The Role of Working Memory in Bilingual Language Processing and Brain Activation

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Abstract: This study explores i) how auditory and visual WM affects a bilingual's spontaneous oral and written production and ii) how the WM is revealed using ERP and fNIRS brain activation. Tentative results indicate that the WM capacity in a bilingual's dominant language appears to play some role in language execution.

Keywords: bilingual, fNIRS, EEG

Introduction

Only a handful of studies (e.g. Chen *et al,* 2025) have employed both auditory and visual working memory (WM) tasks to investigate the role of the WM and the effect of bilingualism on the executive functions of the brain. Additionally, to measure the participants' bilinguality, most studies have relied on such standardized tests as IELTS or TOEFL, rather than directly collecting spontaneous oral and written data from the participants in these different modalities. Furthermore, even less studies have collected both linguistic and neurolinguistic data to examine this issue.

To fill in this gap, the current study has addressed the issue by collecting data using a i) Reading Span (visual WM) Test and Listening Span (auditory WM) Test, ii) spontaneous linguistic data from both oral narrative and writing tasks, and iii) neurolinguistic data with the use of a temporal and spatial- sensitive apparatus. In addition, instead of comparing bilinguals against monolinguals, only bilinguals who are similar in language proficiency in two languages are targeted, but they are different in the manner in which they acquired the languages – from birth onwards or later in life. This decision is based on the assumption that qualitative changes in the brain take place as additional languages are acquired (Ortega, 2009), making it logical to compare results among bilinguals rather than comparing monolinguals and bilinguals because they are qualitatively different in the first place.

Methods

Data was collected from an early balanced Japanese-English bilingual (EB) and a late Japanese-English bilingual (LB). They were matched in age, gender, and socio-economic status. Both auditory (listening) and visual (reading) Span Tests entailed progressively longer sentences with up to 5 sentences in each in Japanese and English. To reveal the linguistic proficiency in English, a spontaneous narrative task based on a picture book 'Frog, where are you?' and an essay-writing task (TOWL-3) were administered. Oxygenated hemoglobin (Oxy-Hb) was measured to identify whether ACC, IFG, DLPFC, pre-SMA, and SMG were bilaterally activated when EB & LB engaged in a verbal fluency task (VFT) in Japanese and English (Figure 1), and ERPs were monitored when the participants were code-switching (CS) between Japanese and English task (Figure 2).

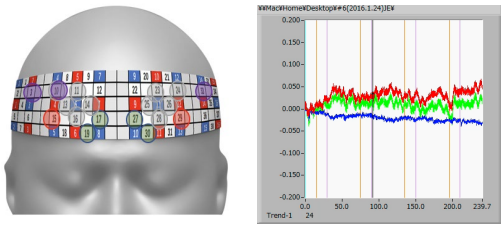

Figure 1. fNIRS

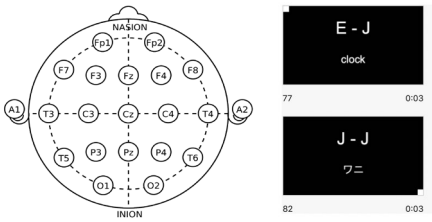

Figure 2. ERP

Results

Auditory and visual WM scores showed EB's superiority to LB in English but little difference in Japanese. The spontaneous English oral narrative data analysis has been summarized in Table 1, which indicates no difference in the pause ratio or inter-sentential pauses between the bilinguals, but EB is superior in accuracy while LB's superiority lies in the narrative execution speed. The writing task score revealed that EB writes a better English essay than LB. The fNIRS data analysis disclosed no difference between the participants in the IFG activation when they used English (Figure 3) but more IFG activation in EB in Japanese (Figure 4). The ERP data analysis on the CS exhibited no activation differences in English or

Japanese likewise no difference with the English-English repetition tasks however distinct differences were observable in EB's N400 and LB's P600 (Figure 5).

	Early	Late
total task duration (ms)	353,562	355,976
total pause duration (ms)	120,794	139,965
total talk duration (ms)	232,768	216,011
pause/total (%)	34.20%	39.30%
talk/total (%)	65.80%	60.70%
#intra-sentential	57	104
#inter-sentential	32	34
total intra-sentential (ms)	48,493	61,626
total inter-sentential (ms)	72,301	78,339
Ave intra-sen (ms)	850.8	592.6
Ave inter-sen (ms)	2,259.4	2,304.1
#token	481	523
ave token (ms) Task	735.1	680.6
ave token (ms) Talk	483.9	413.0

Table 1. Narrative task

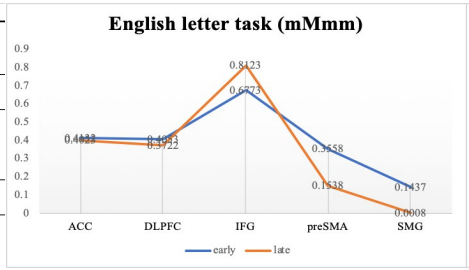

Figure 3. VFT@fNIRS in English

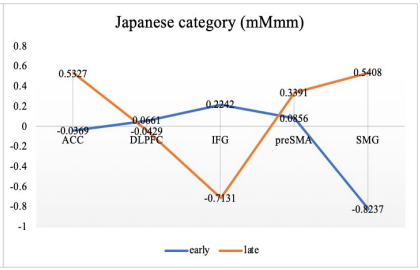

Figure 4. VFT@fNIRS in Japanese

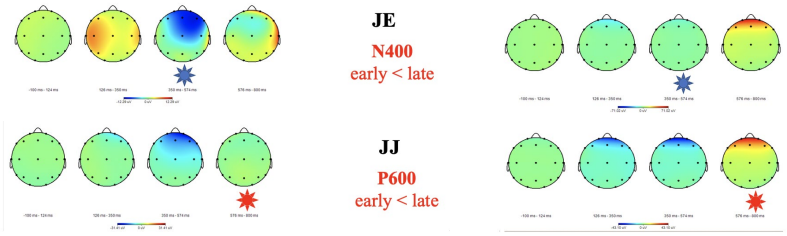

Figure 5. ERP@CS in Japanese-English (JE) and Japanese-Japanese (JJ)

Discussion

Our preliminary analysis of the data taken from the two bilinguals shows i) EB = LB in Japanese auditory and visual WM but EB > LB in English auditory and visual WM, ii) they were different in pause distribution and accuracy in their English narratives, and EB's writing is better than LB's, iii) Oxy-Hb in the English VFT was at the same level in the IFG in the left hemisphere in both EB and LB, but the Japanese VFT resulted in a higher Oxy-Hb in EB than LB in the IFG, while the Oxy-Hb was higher in LB in the ACC, pre-SMA, and SMG areas, in the left hemisphere, and iv) the degree of N400 was more acute in EB for the Japanese-English CS task whereas the degree of P600 was more acute in LB's Japanese-Japanese word repetition task.

Conclusions

A more detailed analysis on all the data will be revealed in the presentation to find further answers on the role played by WM in bilingual language production, though it tentatively appears that a better WM results in a better linguistic performance.

Acknowledgements

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