LEXICON ON BOARD: A MEG STUDY BASED ON EXPRESSIVE PICTURE-NAMING

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Abstract. No task can better depict the path underlying word production in human brain than picture naming as it covers all the stages of production from visual analysis to motor execution. Nevertheless, the cognitive processes associated with word retrieval and the investigation on word-picture differences are complex and not fully understood. Uttering a word entails orchestrating several steps as visual object recognition, accessing a lexical concept, lemma selection, lemma retrieval, accessing the morpheme(s) and generating the phonological word, and finally retrieving syllabic gestural scores and articulation. Moreover, it is already known that the brain function is not the outcome of isolated regions but the network of regions interacting with each other. To study the mechanisms of word retrieval in lemma selection phase, we compared the three groups of monolingual, semi-bilingual and bilingual learners Spanish-English speakers through a functional neuroimaging technique with respect to their topography and strength of Functional Connectivity (FC) values of the most highlighted pair of activated nodes in the time range of 0-150 ms in different frequency bands (delta, theta, alpha, beta, and. gamma) upon application of the stimuli. We have seen no significant difference between difference frequency bands (p >.05) at the most highlighted FC pairs. However, we observed higher gamma values signifying the semantic activation of the word. We could not find any significant difference between the three groups in terms of FC values at designated pairs of nodes signifying that different amount of exposure could not affect electrophysiological patterns in the preliminary step of word production.

Keywords: *lexicon, MEG, picture naming, monolingual, semi-bilingual, bilingual, Content and Language Integrated Learning (CLIL).*

Табарі Фатіме. Лексикон у розпорядженні: дослідження експресивного називання на основі зображень із використанням МЕГ.

Анотація. Жодне із завдань не здатне так добре описати шлях від породження слова в людському мозку, ніж називання зображень, оскільки воно охоплює всі стадії породження від візуального аналізу до моторного втілення. Водночас, когнітивні процеси, пов'язані з пошуком слів і дослідженням відмінностей слів і зображень, є складними і не повністю зрозумілі. Породження слова передбачає декілька етапів, таких як розпізнавання візуального об'єкта, доступ до лексичного поняття, вибір леми, її вилучення, доступ до морфем(и) й створення фонологічного слова, і, нарешті, вилучення складів і артикуляції. Крім того, відомо, що функція мозку – це не результат роботи ізольованих ділянок, а мережа цих ділянок, що активно взаємодіють одне з одним. Щоб вивчити механізми вилучення слів на етапі вибору леми, порівнювали три групи учнів-монолінгвів, іспансько-англійських

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напівбілінгвів і білінгвів з огляду на їхню топографію та значущістьфункціонального зв'язку (ФЗ) найвиділенішої пари активованих вузлів у часовому діапазоні 0-150 мс у різних діапазонах частот (дельта, тета, альфа, бета і гамма) під час застосування стимулів. Не помічено суттєвої різниці між діапазонами різниці частот (p>0,05) у найбільш виділених парах ФЗ. Проте ми спостерігали вищі показники гамма-значення, що означає семантичну активацію слова. Не виявлено істотної різниці між групами щодо значень ФЗ у визначених парах вузлів, що означає, що різна кількість експозицій не може вплинути на електрофізіологічні патерни на попередньому етапі породження слова.

Ключові слова: *лексикон, МЕГ, називання зображень, монолінгв, напівбілінгв, білінгв, предметно-мовне інтегроване навчання (CLIL).*

Introduction

One of the most impressive capabilities of human is to access right word at the right moment (Levelt & Schriefers, 1987). How do we access and retrieve words when we are speaking? The answer to this question is embedded in the findings from neuropathology of lexical access (e.g. analysis of speech errors, tip of tongue, and aphasiology) and reaction time research (Brown & Nix, 1996; Rastle & Burke, 1996). Among all methodologies, picture naming and picture-word interference studies contribute a lot to the understanding of underlying mechanism of lexical access.

The cognitive processes associated with word retrieval and the investigation on word-picture differences are complex and not fully understood. It has become the center of attention in modern cognitive science and psychology. Many new theories and advances are elaborated based on the findings derived from such investigation. Efficient word retrieval is necessary for most high-level tasks in the workplace, so even mild deficits can have a deleterious effect on communication in daily life (Frantantoni et al., 2017). The inability to retrieve and integrate features can interfere with activation of a semantic memory and its associated word representation.

Uttering a word entails orchestrating several steps as visual object recognition, accessing a lexical concept, lemma selection, lemma retrieval, accessing the morpheme(s) and generating the phonological word, and finally retrieving syllabic gestural scores and articulation. At the beginning, visual representation of the object (percept) which involves abstract properties of the objects (like color, orientation or size) is computed from the visual image (Hart & Gordon, 1992). Then proper lexical concept is activated to refer to the percept and it is totally depends on the perspective meant by the speaker in various communication situations (Levelt, 1996; Levelt et al., 1999).

The percept can be conceptualized in the basic level (such as House, Piano, Car) which is easily induced to operate in picture naming. However, some activation has always been spreading from the target concept to semantically related concepts. Afterward, the activation of a lexical concept normally spread to all associated lemmas which is a lexical record that encodes a word's semantic and grammatical features, but not its phonological or orthographic properties (Badecker et al., 1995).This step as the syntactic representation and the prerequisite of grammatical encoding of the word, extract initial information like syntactic category, gender, part of speech. Ultimately one lemma is chosen from all lexical concepts.

At lemma selection, phonological form of the word is created by retrieval of morphemes (which is word form representation of lemma) by phonemes (word's phonological shape) and metrical structures (Levelt, 1992; Roelofs & Meyer, 1997). Then the phonemic segments correspond to their metrical structures and create phonological syllables (Levet et al., 1998). And at the end, by spreading activation, syllabary which is the depot of abstract motor representation for language syllables sends the appropriate gestural scores after a syllable being retrieved (Levelt & Wheeldon, 1994). As soon as all syllabic score are retrieved, the articulatory system executes the gestural scores and provides motor instructions for the respiratory, the laryngeal, and the supralaryngeal systems involved in articulation of speech. The overt speech is then monitored by the speaker by activating comprehension, and self-correction or monitoring prearticulatory internal speech happens appropriately (Levelt, 1989; Levelt & Wheeldon, 1994).

Lemmas can become available at different moments in time, dependent on the speaker's unfolding of the message. Unfolding the time course and mechanism of encoding stages of word production is one of the big concerns in expressive language production. Moreover, word retrieval requires precise timing of interactions between brain regions (Hart et al., 2013). EEG and MEG have high temporal resolution and is sensitive to the timing of neuronal synaptic and dendritic activity. According to the literature, the average picture naming latency starting from visual input to articulation lasts 538 ms (Thorpe et al., 1996). It seems really difficult to distribute the timing on different stages. ERPs can be a great resource to disentangle multiple components involved in comprehension, production, and domain-general processes.

It is already known that the brain function is not the outcome of isolated regions but the network of regions interacting with each other. The neurofunctional imaging methods used for brain mapping categorizes different brain regions recruited by functionalities such as the regions around the posterior part of the superior temporal sulcus (superior and middle temporal gyri) for language comprehension, left posterior temporal regions and the left inferior frontal cortex (IFC) for semantic processing, basal inferior temporal areas that are involved in lexical retrieval for visual tasks such as reading or naming, IFC inferior and anterior parts, i.e. the pars orbitalis [Brodmann area (BA) 47] pars triangularis (BA 45) dorsolateral prefrontal cortex (DLPFC) (BA 46/9) executive aspects of semantic processing (Duffau et al., 2005). Although the involved cortical areas in picture naming may vary by the individuals, the mapped areas identified during such procedures has been included triangular or opercular part of the inferior frontal gyrus, the angular gyrus or posterior part of the superior temporal gyrus, the motor strip, and premotor Broca's area, language sites, medial temporal gyrus and the parietal and prefrontal cortices (Ojemann et al., 1989; Friederici, 2011; Ardila et al., 2016; Westwood & Romany, 2017).

No task can better depict the path underlying word production in human brain than picture naming as it covers all the stages of production from visual analysis to motor execution. This task which is very demanding on brain activation and selection in lexical system involves word retrieval and inhibition. Picture naming as a tested psycholinguistic metrics is a great measure for speculating the correlations between distinct stages of cognitive processing and cortical dynamics (Levelt et al., 1998). Uncovering spatial and temporal mechanism of the core cognitive processes involved in word production has been the main concern of neuroscience of language (Valente et al., 2014).

From Bilingualism Perspective

It is well documented that bilinguals attain higher cognitive ability due to their unique brain architecture. This cognitive ability contributes to inhibit impulses and natural, habitual, or dominant behavioral responses to stimuli or control the automatic or impulsive responses (Diamond, 2013; Ilieva et al., 2015). If being bilingual means being equipped with an additional cognitive tool, bilingualism should have a profound effect on neural development and cognitive improvement.

Many studies have report the superiority of bilinguals over their monolingual peers on different aspects such as executive function (Braver et al., 2001; Morales, Gómez-Ariza, & Bajo, 2013; Morales et al., 2015; Teubner-Rhodes et al., 2016), working memory and attention (Eunju Yang, 2017; Bialystok, 2017), greater structural density or better functional patterns and structural pattern (Mohades et al., 2012; 2015), greater sensitivity (Kuipers & Thierry, 2012; Barac et al., 2016) and many more facilities. However, in most of the studies the compared populations were early versus late bilinguals (Hull & Vaid, 2006; 2007; Martin et al. 2013; Gullifer et al., 2018; Lukasik et al., 2018), simultaneous versus sequential bilinguals (Giedd et al., 1996; Schlegel et al., 2012) or bilinguals versus monolinguals (Kovelman et al., 2008; Grady et al., 2015; Grundy et al., 2017; Frutos-Lucas et al., 2019).

However, bilingual education takes different forms based on the curricula adopted by educational systems. It can vary from a few hours of L2 education during the week or being a fully proficient bilingual who maintains regular use of L1 and L2. Not all types of bilingualism have the same effect in learning, and may lead to different cognitive, behaviour and neural responses. The concept of “the many kinds and degrees of bilingualism and bilingual situations” (Crystal, 2003, p. 51) calls the attention toward to importance of the context and the setting where bilingual experience occurs. The amount of environmental stimulation can also vary the effect size. Increased grey matter density in the Left Inferior Parietal-LIP (center of language processing), especially LIPG (Left inferior parietal gyrus), has been found to be positively correlated to participants’ degree of bilingualism (Mechilli et al, 2004; Della Rosa et al., 2013) and increases as more time is spent in a foreign language class (Stein et al. 2012). In this paper, the classical bilingualism categorizations will not be followed, but rather based on the amount of exposure classification, that is, the time spend on learning the other language through a weekly schedule. Accordingly, we categorized our participants to monolingual, bilingual and semi-bilingual groups. Our semi-bilinguals are enrolled in a bilingual educational system in Spain called Content and Language Integrated Learning (CLIL).

Among all different approaches, functional connectivity (FC) is an advanced measure for studying how different brain regions synchronize to interact with each other. This approach has already been used in bilingual studies especially at resting state (Chai et al., 2016; Hsu et al., 2015; Perani et al, 2017; Frutos-Lucas et al., 2019). For example, bilinguals exhibited greater FC at rest between the inferior frontal gyrus (an area that has been demonstrated to be susceptible to structural and functional changes as a result of second language acquisition) and other brain regions (Berken et al. 2016).

So far much has been said about cortical activation during picture naming but in the present study we try to shift our focus from localizing functional regions to interaction between different regions in initial stages of word production. To study the mechanisms of word retrieval in lemma selection phase, we compared the three groups of monolingual, semi-bilingual and bilingual learners with respect to their topography and strength of FC values of the most highlighted pair of activated nodes in the time range of 0-150 ms in different frequency bands (delta, theta, alpha, beta, and. gamma) upon application of the stimuli.

Materials and Methods

The study was approved by the local Ethics Committee at Autonomous University of Madrid. The methodology and the aim of the study were clearly explained to all subjects, and informed written consents were obtained from each of them.

Participants

Fifteen right-handed healthy teenagers (range: 11-13 years) participated in the experiment including five Spanish-English semi-bilinguals (2 males, 11.4 mean age), five Spanish-English bilinguals (3 males, 12 mean age) and five Spanish monolinguals (2 males, 11.4 mean age). The participants' handedness was checked through Edinburgh Handedness Inventory (Oldfield, 1971). The participants were administered a general health screening and a language history questionnaire, which included self-ratings of proficiency in each speaking language (on a 5-point Likert scale). None of the participants reported a history of neurological or psychiatric illness, had experienced a neurological injury, or had used a psychotropic medication.

Their vocabulary and grammar proficiencies were measured through Oxford Placement Test which is a written multiple-choice test of 60 questions of English morphosyntax, and the scores range from 0 to 60. The summary of participants' information is depicted in table 1. All participants were living and studying in Spain at the time of testing. All immersions (bilinguals) judged themselves to be totally bilingual and equally fluent in both Spanish and in English. Our tests also proved that.

Table 1
Participants' Information

	Age (testing)	Age (exposure)	Proficiency	Exposure
Monolingual	11.4 y	5 y	41.0 (2.07)	5 hrs
CLIL	11.4 y	5 y	46.4 (2.59)	11 hrs
Bilingual	12 y	4-6 y	55.5 (1.46)	25 hrs

Note: The age difference was due to classification of education in different schools (e.g., the 5th grade of one school was equal to the 6th grade of another school).

The participants were enrolled from four different schools located in Madrid (Spain). The English education in the monolingual school was delivered at least 5 hours per week through English as a Foreign Language (EFL), while the students of semi-bilingual schools (which we call a CLIL system, studied English for at least 11 hours per week including EFL together with other courses, such as Natural Sciences, Social Sciences, and Arts and Crafts. At the same time, bilinguals were recruited from two British schools (which we call an Immersion system), where all subjects were taught in English except social studies and Spanish language for at least 25 hours per week. The summary of participants' information is depicted in

Table 1.

The Peabody Picture Vocabulary Test (2007 edition) was administered in Spanish and English to test participant's receptive vocabulary ability for Standard Spanish and English. The Raven's SPM 60-item test was also used for measuring abstract reasoning, regarded as a non-verbal estimate of fluid intelligence. Selective attention capacity and skills, as well as their processing speed ability were also measured through the Stroop effect test. The three groups were matched based on the above-mentioned qualities and GPA of previous academic year.

Stimuli and Task

The standardized set of picture naming that was born in 1980 by Joan G. Snodgrass and Mary Vanderwart and widely used so far. Although this 260-image set were added and normed in different languages, the main set was actually designed for American English. Therefore, in this study, our target stimuli for this experiment consisted of 120 black and white drawings and their corresponding modal names adopted from MultiPic databank which was generated and normed in order to facilitate replication and extension to other languages than English including German, Italian, Spanish, French, and Dutch. The materials are open-access and free from copyright restrictions for non-commercial purposes at http://www.bcbl.eu/databases/multipic.

All items are presented in two blocks of 60 stimuli, a pseudo-random order without the intervention of the participants, a different order for each participant and a break after each block. The pseudo-randomization was preferred to a complete randomization to avoid succession of stimuli from the same semantic category or with high phonological overlap. Ten warm-up filler trials corresponding to easy-to-name stimuli were set at the beginning of the experiment and after the break. There was a short break between the two blocks. On each trial a fixation white cross was projected on a black background appeared for 500 ms. The drawing was presented for 3000 ms followed by a blank screen for a variable duration 1000ms after the stimulus.

MEG Recording and Preprocessing

Experiment stimuli were presented using Psychopy software (Peirce, 2007). Recordings were performed with an The Elekta Neuromag® (Elekta AB, Stockholm, Sweden) MEG whole-head scanner (102 magnetometers, 204 planar gradiometers) placed inside a magnetically shielded room (VacuumSchmelze GmbH, Hanau, Germany) at the "Laboratory of Cognitive and Computational Neuroscience" (Madrid, Spain). This scanner comprises 306 channels, of which, 204 are planar gradiometers and 102 magnetometers.

Digital models of each subject's headshape were determined before the recordings using a digitizer (3Space Fast-Track, Polhemus, Colchester, VT, USA). The scans included coordinates of three anatomical landmarks and five reference points in order to coregister neuromagnetic data with MEG. Channels with poor signal quality were manually de-selected after visual inspection for artifacts and a Signal-Space Separation (tSSS) filter (Elekta data) was applied for artifact removal using MaxFilter software. Head position with respect to the MEG helmet was monitored using three coils placed at anatomical landmarks of the head (nasion, left and right pre-auricular points).

The participants were seated in a padded chair inside a magnetically shielded room containing the MEG instrument 135 cm from a CRT monitor. They were guided to say the words covertly to avoid muscle contamination artefacts due to mouth movements during language production, The potential artefacts may distort the signals and lead to a bad signal-to-noise ratio in the measurements. However, there is a great body of literature on overt language production in ERP studies that is extensively explained by a review from Ganushchak, Christoffels and Schiller (2011). The analysis was carried out using MATLAB (R2017a; Mathworks Inc., MA, USA) and its Brainstorm toolbox (Tadel et al., 2011).

Standard default anatomy of Brainstorm was warped to fit the digitized head points recorded using Polhemus Fastrak device. Cortical surface was modelled using *Overlapping spheres* as the forward model, having approximately 15000 vertices on the mesh. The brain sources underlying the recorded MEG were estimated using Minimum norm imaging method and sLORETA maps, where the dipoles were constrained to be normal to the cortex as most of the cortical neurons are pyramidal and have normal-to-cortex electrical activity.

Desikan-Killiany atlas was used to identify regions of the posterior left hemisphere such as inferior temporal (IT), medial temporal (MT), superior temporal

(ST), supramarginal (SM), inferior parietal (IP), superior parietal (SP), and lateral occipital (LO). The choice of these regions is based upon the findings of the study by (Kielar et al., 2015). Besides, the estimated brain source activations in the posterior left hemisphere (PLH) regions discussed above were evaluated for their principal component to get the event-related fields (ERF) for each subject. These ERF were then also normalized to the maximum of their absolute value before averaging them between subjects of the same class or group such as Bilingual, Semi-bilingual, or Monolingual. This group average has been referred to as average normalized response.

Recordings were performed with the Elekta Neuromag® (Elekta AB, Stockholm, Sweden) MEG whole-head scanner (102 magnetometers and 204 planar gradiometers) placed inside a magnetically shielded room (VacuumSchmelze GmbH, Hanau, Germany) at the Laboratory of Cognitive and Computational Neuroscience (Madrid, Spain). The participants were placed 135 cm from a CRT monitor. Digital models of each subject's headshape were determined before recordings using a digitizer (3D Space Fast-Track, Polhemus, Colchester, VT, USA) which were coregistered with three fiducial points. Channels with poor signal quality were manually unselected after visual inspection for artifacts and a temporal Signal-Space Separation (tSSS) filter was applied for artifact removal using the MaxFilter software. The head position with respect to the MEG helmet was monitored using four coils placed on the head.

Source Localization and Time Course

The standard default anatomy of Brainstorm was warped to fit digitized head points recorded using the Polhemus Fastrak device. The cortical surface was modeled using Overlapping spheres as the forward model, having approximately 15000 vertices on the mesh. The brain sources underlying the recorded MEG were estimated using sLORETA method, where dipoles were constrained to be normal to the cortex as most of cortical neurons are pyramidal and have normal-to-cortex electrical activity.

After removing a DC offset for each channel using the baseline -1000 ms to -1 ms and removing Signal-Space Projections (SSP) for eye blinks and heartbeats[1], 120 4-s epochs (-1 to 3 seconds) were generated corresponding to each image. Our continuous data were then segmented into non-overlapping epochs spanning from 500 ms before to 2000 ms after the presentation of the visual stimuli. Epochs containing high amplitude, high frequency muscle noise and other irregular artifacts were removed. We time-locked to the beginning of visual stimuli to the onset of lemma selection.

Connectivity Calculation

[1] Due to a technical error, electrocardiogram activity was only recorded for subjects 1-4. For this reason, SSP for heartbeats couldn't be removed for the rest of the subjects. Consequently, we can't study lower band frequencies in the collected MEG data.

Since the brain is a nonlinear dynamical system, phase locking is an appropriate approach to quantifying interaction. Phase interaction measure of Phase Locking Value (PLV) is absolute value of the mean phase difference between the two signals expressed as a complex unit-length vector (Lachaux et al., 1999; Mormann et al., 2000). A more pragmatic argument for its use in studies of LFPs (local field potentials), EEG and MEG is that it is robust to fluctuations in amplitude that may contain less information about interactions than does the relative phase (Lachaux et al., 1999; Mormann et al., 2000). FC between all pairs of sources was estimated using phase-locking value (PLV) algorithm.

If the marginal distributions for the two signals are uniform and the signals are independent, then the relative phase will also have a uniform distribution and the will be zero. Conversely, if the phases of the two signals are strongly coupled then the PLV will approach unity. For event-related studies, we would expect the marginal to be uniform across trials unless the phase is locked to a stimulus. In that case, we may have nonuniform marginals which could in principle lead to false indications of phase locking.

Phase synchronization between two narrow-band signals is frequently characterized by the Phase Locking Value (PLV). Consider a pair of real signals s1(t) and s2(t), that have been band-pass filtered to a frequency range of interest. Analytic signals can be obtained from s1(t) and s2(t) using the Hilbert transform:

$$z_i(t) = s_i(t) + jHT\left(s_i(t)\right) \tag{1}$$

Using analytical signals, the relative phase between z1(t) and z2(t) can be computed as,

$$\Delta\phi(t) = arg\left(\frac{z_1(t)z_2^*(t)}{|z_1(t)|\,|z_2(t)|}\right) \tag{2}$$

The instantaneous PLV is

$$PLV(t) = \left|E\left[e^{j\Delta\phi(t)}\right]\right| \tag{3}$$

Data were analyzed separately using a mixed effect two-way analysis of variance (ANOVA) with method of acquisition (between-subject factor: group [Immersion vs. Bilingual vs Monolingual]; within-subject factor: condition [Delta vs. Theta vs Alpha vs Beta vs Gamma band]). We performed statistical comparisons for each frequency band separately, we Bonferroni-adjusted the p-value of each significant cluster such as $\alpha = .01$. Level of bilingualism was included as a covariate in statistical analyses.All statistical analyses of behavioral data were performed using IBM SPSS Statistics 21 for Windows (SPSS Inc., Chicago, USA).

Results

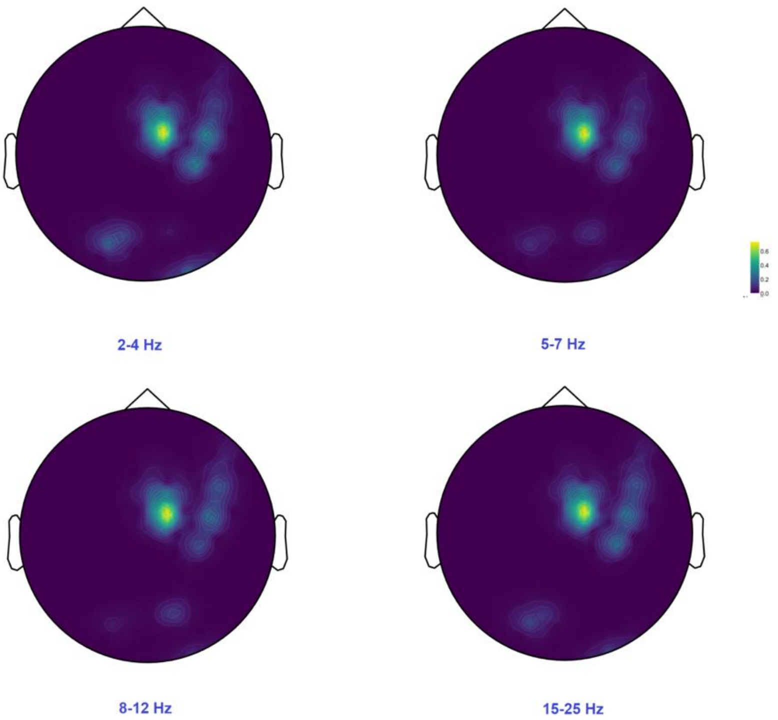
The research dataset has been uploaded to Mendeley Data Repository (Tabari, 2021).

The analyses brought significant six FC pair in five frequency ranges all of them exhibiting in all the groups. Among all the FC links between our MEG channels the following were more pronounced: 1941-1911 (LO1), 2042-1912 (LO2), 1913-1942 (LO3), 1311-1131 (RP-RT), 1221-1311 (RT-RF1) and 1232-1323 (RT-RF2)[1].

Figure 1

Regions Activated in Phase-locked to Lemma Selection Time Window (0-150 ms) in 4 Different Bands (Averaged for 3 Groups)

Abbreviation	Full name
LO	Left occipital
RP	Right Parietal
RO	Right occipital
LP	Left parietal
RF	Right Frontal
LF	Left Frontal



[1] Authors labled the pair of MEG channels to ease addressing.

To compute the difference between the conditions (high vs low proficiency), we used the normalized form (A-B/A+B). We found difference in the pairs (1131-2031=.7785), (1131-1322=.8575), (1131-1232=.7037) and (1043-2013=.7063), which involves the right parietal , temporal, frontal, and occipital and left parietal probably due to the preparation to select lemma.

RO	LO	RP	RT	RF	LP
2031	1911	1131	1311	1221	2013
2131	1912	1132	1332	1222	
2132	1913	1133	1322	1232	
2133	2042	1042	1323		
	2043	1031			
	1941				
	1942				

LO1=1911-1941; LO2=1912-2042;LO3=1913-1942; RP-RT=1131-1311; RT-RF1=1311-1221; RT-RF2=1232-1221

Repeated measures ANOVAs were conducted on each FC link and the data were screened for missing values, normality, presence of outliers and variable correlation. However monolingual group showed a higher mean value of FC in LO1, LO2, LO3 in Alpha, Beta, Theta and Delta Band than the other two groups but such difference was not significant (p>.05) Tukey's HSD test showed no significant difference between the three groups in Gamma Band (p>.05); although monolinguals had a higher score in LO2 (.7323±.0785), LO3 (.7448±.0665), immersion group scored higher in LO1 (.7219±.0195) and bilingual group leaded in PR-RT (.5963±.0588), RT-RF1 (.6044±.0301) and RT-RF2 (.3637±.0547).

In Delta band, Monolinguals showed a higher score in LO1 (.7457±.737) , LO2 (.7876±.0347) , LO3 (.7869±.0501), while in PR-RT, immersions leaded the peers (.5950±.0375) and bilinguals surpassed the others in RT-RF1 (.7281±.0558) and RT-RF2 (.5662±.0470). However none of the differences were statistically significant (p>.05). Similarly in Theta band, Monolinguals showed a higher score in LO1 (.7463±.950) , LO2 (.7885±.441) , LO3 (.7847±.0448), while in PR-RT and RT-RF1, immersions leaded the peers (.5599±.690 and .7236±.0531 respectively) and bilinguals surpassed the others in RT-RF2 (.5249±.0489). However, none of the differences were statistically significant (p>.05).

Likewise, no significant difference between the three groups in Alpha Band (p>.05); although monolinguals had a higher score in LO1 (.7243±.1195), LO2 (.8146±.0274), LO3 (.7720±.887), and bilingual group leaded in RT-RF1 (.7283±.0809), PR-RT (.5773±.798), and RT-RF1 (.4451±.536). In Beta band, like other bands monolinguals had a higher score in LO1 (.7431±.0575), LO2 (.7657±.0274), LO3 (.7519±.0524) and bilingual group leaded in RT-RF1 (.6802±.0464), PR-RT (.5692±.0990), and RT-RF1 (.4525±.0742). We also did not find any significant difference between the LO1 in the different bands (delta

[MS=.11; F=2.33; p=.140], theta [MS=.004; F=.751; p=0.493], alpha [MS=.001; F=.148; p=.864], beta [MS=.005; F=1.303; p=.308] and [MS=.005; F=2.494; p=.124] gamma).

Figure 2
FC in 4 Frequency Ranges with Intensity Threshold of .005-.798

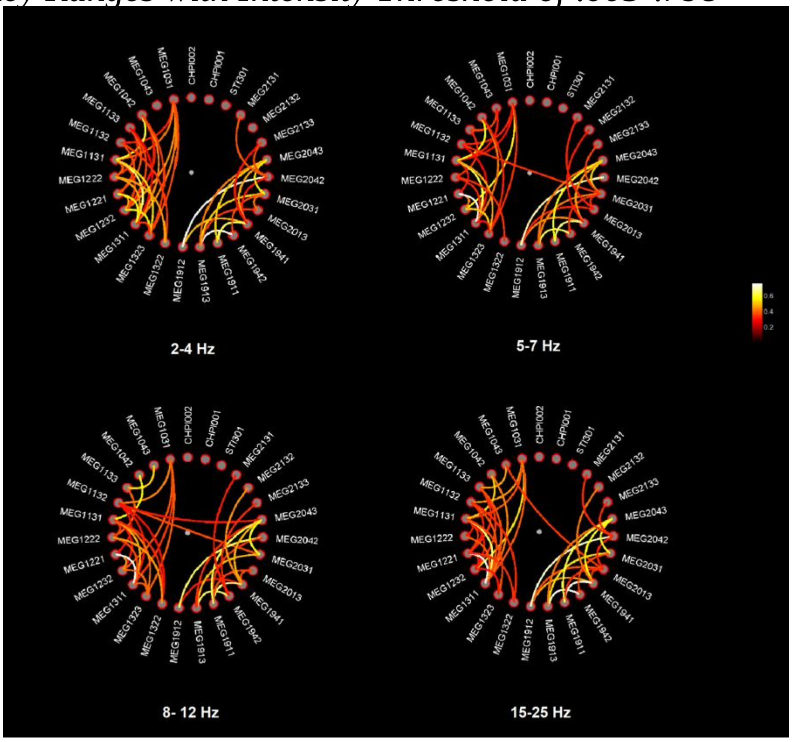


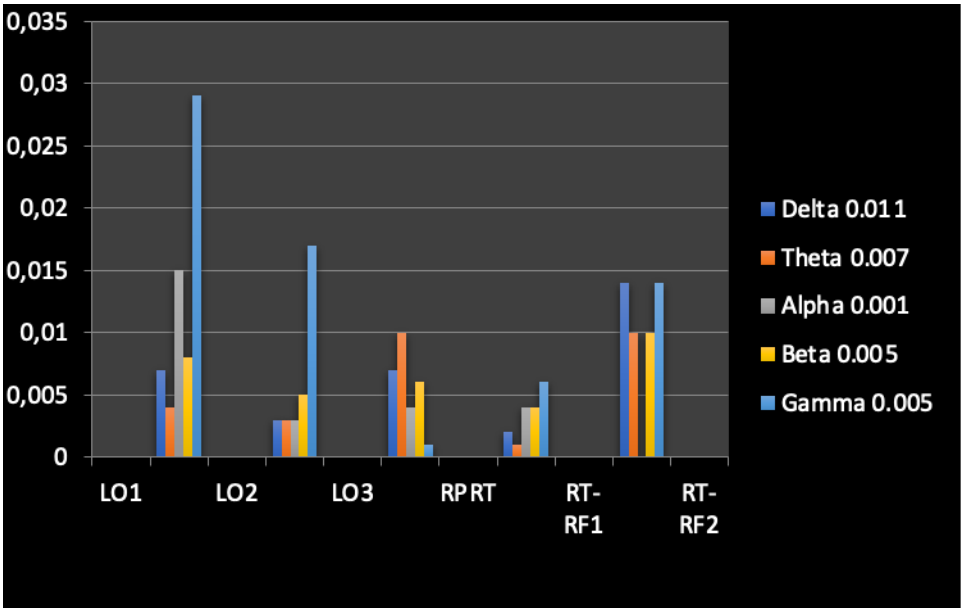
Table 2
Repeated Measures ANOVAs Also Applied to Test Differences Between FC Values in Each Frequency any of Frequency Bands

Pairs of channels		**Delta**	**Theta**	**Alpha**	**Beta**	**Gamma**
	MS	.011	.007	.001	0.005	0.005
LO1	**F**	2.33	3.284	.148	1.303	2.494
	p	.140	.073	.864	0.308	0.124
	MS	.007	.004	.015	0.008	0.029
LO2	**F**	3.284	.751	2.344	2.389	3.113
	p	.073	.493	.138	.134	.081
	MS	.003	.003	.003	.005	.017
LO3	**F**	1.098	1.333	.422	.919	1.935
	p	.365	.300	.665	.425	.187
	MS	.007	.010	.004	.006	.000
RPRT	**F**	2.550	1.548	.495	1.104	.137

	p	.119	.252	.621	.363	.873
	MS	.002	.001	.004	.004	.006
RT-RF1	**F**	.323	.217	.583	.573	.998
	p	.730	.808	.573	.397	.397
	MS	.014	.010	.000	.010	.014
RT-RF2	**F**	2.123	2.289	.038	2.289	2.123
	p	.162	.144	.963	.144	.162

Figure 3

FC Values for Each Pair at Different Frequency Bands



Discussion

The aim of the present study was to investigate whether different level of exposure to second language would be associated with different patterns of functional connectivity at lemma access level (0-150 ms). As we have seen no significant difference ($p > .05$) between monolingual, bilingual and CLIL learners in terms of FC values in lemma selection stage. Hence, we void the assumption of the difference between the groups.

We also observed strong activations between 0-150 ms after the presentation of visual stimuli. According to the results of picture naming/lexical decision experiment by Levelt et al. (1991), the time estimated for lemma access in naming tasks was 115 ms. In Roelofs's (1992) computational model lemma selection durations using semantically related and unrelated distracters was reported in the range of 100 to 150 ms; while, Potter and Faulconer's (1975) estimation of lemma access turn out to be 150 ms.

The results of some ERPs reported that the concept beginning to be accessed some 100 ms after picture onset (Potter, 1983). First, Roelofs's (1997) picture/word interference experiments in the presence of auditory phonological distracters gives an estimate of 265 ms for the interval between lemma selection and accessing the syllable score of a monosyllabic word including syllable node selection and phonemic segment attachment. Second, in a phoneme agreement experiment by Wheeldon and Levelt (1994), the estimate of the internal encoding duration of the whole word phonologically found out to be 125 ms.

Other studies, however, suggest that brain engages in lexical selection around 200 ms after picture onset (e.g., Hirschfeld et al., 2008; Costa et al., 2009; Strijkers et al., 2010; Aristei et al., 2011). An ERP study with go/no go design for semantic picture categorization by van Turennout, Hagoort, and Brown (1997), the duration estimate of phonological encoding was about 120 ms. Accordingly, visual processing plus accessing the lexical concept for an average naming latency of 538 can be split to 150 ms; lemma selection: 125 ms; phonological encoding: 125 ms; and phonetic encoding and initiation of articulation: 138 ms. Strijkers and Costa (2011) assessed such latencies as input to concept: 175 ms; from concept to syntax: 75 ms; from syntax to first phoneme: 40 ms; and from concept to first phoneme: 115 ms. To summerize the whole process begins from lexical selection around 100 ms after picture, phonological encoding between 275 and 400 ms and morphological processes starting around 350 ms after the picture onset (Indefrey & Levelt, 2004; Hirschfeld et al., 2008; Costa et al., 2009; Strijkers et al., 2010; Aristei et al., 2011.; Eulitz et al., 2000, Koester & Schiller, 2008).

Left hemispheric activation has always been the centre of attention in most language studies while the importance of right hemisphere (especially inferior frontal and temporal regions) in some core language processing is rarely discussed (Binder et al. 1997; Fedorenko et al. 2010; Price 2012; Bozic et al. 2015; Chai et al., 2016). However, we observed activations in LO, RF, RP and RT regions ans specifically right IFG due to the preparation to select lemma during the time-locked window of 0 to 150 ms. In a similar study by Salmelin et al (1994) on the dynamics of brain activation during picture naming, the authors reported right occipital visual area reaction followed by early bilateral signals close to the temporo-parieto-occipital junctions. Right IFG has been known as central to attentional control and response inhibition essential for bilinguals to navigate through semantic, syntactic an phonological cues (Dove et al., 2000; Aron et al., 2003 and 2004; Hampshire & Owen 2006). Aron and colleagues (2003) also reported that response selection can be disturbed by damage to right IFG, especially pars triangularis. The activation of this region at this time window could be the effect of right IFG in lemma selection process which entails inhibitory control over interfering non-target language. Selection of the correct lemma involves initial activation of multiple lexical representations corresponding to the target and competitor words, until one lemma attains a level of activation exceeding all others with similar semantic features by some particular threshold (Popescu et al. 2017). The probability that a lemma get selected within a minimal time interval depends on its relative activation (Levelt, 1992).

Little has been said about the association between frequency bands and language networks. It is argued that not the same frequency bands play similar roles in different stages of language production and comprehension (Kösem & Van Wassenhove, 2017) as bottom-up processing evokes high frequency oscillations while mediate top-down process evokes slower frequency range (Palva & Palva 2018). Among all alpha oscillation is associated with verbal working memory while beta oscillation has been correlated with verbal memory, semantic prediction (top-down process) and language production (Weiss & Mueller, 2012). Theta synchronizes with syllabic rates and increases by verbal working memory and verbal information retrieval (Giraud & Poeppel, 2012; Friederici & Singer, 2015; Meyer, 2018). Gamma high frequency oscillations is correlated with phonological perception and semantics of the incoming word (Meyer, 2018). High synchrony in right frontal and right central regions was seen to be associated positively with vocabulary outcome in young participants (Mundy et al., 2003). But delta range synchronizes with intonational processing and syntactic comprehension (Meyet, 2018).

We also compared different frequency bands at the same time window in the three groups of participant. We have seen no significant difference between difference frequency bands ($p > .05$) at the most highlighted FC pairs. However, we observed higher gamma values signifying the semantic activation of the word. Doesburg and colleagues (2012) also reported increased gamma synchronization during expressive language task among task-activated regions.

Conclusion

Functional connectivity is an emphasis on the importance of studying communication between language regions. To our knowledge, this is the first study focusing on linguistic electrophysiological pattern of lemma access from FC perspective in three levels of bilingual students. Due to our small sample size we could not find any significant difference between the groups in terms of FC values at designated pairs of nodes signifying that different amount of exposure could not affect electrophysiological patterns in the preliminary step of word production. More in-depth studies are required to investigate the following stages. Neither had we found any differences between the 5 frequency bands at the pairs. However, higher gamma oscillation and activation is right temporal and frontal lobe confirms ongoing lemma access process in the phased locked time window of 0-150 ms.

Limitation of the study

Due to technical cautions, we had to adopt covert naming protocol which had its own limitations. We could not be sure that participants are following our instructions during the task. There are different cortical patterns for covert versus overt naming.

Secondly, our results are limited by sample size. Due to financial observation, we could not enroll more participants to make the result stronger. Further studies with larger sample size is highly recommended.

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