G68: Covert sentence production in early bilinguals: A study in left and right handed participants

M. Termenon[1*], S. Moia[1], P. Paz-Alonso[1], N. Molinaro[1,2], S. Mancini[1], A. Carrión-Castillo[1], B. Mazoyer[3], N. Tzourio-Mazoyer[3], F. Crivello[3], M. Carreiras[1,2], C. Caballero-Gaudes[1]

[1]Basque Center on Cognition, Brain and Language (BCBL), Donostia - San Sebastian, Spain. [2]Ikerbasque, Basque Foundation for Science, Bilbao, Spain.
[3]Groupe d'Imagerie Neurofonctionnelle, Institut des Maladies Neurodégénératives, Centre National de la Recherche Scientifique, Commissariat à l'Energie Atomique, et Université de Bordeaux, Bordeaux, France.

BASQUE CENTER ON COGNITION, BRAIN AND LANGUAGE

*m.termenon@bcbl.eu

Ikerbasque Basque Foundation for Science

Motivation

- **Hemispheric specialization** (HS) is the relationship between a cognitive, sensory, or motor function and a combination of brain structures of a given hemisphere.
- **Language lateralization** and **hand preference** are particular cases of HS [1, 2].
  - More than 90% of the overall population is right handed (RH) having their language function co-lateralized in the left hemisphere.
  - Around 20% of left handers (LH) present ambilateral or strongly-atypical language lateralization in the right hemisphere [3].
- Multiple studies of HS do not consider the linguistic competences of the participants, in particular, whether subjects speak one language (i.e. monolingual) or several languages (i.e. bilingual or multilingual). A meta-analysis [4] found that early bilinguals showed **bilateral** hemisphere involvement for both languages, while monolinguals and late bilinguals, showed left hemisphere dominance.
- Nevertheless, little is yet known about **how handedness affects brain lateralization in bilinguals**.

Experiment

- One hundred and eleven early (age of acquisition < 6 years) highly-proficient bilingual participants (mean age 26.19 ± 6.15 years; 59 F) were scanned in a 3T Siemens PrismaFit MR scanner. They underwent 2 task fMRI runs (GRE-EPI sequence, TR/TE=850/35 ms, MB factor=6, flip angle=56º,voxel size=2.4x2.4x2.4 mm3, 66 slices, matrix size=88x88, 452 scans) while doing a speech production task in Basque (BSQ) and Spanish (SPN).
- During the fMRI session, Subjects were presented during 1 sec white line drawing pictures on a black screen, which were either scrambled pieces randomly distributed or a cartoon depicting a scene. Right after presentation of a picture, the subject had to covertly generate either the list of months of the year or a sentence describing the cartoon. More detailed information about the task in [3].

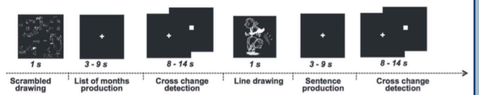

Figure 1. Illustration of the fMRI paradigm used for assessing language hemispheric lateralization.

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Language lateralization in early bilinguals

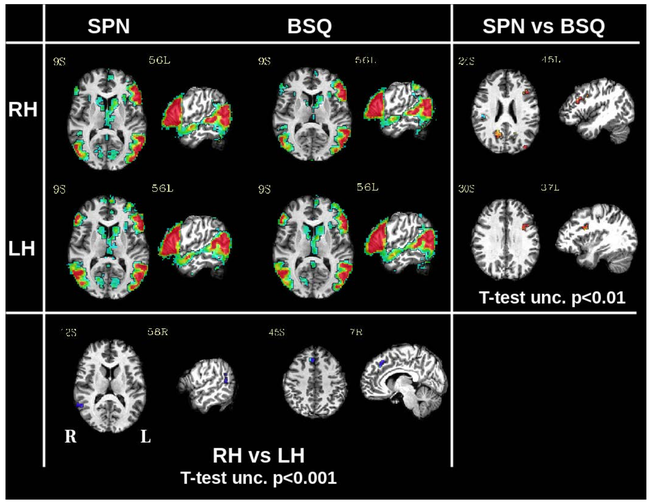


Figure 2. Brain activation pattern of language production versus recitation. Brain activation pattern is shown for left (LH) and right handed (RH) bilinguals in both languages, Spanish (SPN) and Basque (BSQ). A paired t-test was performed to study the differences among languages (right part of the figure) and two sample a t-test to study differences between LH and RH bilinguals (at the bottom).

1. Brain activation pattern of language production versus recitation is shown in **Fig. 2**. Most active areas are related with language, such as Broca and Wernicke areas, precuneus, middle and superior temporal gyrus and frontal gyrus.
2. No significant differences were found among languages neither among left and right handed bilinguals when comparing the brain activation pattern of language production versus recitation at the group level.
3. The distribution of LI scores shows more negative values in LH in comparison to RH, according to previous findings [3]. Early bilinguals show more ambilateral activation in comparison to monolinguals (see **Fig. 3**).

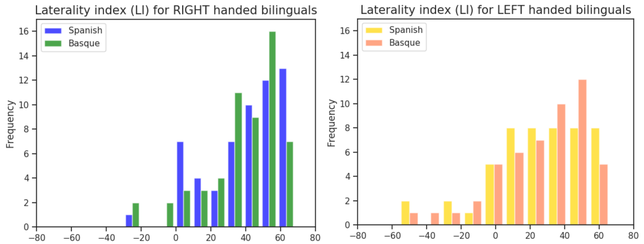
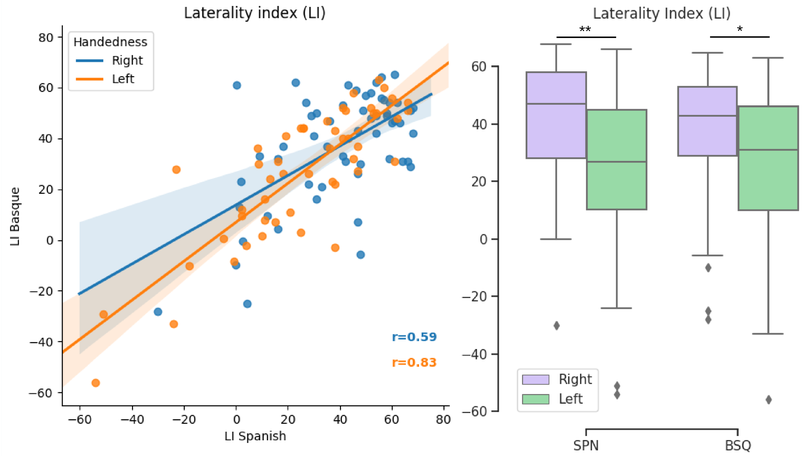


Figure 3. Distribution of LI scores in left and right handed bilinguals and for each language. Histograms with the distribution of the LI scores computed from the individual t-maps of sentence generation versus recitation contrast. A negative (positive) LI score means higher activation in the right (left) hemisphere. Values close to 0 means bilateral brain activation during the task.



4. Regression analysis show that some participants have different LI scores depending on the language. This result suggest that we have to carefully consider the linguistic competences of each individual. A higher correlation value was found between the LI index of Spanish and Basque in LH in comparison to RH (see **Fig. 4** - left).
5. Significant differences were found in the LI scores of RH versus LH bilinguals in Spanish (*p=0.003*) and in Basque (*p=0.024*) (see **Fig. 4** - right).
6. No significant differences were found among languages in LH (*p=0.654*) and RH (*p=0.261*) (see **Fig. 4** - right).

Figure 4. Statistical analysis of LI scores. On the left, linear regression analysis of LI in Basque and Spanish for RH and LH and their corresponding correlation values. On the right, boxplots of the comparison between RH and LH for each language. Significant differences were found between RH vs LH bilinguals for each particular language, but not among languages.

Methods

- fMRI data was preprocessed in AFNI as follows: (i) slice time correction; (ii) head motion realignment; (iii) normalization to MNI template; (iv) extraction of tissue-based masks (based on Freesurfer); (v) nuisance regression for data denoising [5, 6].
- The statistical parametric map of sentence generation versus recitation contrast was computed in AFNI.
- The hemispheric functional laterality index (LI) applied to the sentence generation versus recitation individual t-map was computed in SPM using the LI toolbox [7]. It is computed as follows:

$$LI = \frac{\sum \frac{activation_{left}}{mwf} - \sum activation_{right}}{\sum \frac{activation_{left}}{mwf} + \sum activation_{right}}$$

mwf = mask weighting factor

LI was computed with a bootstrap algorithm using the positive t-map, a lower bootstrap sample of 5 voxels and higher sample size of 1,000 voxels, and a resample ratio of k= 0.25. Values ranging between -100 and +100, with -100 being a purely right and +100 a purely left activation.

- LI was computed for each participant and language (LI-SPN and LI-BSQ).
- Statistical inference was performed at (i) the group level to evaluate differences in the brain activation maps of the LH versus RH bilinguals (two sample t-test) and among languages (paired t-test); and (ii) the individual level to study the differences in LI scores of LH versus RH bilinguals.

Take-home message

- Early biliguals show **more bilateral brain activation** than monolinguals in language related areas during covert speech production.
- Necessity of performing analyses at the level of **individual subjects** to investigate HS of language.
- Our study highlitghs the importance of considering **linguistic profiles** in determining HS in single subjects.

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