Source-resolved event-related potentials reveal differences in hemispheric recruitment for joke comprehension between left- and right-handers

Masaki Nakanishi[1], Haoyin Xu[1,2], Makoto Miyakoshi[1,3,4], Seana Coulson[2]

[1]Swartz Ctr for Computat. Neurosci., [2]Dept. of Cognitive Sci., Univ. of California San Diego, La Jolla, CA, USA
[3]Div. of Child and Adolescent Psychiatry, Cincinnati Children's Hosp. Med. Ctr, [4]Dept. of Psychiatry, Univ. of Cincinnati Col of Med, Cincinnati, OH, USA

Introduction

- Most people exhibit language lateralization to the left hemisphere although left-handers are less lateralized than right-handers [1].
- However, few studies have addressed the association between handedness and hemispheric asymmetry in high-level language processing such as joke comprehension [2].
- This study combines regression with the source-resolved event-related potential (ERP) technique to examine whether the amplitude of single-trial cortical ERPs elicited by the critical words in jokes and non-funny controls can be explained by condition, handedness, and/or statistical characteristics of the words.
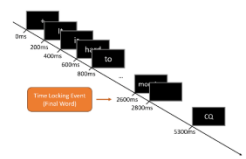
Materials

- 29-channel EEG data were recorded at the sampling rate of 250 Hz from 17 left- (22.69 ± 3.90 years) and 17 right-handers (21.75 ± 1.04 years) as they read one-line jokes and non-funny control stimuli [2].
- In total 240 sentences were used:
  - 80 **Jokes**: Low cloze funny ending
  - 80 **Straights**: Cloze-matched but non-funny ending
  - 80 **Expected**: Filler sentences with predictable ending

Condition	Example
Joke	It is hard to raise a family nowadays, especially in the **morning**
Straight	It is hard to raise a family nowadays, especially in the **country**
Expected	My green car blocked the narrow **driveway**

- The sentences were presented word-by-word to the subjects with inter-stimulus interval of 200 milliseconds.

- The predictability of the critical words in the joke and non-funny controls were measured using cloze probability and surprisal derived from the large language model.

Predictability measures

Cloze probability:
- The proportion of people who fill a gap in a sentence with a specific word.

Surprisal:
- A measure that reflects the predictability of a word given the preceding contexts.

$$S(\omega_i) = -\log P(\omega_i | \omega_1, \omega_2, \cdots \omega_{i-1})$$
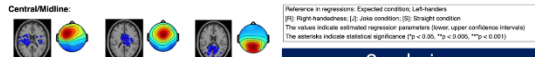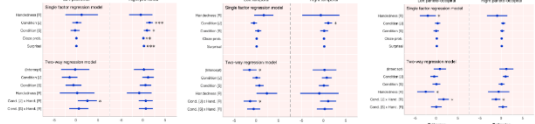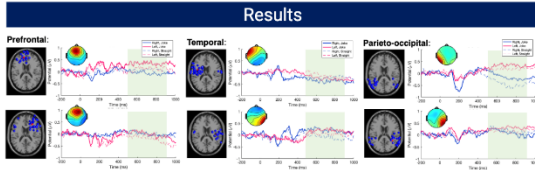
- Computed by the general pre-trained transformer 3 (GPT-3).

EEG preprocessing

- The EEG data were preprocessed using EEGLAB [3] as follows:

Import data
(n = 34, 64 channels, 256 Hz)

Remove and interpolate bad channels
(> 5-s flat line; high-frequency noise > 4SD)

Re-reference to average

Extract epochs time-locked to critical words
([-1, 2] s)

Remove bad trials
(PSD > 3SD)

ICA using *AMICA*

Fit equivalent current dipoles

ICLabel to classify ICs

Remove non-brain comp.
(r.v. > 15%; Brain probability < 70%)

K-means with Calinski Harabasz index to generate 14 clusters

Method

- The amplitude of single-trial ERPs of each cluster was measured by averaging across the time window of a language-related ERP component (500 – 900 ms) [4, 5].
- A series of linear mixed-effects models, which include handedness, condition (i.e., joke or control), and predictability measures as fixed effects and subject as a random intercept term, were constructed to predict the amplitude of the single-trial ERPs.

Results

Prefrontal:

Temporal:

Parieto-occipital:

Central/Midline:

Reference in regressions: Expected condition; Left-handers
[R] Right-handedness; [J] Joke condition; [S] Straight condition
The values indicate estimated regression parameters (lower, upper confidence intervals)
The asterisks indicate statistical significance (*p < 0.05, **p < 0.005, ***p < 0.001)

Conclusion

- The results suggest that the anterior sources were more sensitive to the contextual probability of words than the posterior sources.
- The left and right parietal sources showed significant interaction effects between handedness and condition, implying increased recruitment of the right hemisphere in left-handers.

References:
1. Rasmussen, T., and Milner, B. 1977. "The role of early left-brain injury in determining lateralization of cerebral speech functions." *Ann. N. Y. Acad. Sci.* 299: 355–69.
2. Coulson, S, and Christopher, L. 2004. "Handedness, hemispheric asymmetries, and joke comprehension." *Cogn. Brain Res.* 19 (3): 275–88.
3. Delorme, A., and Makeig, S. 2004. "EEGLAB: An Open-source toolbox for analysis of single-trial EEG dynamics including independent component analysis." *J. Neurosci. Methods* 134 (1): 9–21.
4. Coulson, S., and Kutas, M. 2001. "Getting it: Human event-related brain response to jokes in good and poor comprehenders." *Neurosci. Lett.* 316 (2): 71–74.
5. Nelson, C. A., P. F. Collins, and F. Torres. 1990. "The lateralization of language comprehension using event-related potentials." *Brain Cogn.* 14 (1): 92–112.