КОГНИТИВНАЯ НАУКА В МОСКВЕ

НОВЫЕ ИССЛЕДОВАНИЯ

МАТЕРИАЛЫ КОНФЕРЕНЦИИ 2017

ПОД РЕД. Е.В. ПЕЧЕНКОВОЙ, М.В. ФАЛИКМАН

УДК 159.9

ББК 81.002

К57

К57 Коллективный

Когнитивная наука в Москве: новые исследования. Материалы конференции 15 июня 2017 г.

Под ред. Е.В. Печенковой, М.В. Фаликман. – М.: ООО «Буки Веди», ИППиП. 2017 г. – 596 стр.

Электронная версия

ISBN 978-5-4465-1509-7

УДК 159.9

ББК 81.002

ISBN 978-5-4465-1509-7

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VISUAL WORD RECOGNITION DIFFERS IN SILENT READING AND VERB GENERATION TASKS: AN MEG STUDY

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Abstract. Previous studies showed that the brain response to a written word depends on whether the word is a target of a lexico-semantic task or is only read. Here we aimed to examine whether the task that uses the presented word not as the target but a cue to produce another word still modifies its recognition process. Using MEG and magnetic source imaging, we compared the spatio-temporal pattern of the brain responses elicited by a noun cue when it was read silently, either without an additional task (SR) or with a requirement to produce an associated verb (VG). We found that the task demands penetrated into early (200 – 300 ms) and late (500 – 800 ms) stages of written word processing by enhancing the brain response under the VG versus SR condition. The cortical sources of the early differential response were localized to the bilateral inferior occipito-temporal and anterior temporal cortices, suggesting elaborate orthographic and lexico-semantic analysis in the VG task. A late effect was observed in the middle and superior temporal gyri and the motor representation of articulators bilaterally and can be associated with enhanced sensorimotor transformations under the VG condition. Overall, our results suggest that written word processing depends on the task goal while intensified linguistic processing recruits bilaterally lateralized networks.

Keywords: visual word recognition, top-down modulations, sensorimotor transformation, speech lateralization, magnetoencephalography (MEG)

Visual word recognition is incorporated in various tasks, from covert reading to overt association production. Previous studies showed that a task's goal modulates the word recognition process. The brain's electrical or magnetic response to a written word differs from around 200 ms after word onset in reading and semantic categorization tasks (Strijkers et al., 2011), in reading and semantic decision

(Chen et al., 2013), and in reading and lexical decision tasks (Mahé, et al., 2015). However, the combination of reading with any lexico-semantic task increases word processing difficulty (compared to reading without a specific task); therefore, task effects can be confounded with unspecific attention influence. In the present study, we aimed to reduce the effect of attention directed to the presented word by implementing a verb generation task that does not require an immediate response to the word itself but uses it as a trigger for a subsequent memory search for a target verb. Using MEG and a distributed source estimation procedure, we compared brain responses elicited by silent reading of a visually presented noun either without any additional task (SR) or with a requirement to further produce an associated action verb (VG).

Method

Thirty-five volunteers (age range 20–48, mean age 26, 16 females) were visually presented with 130 Russian concrete nouns twice in two consecutive sessions. Within the silent reading session, the nouns were to be read inwardly. During the verb generation task, participants verbally answered a question: "What does this noun do?" MEG data were acquired using the dc-SQUID Neuromag™ Vector View system (Elekta-Neuromag, Helsinki, Finland) comprising 306 sensors. Vocal responses were recorded by means of an accelerometer located on the throat. The structural MRIs of 28 participants were acquired with a 1.5 T Philips Intera system.

The pipeline for MEG data analysis was created using SPM12 software (Wellcome Trust Centre for Neuroimaging, London). The raw sensor data were divided into epochs from −350 ms before to 1000 ms after the stimulus onset, baseline corrected over −350 to −50 prestimulus interval. The epoched trials were averaged within each task and subjected to paired *t*-tests. The resulting statistical parametric maps underwent a false discovery rate (FDR) correction for multiple comparisons with the cluster-level threshold at $p < .05$. The survived spatio-temporal clusters of SR-VG differences were used to guide the subsequent analysis in the source space.

The source reconstruction was performed by a "depth-weighted" linear L2-minimum norm estimation method embedded in Brainstorm software Coregistration with individual MRIs was done by means of FreeSurfer software (Martinos Center for Biomedical Imaging). The forward solution was computed using an overlapping spheres approach. A noise covariance matrix was calculated over a −250 to −150 baseline interval. The individual source maps were projected to the cortical surface of the Montreal Neurological Institute brain template (MNI-Colin27). Differences in source activation between verb generation and silent reading were tested via paired *t*-tests ($p < 0.05$, uncorrected) within the time windows defined by the sensor-level analysis.

Results

The average response time in the overt verb generation task was 1.56 sec ($SD = 0.2$). The evoked response to a written noun was stronger in the VG compared

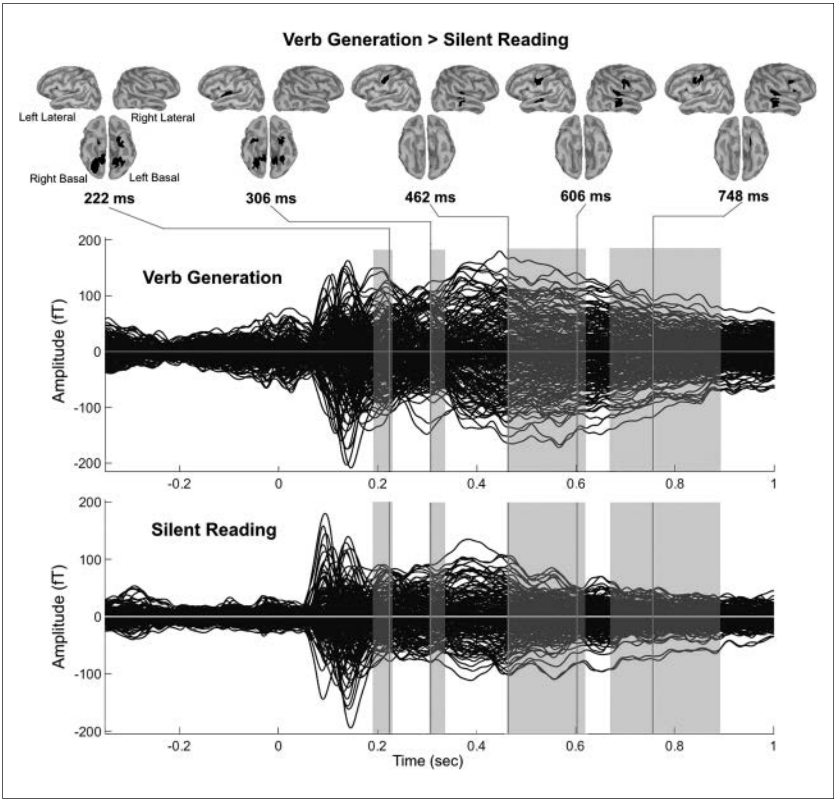

Figure 1. Brain responses to written nouns in verb generation (VG) and silent reading (SR) tasks. Upper panel: reconstructed cortical activation that displays greater response in the VG versus SR task. The time points correspond to the temporal peaks of significant sensor-level differences. Bottom panel: butterfly plots of MEG evoked waveforms from 306 MEG channels. The strength of the magnetic fields is represented in femto-Tesla (fT). Zero point denotes the onset of the noun cue. Shaded rectangles denote the time windows with significant a VG-SR difference.

to the SR task (see Fig. 1). The earliest task-related difference in response strength appeared at 191 – 227 ms, at the time window of the M200 component ($p < .0001$, FDR-corr.), and was localized to the basal surface of the left occipito-temporal cortex. The following cluster of differential responses emerged at 306 – 340 ms ($p < .0001$, FDR-corrected) and was localized in the anterior temporal pole and inferior occipito-temporal cortex bilaterally, and in the left transverse gyrus. At the late time windows — 462 – 619 and 676 – 891 ms ($p < .0001$, FDR-corrected) — the difference in the response engaged the right superior and middle temporal gyri and the ventral regions of the left precentral and postcentral gyri, with a maximum at 600 ms, when the differential activation spread to the homotopic areas in both hemispheres.

Discussion and Conclusions

Our data suggest that task demands penetrate into both early (200 – 300 ms) and late (500 – 800 ms) stages of written word processing. The first brain areas that showed an elevated response in the VG as compared to the SR condition were the inferior occipito-temporal cortex and anterior temporal region. The left inferior occipito-temporal cortex has been previously implicated in matching input letter strings with the orthographic forms stored in memory (Dehaene, Cohen, 2011). Our observation of increased activity in these regions and its right counterpart within the first 200 – 300 ms after word presentation suggests more elaborate visual form processing under the VG task. We speculate that a participant's need to further use the retrieved word information intensifies and deepens its visual processing.

Bilateral regions of the temporal pole have been assigned the role of a semantic hub linking word forms with distributed representations of the same word in different sensory modalities (Binney et al., 2010). The greater engagement of the temporal pole within the 200 – 300 ms window may promote lexico-semantic analysis in the VG task.

A late effect of task demand (500 – 800 ms) was observed in the lateral temporal regions and, to a lesser extent, in the ventral pericentral region. The long verb production time (1560 ms on average) precluded the possibility that the task effect in the sensorimotor cortex within the first 800 ms after its presentation was elicited merely by motor response preparation. Following a recent ECoG study (Cogan et al., 2014), we proposed that bilateral activation in the middle temporal gyrus, superior temporal gyrus, somatosensory, motor and premotor cortices at 500 – 800 ms post-word onset represents sub-vocal sensory-motor transformations, facilitating access to higher order language functions. Intriguingly, higher task demands in the VG task seem to increasingly recruit the right hemisphere networks in such a transformative activity.

Thus, our results show that the recruitment of neural resources at both early and late stages of written word processing depends on the final goal of the recognition process. Contrary to the models of a left-lateralized speech system, enhanced linguistic processing is shown to involve both hemispheres.

References

Binney R.J., Embleton K. V., Jefferies E., Parker G.J.M., Lambon Ralph M.A. The ventral and inferolateral aspects of the anterior temporal lobe are crucial in semantic memory: evidence from a novel direct comparison of distortion-corrected fMRI, rTMS, and semantic dementia // Cerebral Cortex. 2010. Vol. 20. No. 11. P. 2728 – 2738. doi:10.1093/cercor/bhq019

Chen Y., Davis M. H., Pulvermüller F., Hauk O. Task modulation of brain responses in visual word recognition as studied using EEG/MEG and fMRI // Frontiers in Human Neuroscience. 2013. Vol. 7. P. 376. doi:10.3389/fnhum.2013.00376

Cogan G. B., Thesen T., Carlson C., Doyle W., Devinsky O. andPesaran B. Sensory-motor transformations for speech occur bilaterally // Nature. 2014. Vol. 507. No. 7490. P. 94 – 98. doi:10.1038/nature12935

Dehaene S., Cohen L. The unique role of the visual word form area in reading // Trends in Cognitive Sciences. 2011. Vol. 15. No. 6. P. 254 – 262. doi:10.1016/j.tics.2011.04.003

Mahé G., Zesiger P., Laganaro M. Beyond the initial 140ms, lexical decision and reading aloud are different tasks: An ERP study with topographic analysis // NeuroImage. 2015. Vol. 122. P. 65 – 72. doi:10.1016/j.neuroimage.2015.07.080

Strijkers K. Early goal-directed top-down influences in the production of speech // Frontiers in Psychology. 2011. Vol. 2. P. 371. doi:10.3389/fpsyg.2011.00371

Особенности зрительного восприятия слова в задачах чтения про себя и генерации глагола: МЭГ исследование

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Аннотация. Предшествующие исследования показывают, что ответ мозга на печатное слово меняется в зависимости от того, стоит ли задача немедленно дать ответ о его лексико-семантических свойствах, или достаточно прочитать про себя. Используя магнитоэнцефалографию, мы исследовали влияние отставленного задания на активность мозга во время чтения слов, не являющихся непосредственными целевыми стимулами. Мы сравнили вызванные потенциалы, фазово-связанные с предъявлением существительного в двух задачах: чтении про себя и чтении про себя с последующим подбором подходящих по смыслу глаголов. Мы обнаружили, что задача генерации глагола усиливает ответ мозга как на ранних (200 – 300 мс), так и поздних этапах (500 – 800 мс) обработки печатного слова. Корковые источники ранних различий были локализованы в билатеральные зоны затылочно-височной коры, ответственные за распознавание графической формы слова, и в зоны височного полюса, предположительно связанные с лексико-семантическим анализом. Поздний эффект был обусловлен совместной активацией средней и верхней височных извилин и зон моторной проекции артикуляционных мышц обоих полушарий, по-видимому, отражающей процессы перекодирования фонологической информации в моторные коды слова. Таким образом, нейронные механизмы восприятия слова оказываются восприимчивы даже к отставленной во времени задаче, задействуя билатеральные сети в усиленной обработке лингвистической информации.

Ключевые слова: восприятие слова, нисходящие влияния на обработку зрительной информации контроль, сенсомоторное кодирование, латерализация речи, магнитная энцефалография (МЭГ)