Journal of Language Research
ZABANPAZHUHI
Quarterly Scientific Journal of Language Research, Vol. 16, No.51, Summer 2024
Alzahra University, http://jlr.alzahra.ac.ir
Article Type: Research
pp.285-315

The contribution of Planum Temporale in Number-Person features processing in bilinguals: An fMRI study*

Simin Meykadeh[1], Werner Sommer[2]
Seyed Amir Hossein Batouli[3]

Received: 2023/07/09
Accepted: 2023/10/03

1. Introduction

The Planum Temporale (PT) is a cortical area posterior to Heschl's gyrus and within the Sylvian fissure. Hemispheric PT asymmetry of functional activation during hearing- or language-related tasks is well-established. Due to the role of the PT in language processing, we examined its contribution to phi-feature agreement processing.

The theory of phi-features (Ackema and Neeleman, 2018, 2019) has proposed two core hypotheses for Number and Person agreements. First, R-expressions do not have Person, while pronouns do. Second, all Persons have a Person feature. By contrast, singular is the absence of a Number feature. This account is based, among others, on the evidence reported by Zawiszewski, Santesteban and Laka (2016) and Mancini et al. (2017), which proposes two generalizations for fMRI activation when the verb carries incorrect agreement. In sentences with R-expressions as subject, Person behaves qualitatively differently from Number and will have a quantitatively larger effect. In sentences with pronouns as subject, there are no qualitative differences between Person and Number, but Person will have a quantitatively larger effect. Recently, Meykadeh et al. (in press) addressed the case where R-expressions and Pronouns were used as subject, respectively, for Number and Person Violations and showed that Number Violations evoked more effects than Person Violations in posterior Superior Temporal Gyrus. The authors suggested that R-expression and pronoun processing are qualitatively different. It is currently unknown whether this pattern is also true for the PT area. Hence, in the present analysis we investigated the contribution of PT to phi-features processing of L1 and L2 sentences.

---

* This research was supported by the Cognitive Sciences and Technologies Council (Grant no. 7401) awarded to S.M. It was also funded by a Doctoral Dissertation Grant from the Department of Linguistics, Tarbiat Modares University to S.M., and a Scholarship Fund (Ph.D. Visiting Scholar Program) from the Iranian Ministry of Science, Research and Technology to S.M.

[1] PhD in Linguistics, Department of Linguistics, Tarbiat Modares University, Tehran, Iran (corresponding author); a.meykadeh@modares.ac.ir
[2] Professor, Department of Psychology, Humboldt-Universität zu Berlin, Berlin, Germany, werner.sommer@cms.hu-berlin.de
[3] Assistant Professor, Department of Neuroscience and Addiction Studies, Tehran University of Medical Sciences, Tehran, Iran, batouli@sina.tums.ac.ir

The current study addresses the following questions:

1. To what extent is left and right PT involved in phi-features processing by balanced bilinguals?
2. How does the PT area contribute to L1-L2 Number-Person phi-features processing?
3. Is the PT area equipped with feature-mapping mechanism to identify Number and Person features?

To answer these questions, we adapted a bilingual task with an alternating language switching paradigm, in a population of balanced bilinguals and applied fMRI recordings.

2. Materials and methods

The participants were 36 balanced Turkish-Persian bilingual students, recruited primarily through university referrals. All participants were right-handed, highly proficient in both L1 and L2, had equal socioeconomic status and educational level, and reported normal hearing. All participants were native speakers of Turkish and learned Persian at school beginning at the age of seven. The language proficiency levels of the participants were assessed using behavioral measurements. According the Bilingual Dominance Scale (BDS), participants did not exhibit any significant difference between Turkish and Persian (i.e., between L1 and L2) in language dominance. The study was approved by the Research Ethical Committee of Iran University of Medical Sciences (IR.IUMS.REC.1398.465).

In total, 128 spoken sentences (50% in L1 and 50% in L2, with 50% violation per language) were used to assess processing of the phi-features. The materials per language contained 64 sentences, consisting of sixteen sentences for each of the following conditions: Number Correct, Person Correct, Number Violations and Person Violations. We used only R-expression for subjects in Number Violation and Number Correct conditions and Pronoun for subjects in Person Violation and Person Correct conditions.

All participants completed two behavioral and experimental sessions. Stimuli were presented via headphones using MATLAB's Psychtoolbox. During event-related fMRI recordings, they performed a Number/Person phi-features agreement judgement task, including four alternating rest and auditory sentence blocks. Each auditory sentence block consisted of 32 runs and was preceded and followed by 30-s resting periods during which no stimuli were presented, providing hemodynamic baseline data (318 s per block). Within each block correct and incorrect sentences were randomly intermixed, but language blocks alternated in a fixed sequence.

Data were acquired using a 3T Siemens Prisma MRI Scanner at NBML. Participants first underwent a 5-min, high resolution, T1-weighted gradient-echo anatomical MRI scan. The parameters for this scan were as follows: slice thickness = 1 mm, slice gap = 0 mm, TR = 1800 msec, TE = 3.53 msec, flip angle: 7°, voxel size: 1×1×1 mm, matrix size: 256×256, FOV: 256 mm^2. Participants underwent a 21.5-min fMRI scan that used a whole brain echo planar imaging (EPI) sequence (TE: 30 ms, TR: 3000 ms, flip angle: 90°, slice thickness: 3 mm, voxel size: 3×3×3 mm, matrix size: 64×64, FOV: 192 mm^2, slice gap: 0 mm) with a 20-channel head coil, 430 volumes and 45 axial slices per volume.

All fMRI data preprocessing was performed using FEAT in FSL. Preprocessing steps included motion correction, slice-timing correction, non-brain removal using BET, spatial smoothing (6 mm FWHM), normalization, temporal filtering (with

sigma = 50.0 s), and exploratory ICA-based data analysis. Statistical analyses of fMRI data were conducted using general linear modeling (GLM), as implemented in FSL. Z (Gaussianised T/F) statistic images were thresholded using clusters determined by $Z > 3.1$ and a (corrected) cluster significance threshold of $P < 0.05$. To detect the mechanisms underlying Number/Person phi-features agreement in bilateral PT, a whole-brain analysis was performed. Then, percent signal change (PSC) was extracted as an intensity measure for each participant from this brain region, using the Harvard-Oxford Atlas implemented in FSL. All statistical analyses were conducted in IBM SPSS Statistics 26.

3. Results

At the whole-brain level, relative to the baseline, there was strong activation in the left and right PT which is held to be involved in auditory language processing. A direct contrast between Violation and Correct conditions per feature, language type, and hemisphere in PT showed that in both L1 and L2 the Number Correct conditions activated the PT significantly more than the Number Violation conditions in each hemisphere. However, in both L1 and L2, the left hemisphere was reliably more sensitive to Number/Person features than the right hemisphere. A direct contrast was also performed between Number and Person Violations per hemisphere, as proposed by Mancini et al. (2017). Regardless of the language being processed, ROI-based results showed that Number Violation conditions generated more consistent activation than Person Violation conditions only in left PT. No difference was found in Number Violation > Person Violation contrast in the right homologue.

4. Conclusion

Our findings indicate that the left PT is more involved than the right hemisphere in processing the Number and Person agreement in bilinguals during a bilingual phi-features agreement judgment task. Moreover, our experiment showed that, regardless of the language being processed, sentences containing Number feature reliably triggered a greater activation in the PT as compared to sentences containing Person feature. This suggests distinguishable underlying processing mechanisms for R-expressions and pronouns in this brain region. Importantly, balanced bilinguals do not appear to differ in their auditory processing of Number and Person features.

Keywords: Turkish-Persian balanced bilinguals, Number-Person features, Planum Temporale, left hemisphere, fMRI