trial sequence for each block: ongoing, focal, and non-focal blocks. Each block was composed of an encoding phase followed by an ongoing activity (ongoing block) or by an ongoing activity where focal or non-focal PM trials were interleaved (focal and non-focal block, respectively).

Table 2
Means of accuracy (ACC) and response times (RTs; standard deviation in brackets) by type of trial, group and focality in the PM task.

	Monolinguals		Late Bilinguals		Early Bilinguals		TOTAL	
Type of trial	ACC	RT	ACC	RT	ACC	RT	ACC	RT
ON focal	0.97 (0.04)	604 (68)	0.97 (0.03)	589 (95)	0.96 (0.04)	660 (124)	0.97 (0.04)	613 (97)
ON non-focal	0.92 (0.05)	756 (142)	0.94 (0.03)	691 (127)	0.92 (0.04)	765 (144)	0.92 (0.04)	736 (139)
PM focal	0.95 (0.05)	698 (110)	0.95 (0.11)	742 (227)	0.95 (0.05)	764 (145)	0.95 (0.08)	730 (167)
PM non-focal	0.70 (0.13)	918 (168)	0.64 (0.17)	944 (250)	0.67 (0.20)	947 (144)	0.67 (0.17)	935 (194)

Table 3
Mean wave amplitudes (standard deviation in brackets) by focality, type of trial, group, and the interactions in the N300 component (175–300 ms in parieto-occipital regions).

Effects	**Groups**			
	Monolinguals	**Late bilinguals**	**Early bilinguals**	**TOTAL**
Focality				
Focal	1.88 (1.98)	2.23 (2.25)	3.06 (2.06)	2.38 (2.14)
Non-focal	1.40 (1.24)	1.86 (1.75)	1.88 (1.26)	1.70 (1.61)
Type of trial				
Ongoing	2 (1.45)	2.45 (1.86)	2.87 (1.63)	2.44 (1.85)
PM	1.27 (1.77)	1.6 (2.14)	2.06 (1.67)	1.64 (1.90)
Focality by type of trial				
Ongoing focal	2.32 (1.83)	2.73 (1.93)	3.09 (2.13)	2.70 (1.96)
PM focal	1.43 (2.13)	1.73 (2.57)	3.03 (1.99)	2.05 (2.31)
Ongoing non-focal	1.68 (1.07)	2.24 (1.78)	2.64 (2.13)	2.18 (1.73)
PM non-focal	1.11 (1.40)	1.47 (1.71)	1.12 (1.38)	1.23 (1.50)
Group	1.40 (1.61)	2.04 (2)	3.29 (1.91)	

native-like proficiency. Those who scored 25 or less were classified as monolingual (monolinguals: M = 19.19, SD = 4.65; late bilinguals: M = 39.72, SD = 4.06; early bilinguals: M = 41.76, SD = 3.94; comparisons between groups indicate significances differences ($p < .05$) only for monolinguals group) (see Chun & Kaan, 2019; Contemori & Tortajada, 2020; Torres & Sanz, 2015). Table 1 reports a summary of the average scores provided by the different groups of bilinguals in the questionnaire LEAP-Q (Marian et al., 2007). Inspection of this table indicates that early and late bilinguals differ not only in the age at which they acquired language fluency in English, but also in language exposure, language preference, feeling of language competence etc. Correlational analyses indicated that all these variables highly correlated with each other ($p < .05$).

Psychology students received course credits, while the remaining participants received € 21 or 20$ for their participation. All participants gave written informed consent.

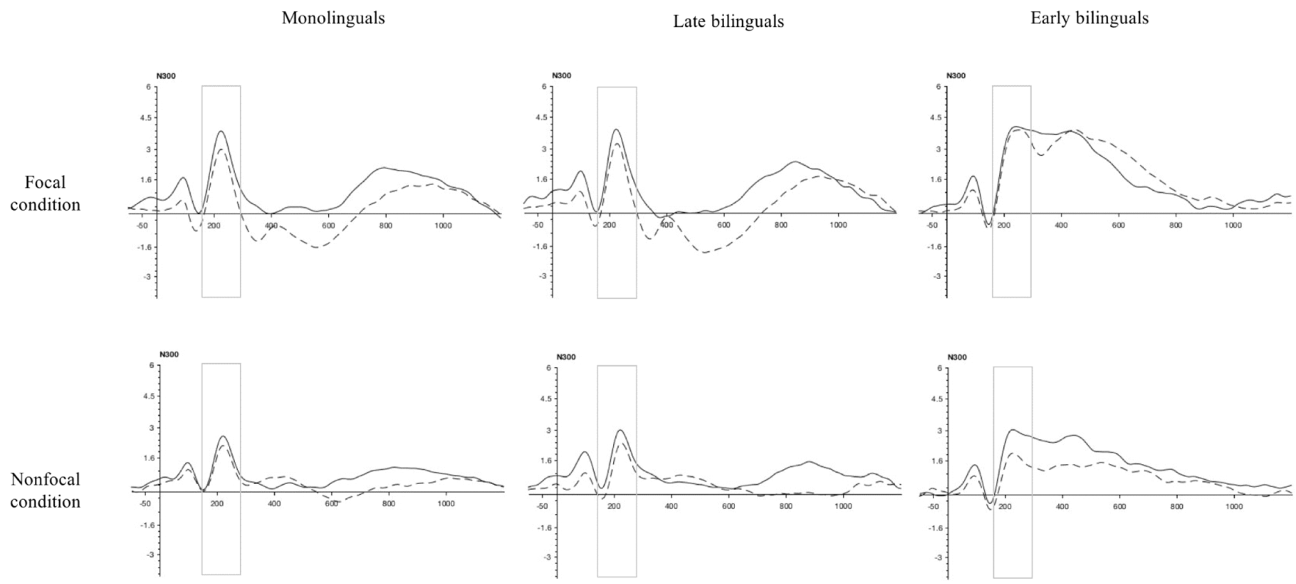

Fig. 2. Grand-averaged event-related potentials (ERPs) at occipital-parietal electrodes demonstrating N300 for the ongoing and PM trials in the focal and non-focal conditions for each group. Legend: ___Ongoing trial/——PM trial.

2.2. Design

The experiment employed a 3x2x2 mixed factorial design using groups (monolingual, early, and late bilinguals) as a between subject factor variable and focality of the cue (focal, non-focal) and type of trial (ongoing, PM) as within subject factors.

2.3. Procedure

The tasks were carried out in well-lit, individual rooms that were isolated from external noise. The study consisted of two sessions of approximately 90 min each. There was a time interval of one week between each session. Part of this sample took part in a larger individual differences study from which other non-overlapping findings had been already reported (Aguerre et al., 2021). For this study, however, we focused on the PM task performed in the second session.

2.3.1. PM task

Participants performed a PM task while EEG brain activity was recorded using an EEG. We employed the PM task used by Cejudo et al. (2019). This task has the advantage of producing high levels of performance which is ideal for subsequent EEG analyses (very few trials are eliminated due to erroneous responses). The PM task consisted of three blocks of trials (see Fig. 1). In the first block, participants were asked to practice the ongoing activity by itself which consisted of a categorization task with pictures. They were instructed to press the “yes” key when the picture presented on the screen was an animal and the “no” key in all other cases. In the second and third blocks, the participants had to also perform the ongoing activity, but they were also asked to implement the prospective intention. The prospective cues were either focal or non-focal. In the focal condition, participants had to press the ’’k’’ key whenever the picture of a ball appeared and the ’’l’’ key when presented with the picture of a kite. These cues were considered focal because they were part of the features of the ongoing activity (identifying the contents of the picture) and thus, were within the focus of attention of the participant. In the non-focal condition, participants were asked to press ’’k’’ when the frame bordering the screen was magenta and ’’l’’ when it was grey. These cues were considered non-focal because participants did not need to focus on the colour of the frame when performing the ongoing activity. For both focal and non-focal cues, participants were asked to interrupt the ongoing activity and execute the prospective intention when the cues were presented. Trials where the prospective cues were presented will be referred to as “PM” because they correspond to the PM task. In the results section, the trials with no prospective cues where the participants performed the ongoing activity, will be referred to as “ON”. The focal and non-focal blocks were counterbalanced, while the block in which the ongoing activity was performed by itself was always done first since trials in this block were mainly practice trials. For the stimulus materials, we used 65 images from Rossion and Pourtois (2004). Each image appeared twice during the three parts of the experiment. Images were centred on the screen and surrounded by a 15-pixel colour frame, which was randomly changed for each trial (red, blue, green, or yellow). Each block in both the focal and non-focal conditions consisted of 300 trials of the ongoing task and 30 trials in which prospective cues were presented for participants to perform the intention. Each trial presentation was established to be between 1600 and 2800 ms. If participants responded after 1600 ms, the subsequent trials occurred after an interval between stimuli (ISI) of 250 ms. However, if participants responded before 1600 ms, a black screen was presented up to 1600 ms, followed by the ISI. In cases where the participants did not respond before 2800 ms, the ISI appeared. The task described in this section were carried out on a computer using the E-Prime 2.0 software.

2.3.2. EEG recording and pre-processing

For the monolingual and late bilingual group, the EEG data was recorded using the Neuroscan Synamps2 (El Paso, TX) and 40 Ag/AgCl electrodes distributed on the scalp. The EEG for the early bilingual group was recorded using an actiCHamp amplifier (Brain Products GmbH, Munich, Germany) with 32 Ag/AgCl electrodes distributed on the scalp. The data processing was performed with EEGLAB 14.1 (Delorme & Makeig, 2004), running in a Matlab environment (Version 7.4.0, MathWorks, Natick, MA, USA). We imported the files from Brain Vision Software and integrated data from the two systems by using the EEGLAB “bva-io” plugin (available at http://sccn.ucsd.edu/wiki/EEGLAB_Extensions_and_plug-ins). Moreover, we used the same coordinates to match the electrodes from the systems (see Bergmann et al., 2015; Bice & Kroll, 2019 for other studies using different systems across different bilingual groups). Except for this difference, the rest of the EEG recording parameters and off-line processing was identical for the three groups. Two pairs of bipolar electrodes were placed vertically and horizontally to record eye movements. The EEG analogue signal was amplified and digitised at a sampling frequency of 1000 Hz. The impedances of the electrodes were maintained at <10 kΩ during recording. The ground electrode was placed along the midline in front of the Fz position. All electrodes were referenced off-line to the average of both mastoids. The EEG data was bandpass filtered between 0.5 and 1000 Hz during online recording. Also, a high pass filter of 0.1 Hz and a low-pass filter 30 Hz were also applied off-line to the data. Moreover, we applied a notch filter to clean the electronic noise in the signal. For the groups tested in Spain the filter was 50 Hz and for the group tested in the USA the filter was 60 Hz. Artefacts were also removed through visual inspection. Thus, channels with a high level of artefacts were detected by careful visual inspection and interpolated from neighbouring electrodes. The temporal windows were located at the appearance of the stimulus, that is, when the cue appeared. The times for the ERP analysis were a 200 ms pre-stimulus period used as a baseline correction and 1200 ms of post-stimulus activity. Artefact correction was done using the independent component analysis (ICA) toolbox in EEGLAB for semi-automatic artifact removal. The epoch rejection was performed with a cutoff of ± 100 μV (<25% per participant). The number of epochs used for analyses was similar for the different conditions (59, 57 and 55 for the focal trials in the monolinguals, late bilinguals and early bilinguals, respectively. For the non-focal trials these values were 60, 57 and 54, respectively).

2.4. Data analysis

2.4.1. Behavioural analyses

Accuracy and response times in the PM task were analyzed. First, we filtered the data following the criteria used by Czernochowski et al. (2012), that is, RTs faster than 200 ms and participants with accuracy scores greater than three times the interquartile range were removed from the analyses. This resulted in the removal of five participants (three participants from the late bilingual group and two from the early bilingual group).

All these analyses were carried out on the ON and PM trials for each focality condition in each group. To ensure the same number of trials in each condition and to reduce variability due to changes in attention across the experimental session, we only selected the ON trials that appeared before the PM cue. Thus, for each PM trial (a total of 30), the previous ON trials (30) were considered for comparison (see Cejudo et al., 2019 for a similar procedure). Thus, we performed 3 × 2 × 2 mixed factorial ANOVAs with group (monolingual, late bilingual, and early bilingual), cue focality (focal vs. non-focal) and type of trial (ON vs. PM) as independent variables. When appropriated, Bonferroni correction for multiple comparisons for post hoc tests was applied.

The order of presentation of focal and non-focal conditions was analysed, and there were no differences due to the order of presentation ($p_s > 0.05$), and therefore, this variable would not be considered any further.

2.4.2. Electrophysiological data analysis

To explore ERP modulations as a function of task, focality, and group, we selected two time periods that have been associated with prospective components in previous PM studies (Cona et al., 2013; West et al., 2006). For each of these components, we explored ERPs for hits in PM and ON trials. Thus, to study the N300 component associated with cue detection, we selected the 175–300 ms time window over the centro-posterior regions (West, 2011). As mentioned, the N300 refers to the reduction in amplitude observed in central-posterior electrodes upon presentation of the PM cue and relative to ON trials. In addition, the P3b component associated with working memory (WM) updating upon cue detection was registered at 300–400 ms in posterior regions (West et al., 2003; West, 2011).[1] Besides, prior to the actual analysis, non-parametric cluster-based permutation analysis as implemented in the Fieldtrip Matlab toolbox software (Oostenveld et al., 2011) was performed to identify the electrodes for each time window that maximised the differences between the PM and ON trials. An advantage of this procedure is that the selection of a particular region of interest (electrode cluster) is defined in a data-driven manner and not based on the sometimes inconsistent Regions of Interests (ROIs) from previous studies or by assumptions regarding the sampling distribution under the null hypothesis. Results of these analyses indicated that electrodes CP3, CPZ, CP4, P3, PZ, O1, OZ, and O2 yielded significant differences ($p < .05$) for 175–300 ms intervals. For the 300–400 ms time window, the cluster included the electrodes CP3, CPZ, P3, PZ, O1, OZ, and O2 ($p < 0.05$). Hence, these electrodes correspond to the usual posterior site of the N300 and to the parietal site of the P3b.

For each ERP component, the mean amplitude for each cluster of electrodes and condition was averaged and introduced into a 3 (group) × 2 (cue focality) × 2 (type of trial) mixed factorial ANOVA. After preprocessing the EEG data, 16 participants (8 monolinguals, 8 late bilinguals) were eliminated due to high levels of noise in the EEG signals or a high rejection of epochs. Thus, data from 22 monolinguals, 21 late bilinguals, and 21 early bilinguals were entered into the ANOVAs.

Finally, correlations between electrophysiological and behavioural data were carried out. Specifically, we examined the correlations between the N300 and P3b components and the accuracy and RTs in ON and PM trials respectively.

3. Results

We will report the behavioural results (response times and accuracy) followed by ERP analyses of the electrical activity and correlational analysis between the behavioural and EEG data.

3.1. Behavioural results

We performed 3 × 2 × 2 mixed factorial ANOVAs with group (monolingual, late bilingual, and early bilingual), focality of the cue (focal vs. non-focal), and type of trial (ON vs. PM) as the independent variables on response times (RTs) and accuracy (see Table 2).

3.1.1. Response times

We averaged response times (for correct responses) per participants and condition and submitted them to a 3 (group) × 2 (cue focality) × 2 (type of trial) mixed factorial ANOVA. The result of this analysis showed that the main effects of focality ($F(1,72) = 152.982$; $p < .0001$; $\eta_p^2 = 0.680$) and type of trial ($F(1,72) = 154.258$; $p < .0001$; $\eta_p^2 = 0.682$) were significant, indicating that, in general, responses to the focal condition were faster (M = 671.5, SD = 132) than responses to the non-focal condition (M = 835.5, SD = 166.5) and that participants were faster in performing the ON trial (M = 674.5, SD = 118) than the PM trial (M = 833, SD = 180.5). The interaction focality by type of trial ($F(1,72) = 21.812$; $p < .0001$; $\eta_p^2 = 0.233$) indicated that the difference between the ON (M = 613; SD = 97) and the PM trial (M = 730; SD = 167) was

[1] Note that these two components that usually appear in studies exploring prospective memory need to be dissociated from the attentional P200 that occurs at 200–300 ms intervals at fronto-central electrodes. Inspection of Fig. 2, indicates that the earlier 175–300 ms interval the PM produced more negative amplitudes than the ON trial, and the positive deflection of PM relative to ON trials occurred at a later interval.

Table 4
Mean wave amplitudes (standard deviation in brackets) by focality, type of trial, group and the interactions in the P3b component (300–400 ms in parieto-occipital regions).

Effects	Groups			
	Monolinguals	Late bilinguals	Early bilinguals	TOTAL
Focality				
Focal	−1.28 (1.75)	−1.45 (2.1)	3.27 (2.06)	0.54 (1.97)
Non-focal	0.51 (1.79)	0.75 (1.72)	1.94 (2.04)	1.07 (1.85)
Type of trial				
Ongoing	0.19 (1.58)	0.44 (1.83)	3.22 (2.22)	1.28 (1.88)
PM	−0.46 (1.96)	−0.40 (1.99)	1.99 (1.88)	0.80 (1.94)
Focality by Type of trial				
Ongoing Focal	−0.05 (1.54)	−0.14 (1.83)	3.6 (2.13)	1.12 (2.52)
PM focal	−1.23 (1.95)	−1.31 (2.37)	2.93 (1.99)	0.11 (2.88)
Ongoing Non-focal	0.24 (1.61)	0.58 (1.83)	2.83 (2.31)	1.20 (2.23)
PM Non-focal	0.77 (1.96)	0.91 (1.61)	1.05 (1.76)	0.91 (1.76)
Group	−0.07 (1.77)	0.03 (1.9)	2.61 (2.04)	

greater in the non-focal condition (ON: M = 736, SD = 139; PM: M = 935, SD = 194; $t(76) = -13.399$; $p < .0001$; $d = -1.20$) than in the focal condition (ON: M = 613, SD = 97; PM: M = 730, SD = 167; $t(77) = -7.703$; $p < .0001$; $d = -0.86$).

There was no main effect of group ($F(2,72) = 0.767$; $p = .468$; $\eta_p^2 = 0.021$). However, an interaction between type of trial by group was significant ($F(2,72) = 3.530$; $p = .034$; $\eta_p^2 = 0.089$). This interaction revealed that the difference between the three groups was not significant in the PM trial ($F(2,72) = 0.570$; $p = .568$; M = 856, SD = 131 for early bilinguals; M = 843, SD = 218 for late bilinguals; and M = 808, SD = 123 for monolinguals), whereas there was a trend towards significance in the ON trial ($F(2,72) = 2.730$; $p = .072$; M = 712, SD = 122 for early bilinguals; M = 640, SD = 102 for late bilinguals; and M = 680, SD = 95 for monolinguals), suggesting that early bilinguals were slower in performing the ON trial than the late bilinguals ($t(43) = -2.178$; $p = .035$; $d = -1.54$) with monolingual response times in between those of the two bilingual groups ($t(47) = -1.064$; $p = .293$; $d = -0.30$ for the monolingual and early bilingual comparison and $t(54) = 1.512$; $p = .136$; $d = 2.48$ for the monolingual and late bilingual comparison). For the three groups, the PM versus ON comparisons were significant with all p values < 0.0001. All other interactions were not significant (focality by group: $F(2,72) = 1.072$; $p = .348$; $\eta_p^2 = 0.029$ and focality by type of trial by group: $F(2,72) = 0.329$; $p = .721$; $\eta_p^2 = 0.009$).

3.1.2. Accuracy

The number of correct responses to ON and PM trials was averaged for each condition and submitted to a 3x2x2 mixed ANOVA. The result of this analysis indicated a main effect of focality ($F(1,72) = 365.536$; $p < .0001$; $\eta_p^2 = 0.835$) and type of trial, indicating that the focal condition led to a better performance (M = 0.96, SD = 0.06) than the non-focal condition (M = 0.80, SD = 0.11), and that the ON trial led to more accurate responses (M = 0.95, SD = 0.04) than the PM trial (M = 0.81, SD = 0.13; $F(1,72) = 143.183$; $p < .0001$; $\eta_p^2 = 0.665$). The interaction between focality by type of trial ($F(1,72) = 197.971$; $p < .0001$; $\eta^2 = 0.733$) was also significant, indicating that the better performance in the ON trial (M = 0.97; SD = 0.04) relative to the PM trial (M = 0.95; SD = 0.08) was greater in the non-focal (ON: M = 0.92, SD = 0.04; PM: M = 0.67, SD = 0.17; $t(76) = 14.404$, $p < .0001$, $d = 2.03$) than in the focal condition (ON: M = 0.97, SD = 0.04; PM: M = 0.95, SD = 0.05; $t(77) = 2.272$, $p = .026$, $d = 0.33$).

The main effect of group ($F(2,72) = 0.199$; $p = .820$; $\eta_p^2 = 0.005$) and the interactions involving this variable, namely, focality by group ($F(2,72) = 1.118$; $p = .333$; $\eta_p^2 = 0.835$), type of trial by group ($F(2,72) = 1.141$; $p = .325$; $\eta_p^2 = 0.031$), and focality by type of trial by group ($F(2,72) = 1.490$; $p = .232$; $\eta_p^2 = 0.040$) were not significant.

In summary, behavioural results indicated that the early bilinguals slowed down their responses during the ON trial relative to the late bilinguals, suggesting that they might have been engaging in different monitoring strategies when performing the ON trial.

3.2. Electrophysiological results: ERP

3.2.1. n300

Averaged amplitudes per participant and condition were submitted to a 3 (group) × 2 (cue focality) × 2 (type of trial) mixed factorial ANOVA (see Table 3 and Fig. 2). Results indicated that the main effect of focality ($F(1,61) = 16.569$; $p < .0001$; $\eta_p^2 = 0.214$; focal condition: M = 2.379, SD = 2.136; non-focal condition: M = 1.703, SD = 1.61) and type of trial ($F(1,61) = 32.625$; $p < .0001$; $\eta_p^2 = 0.348$; ON trial: M = 2.441, SD = 1.845; PM trial: M = 1.641, SD = 1.902) were significant. In contrast, the main effect of group ($F(2,61) = 1.515$; $p = .228$; $\eta_p^2 = 0.047$) and the interaction between focality by group ($F(2,61) = 2.305$; $p = .108$; $\eta_p^2 = 0.070$), type of trial by group ($F(2,61) = 0.108$; $p = .897$; $\eta_p^2 = 0.348$), and focality by type of trial ($F(1,61) = 1.266$; $p = .265$; $\eta_p^2 = 0.020$) were not significant.

Most importantly, the focality by type of trial by group interaction was statistically significant ($F(2,61) = 4.505$; $p = .015$; $\eta_p^2 = 0.129$). To explore this interaction, we performed a 3 (group) × 2 (type of trial) ANOVA for each focality condition. Analysis on the focal condition indicated that the effect of type of trial was significant ($F(1,61) = 8.069$; $p = .006$; $\eta_p^2 = 0.117$), with more negative amplitudes in the PM (M = 2.054, SD = 2.311) than in the ON trial (M = 2.704, SD = 1.961). However, the main effect and the interaction involving group were not significant (group effect: $F(2,61) = 2.185$, $p = .121$, $\eta_p^2 = 0.067$; type of trial by group: $F(2,61) = 1.700$, $p = .191$, $\eta_p^2 = 0.053$).

In contrast, for the non-focal condition, although the main effect of group was not statistically significant ($F(2,61) = 0.727$; $p = .487$; $\eta_p^2 = 0.023$), the main effect of type of trial ($F(1,61) = 35.481$; $p < .0001$; $\eta_p^2 = 0.368$) and the type of trial by group interaction ($F(2,61) = 3.418$; $p = .039$; $\eta_p^2 = 0.101$) were significant. This interaction indicated that the greater negativity for the PM trials compared to the ON trials was larger for the early bilinguals (ON: M = 2.644, SD = 2.127; PM: M = 1.105 SD = 1.380; $t(20) = 4.804$, $p < .0001$, $d = 0.86$) than for the group of monolinguals (ON: M = 1.677, SD = 1.069; PM: M = 1.113, SD = 1.403 ; $t(21) = 2.556$, $p < .0001$, $d = 0.46$) or late bilinguals (ON: M = 2.237, SD = 1.782; PM: M = 1.469, SD = 1.719; $t(21) = 2.655$, $p < .0001$, $d = 0.45$).

3.2.2. P3b

To explore this component, we performed a 3 (group) × 2 (cue focality) × 2 (type of trial) mixed factorial ANOVA (see Table 4 and Fig. 3). We observed that the main effects of focality ($F(1,61) = 4.019$, $p = .049$, $\eta_p^2 = 0.062$; focal condition: M = 0.54, SD = 1.97; non-focal condition: M = 1.130, SD = 1.994), type of trial ($F(1,61) = 17.474$, $p < .0001$, $\eta_p^2 = 0.223$; ON trial: M = 1.07, SD = 1.85; PM trial: M = 0.80, SD = 1.94) and group ($F(2,61) = 22.258$, $p < .0001$, $\eta_p^2 = 0.422$; monolinguals: M = −0.07, SD = 1.77; late bilinguals: M = 0.03, SD = 1.9; early bilinguals M = 2.61, SD = 2.04) were significant. In addition, all the interactions containing these variables were significant (focality by type of trial: $F(1,61) = 5.493$; $p = .022$; $\eta_p^2 = 0.083$; focality by group: $F(2,61) = 16.737$; $p < .0001$; $\eta_p^2 = 0.354$; and type of trial by group: F

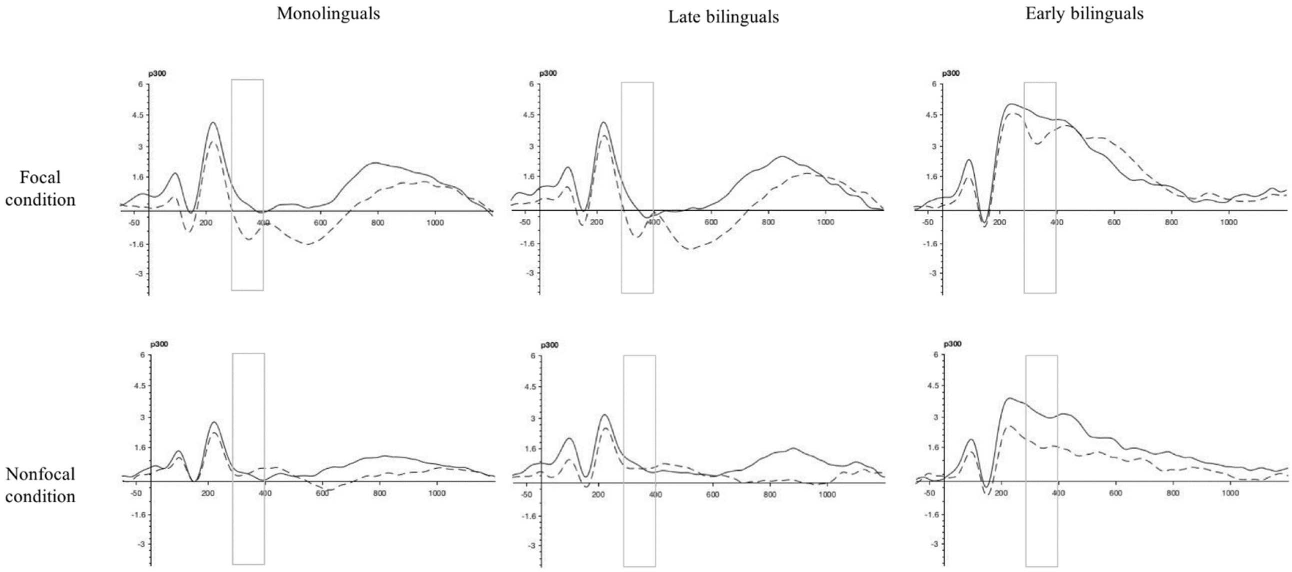

Fig. 3. Grand-averaged event-related potentials (ERPs) at occipital-parietal electrodes demonstrating P3b for the ongoing and PM trials in the focal and non-focal condition for each group. Legend: ___Ongoing trial/——PM trial.

(2,61) = 3.227; p = .047; η_p^2= 0.096).

To explore the higher order focality by type of trial by group interaction (F(2,61) = 8.972; p < .0001; η_p^2= 0.227), a 3 (group) × 2 (type of trial) ANOVA was performed for each focality condition. For the focal condition, we found that the effect of group (F(2,61) = 37.374; p < .0001; η_p^2= 0.551; monolinguals: M = −1.28, SD = 1.75; late bilinguals: M = −1.45, SD = 2.1; early bilinguals M = 3.27, SD = 2.06) was significant. Also, the main effect of type of trial (F(1,61) = 16.582; p < .0001; η_p^2= 0.214; ON trial: M = 1.12, SD = 2.52; PM trial: M = 0.11, SD = 2.88) was significant. However, the type of trial by group interaction (F(2,61) = 0.466; p = .630; η_p^2= 0.015) was not significant, indicating that the difference between the ON and PM trials did not significantly differ for the three groups: the early bilinguals (ON trial: M = 3.6, SD = 2.13; PM trial: M = 2.93, SD = 1.99), the late bilinguals (ON trial: M = −0.14, SD = 1.83; PM trial: M = −1.31, SD = 2.37), and the monolinguals (ON trial: M = −0.05, SD = 1.54; PM trial: M = −1.23, SD = 1.95).

For the non-focal condition, the 3 (group) × 2 (type of trial) ANOVA indicated that the main effect of type of trial (F(1,61) = 2.781; p = .101; η_p^2= 0.044) was not significant. However, the main effect of group (F(2,61) = 4.293; p = .018; η_p^2= 0.123) was modulated by a type of trial by group interaction (F(2,61) = 16.172; p < .0001; η_p^2= 0.347) that indicated that, while there were no differences between groups in the PM trial (F(2,61) = 0.140; p = .870; monolinguals: M = 0.77, SD = 1.96; late bilinguals: M = 0.91, SD = 1.61; early bilinguals: M = 1.05, SD = 1.76), in the ON trial, there were group differences (F(2,61) = 11.219; p < .0001), indicating that early bilinguals showed more positive amplitudes (ON trial: M = 2.83, SD = 2.31) than late bilinguals (ON trial: M = 0.58, SD = 1.83) and monolinguals (ON trial: M = 0.24, SD = 1.61). These results suggested that during the ongoing non-focal activity, the early bilingual group engaged in monitoring processes to update the context and respond successfully to the non-focal cue. Interestingly, while late bilinguals (t(20) = −1.016; p = .301; d = −0.193) and monolinguals (t(21) = −2.249; p = .096; d = −0.147) performed the ON and PM trials in a similar way, early bilinguals showed significant differences between both trials (t(20) = 4.698; p < .0001; d = 0.865). These results indicate that early bilinguals adapt their strategies to the demands of the trial.

3.2.3. Correlational analysis

Correlations between the N300 and P3b components and the accuracy and RTs in ON and PM trials were carried out. For the ERPs we created an index representing the PM/ON effect captured by the N300 and P3b respectively (ON-PM/ON + PM *100), then we calculated the correlation between these indexes and response times and accuracy. Note that behavioral differences were evident in the ON trial for the early bilinguals, but they were not present in the PM trials. We first performed the correlations with the complete sample of participants, but none of the correlations were significant (all ps > 0.05). Second, since the behavioral effects were only present in the early bilingual group, we performed the correlations only for this group, but all the correlations were also non-significant (p > .05).

4. Discussion

The aim of this experiment was to explore whether different language experiences (monolinguals and early and late bilinguals from different contexts) modulated the cognitive processes underlying prospective memory in tasks with varying monitoring requirements. Consistent with the multiprocess framework for prospective memory (McDaniel & Einstein, 2000), participants performed better in focal than in non-focal conditions. According to this framework, focal cues elicit "spontaneous recovery" of the intention in contrast to non-focal cues that require monitoring processes, resulting in longer response times and poorer accuracy.

More importantly, our results provided evidence suggesting that the participants' language experiences modulate how they confront the difficulties of the prospective task. Thus, behavioural and neural results showed that early bilinguals differed from the monolinguals and late bilinguals in the ways they performed the tasks. Behaviourally, early bilinguals slowed down their response times during the ongoing trials relative to the groups of late bilinguals and monolinguals (although the differences with monolinguals did not reach significance), suggesting that they carefully monitored the environment for prospective cues during the ongoing trial to a greater extent than participants in the other groups. This result is important because it points to the need of studying the specific characteristics of the different groups of bilinguals (De Bruin, 2019). Our data demonstrates that some of the cognitive differences related to bilingualism are driven by experience-based individual differences associated with multilingualism, such as the age of acquisition or the linguistic context where the bilingual is immersed. In this sense, bilingual studies should clearly specify the linguistic and contextual variables defining their bilingual participants since results are very dependent on their language experience.

In our study, the differences between monolinguals, late and early bilinguals were still more evident when considering the ERP data for N300 and P3b. Consistent with other PM experiments, we found larger N300 amplitudes for the PM trials than for the ongoing trials (West, 2011) and for the non-focal PM trial than for the focal PM trial (Cona et al., 2013). Thus, the difference between focal and non-focal conditions was larger for the early bilinguals compared to the late bilinguals and monolinguals. In addition, for the more difficult non-focal condition, early bilinguals showed stronger differences between the PM and ongoing trials than the late bilinguals and monolinguals, suggesting that they engaged in monitoring processes related to cue detection during the more demanding non-focal condition to a greater extent than participants in the late bilingual and monolingual groups. This was also supported by the pattern of results regarding the P3b component with a significant interaction between focality, group and type of trial. In our study, focal cues produced less positive amplitudes than non-focal cues, and ongoing trials produced more positive amplitudes than PM trials, signalling that WM and context updating were more strongly involved (Cona et al., 2013; West et al., 2003). More interestingly, the interaction between focality, group, and type of trial indicated that for the focal condition, the differences between the ongoing and PM trials were similar for the three groups, with early bilinguals showing a greater overall positivity. In contrast, for the non-focal condition, there was a significant interaction between type of trial and group, indicating that the differences between the PM and ongoing trials were stronger for the bilingual group. Interestingly, these stronger differences for the early bilinguals compared to the late bilinguals and monolinguals were produced by the greater positivity of the early bilinguals for the ongoing trials relative to the late bilinguals and the monolinguals (these differences were not evident for the PM trials). This pattern of results suggests that the early bilinguals modulated their strategies to adjust to the task's demands. Thus, in the focal condition, where the ongoing and PM trials were highly similar in terms of attentional demands, early bilinguals did not differ from the other groups. However, in the non-focal condition, where processing of the PM cue was more demanding, early bilinguals engaged in monitoring and updating processes to adjust their strategies depending on the task's demands.

The overall pattern of behavioural and neural results is in line with that of previous studies indicating that early bilinguals are able to adjust their monitoring strategies to the demands of the task compared to late bilinguals (Tao et al., 2011). Consistent with our hypotheses, different bilingual experiences have different effects on the processes underlying PM performance. Thus, whereas early bilinguals adjusted their response times and neural ERPs (N300, P3b) so that they differ from those of the monolinguals, late bilinguals did not differ from the monolinguals in their behavioural or neural patterns. This idea is consistent with the proposal of the adaptive control model (Green & Abutalebi, 2013) that language control and its possible consequences over general executive control, depend on the interactional language context of the participants. Our early bilingual group differed from the late monolinguals not only in the age of acquisition, but also in their language use and preferences. For example, in the LEAP-Q questionnaire, early bilinguals reported being more prone to language switching than the late bilinguals and distribute the time between the two languages in a more balanced way than the late bilinguals (see results of LEAP-Q in Table 1). Hence, these features of their language experience could have potentiated context monitoring to facilitate switching to the prospective action. In line with this, it has been suggested that bilinguals who are immersed in an environment with a varying linguistic context are more likely to trigger more proactive cognitive control strategies due to the need to monitor the context (Gullifer et al., 2018). Thus, the early bilinguals might be more sensitive to cue detection and might be able to better adjust their cognitive performances to the demands of the PM task (Prior & Gollan, 2011).

However, overall, our data supports conceptual frameworks suggesting that different bilingual experiences are associated with differences in the engagement of cognitive control strategies (Beatty-Martínez et al., 2020; De Bruin, 2019; DeLuca et al., 2020; Green & Abutalebi, 2013). For example, according to the Unifying the Bilingual Experience Trajectories (UBET) framework proposed by DeLuca et al. (2020) efficient language control may depend on the relative proficiency and duration of the bilingual experience. According to this proposal, diversity/intensity of use and frequent switching will increase executive control and will result in more general reliance on proactive control strategies. The early bilingual group in our study clearly matched these particular features of language use, and therefore, according to the proposal they may have been engaged in more proactive processes than the monolinguals and late bilinguals, resulting in different behavioral and neural pattern when performing the PM intention.

Although our ERP data clearly show differences between early bilinguals, monolinguals and late bilinguals in prospective memory, the study is not without limitations. First, behavioural differences were small and they were only found on response times. This could be due to a possible ceiling effect in the levels of accuracy in our task. However, it is important to remark that some previous studies showed electrophysiological differences in cognitive processes between groups of bilinguals and monolinguals that were not evident in the behavioural data (Grundy et al., 2017; Kousaie & Philips, 2012). Thus, some changes due to bilingualism in cognitive processes might be only captured in brain activity but not in behavioural performance. Second, we considered two very different groups of bilinguals differing in more than one linguistic and contextual difference. This approach had the advantage of maximizing differences between the groups but at the cost of not being able to assess the relative merit of each variable in producing the effects. Further research should try to take a continuous approach to bilingualism so that the relative contribution of different variables might be evaluated (DeLuca et al., 2019; Kaushanskaya & Prior, 2015; Luk & Bialystok, 2013; Sulpizio et al., 2020). Notice that, we created different categorical groups in the current experiment (i.e., we created extreme groups based on the age of acquisition of L2 and other linguistic features defined by the language context). Thus, it would desirable that future studies collected background information (fluid and crystallized intelligence, linguistic and sociodemographic information) to have a wide perspective of the characteristics of the participants that allows studying the different dimensions of the bilingual continuum.

In summary, the findings from the behavioural and ERP results are in line with the wide body of literature that suggests better cognitive strategy adjustment in bilinguals compared to monolinguals (Morales et al., 2013, 2015). In addition, this study shows differences in processing between groups of bilinguals due to their different language experiences. Furthermore, one of the most obvious findings that emerges from this study is that the age of acquisition of the second language and/or the linguistic context where the bilingual is immersed plays an essential role in cognitive processing. Future studies should try to differentiate between the role of language immersion and age of acquisition. Besides, future studies should also test the possible contribution of heritage languages in the PM task. Heritage bilinguals are speakers who have some degree of proficiency in the heritage language from an early age but whose dominant language shifted to L2 during their school-age years (Polinsky & Kagan, 2007). Given that our early bilingual participants come from California and most of them belonged to immigrant Latino families, it is very possible that they acquired their L1 at home and L2 at school. Future experiments should also try to explore the role of heritage languages in modulating PM processes, beyond language immersion and early acquisition.

5. Conclusions

In conclusion, to the best of our knowledge, this is the first study to explore the influence of bilingualism in PM. The observed results support our hypothesis that differences in prospective processes might be due to the different language experiences of the participants. We observed that the language context of the participants modulated the cognitive processes involved in updating and cue detection to adapt them to the task's demands. Thus, early bilinguals were able to selectively adjust their executive control mechanisms in order to detect and respond to the PM cue. These results were attributed to their different language experiences (Green & Abutalebi, 2013). These new insights enhance our understanding of executive control processes in bilinguals and indicate that factors such as the age of L2 acquisition or linguistic context could be modulators of these cognitive differences (Beatty-Martínez et al., 2020; De Bruin, 2019).

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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