A new fMRI language mapping paradigm in Russian

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Developing a reliable localization method of language-related brain regions is critical both for clinical practice and broader context of neurolinguistic research. Many noninvasive localization methods are based on functional magnetic resonance imaging (fMRI). However, it is crucial to develop an optimal linguistic paradigm which would allow to efficiently localize language-related areas. Typically, localizer paradigms use experimental and baseline conditions. Researchers compare activation in the brain elicited by the experimental task against the baseline to target the cognitive processes of interest.

This study presents a new fMRI localizer in Russian based upon current best practices. First, we use a sentence completion task that combines expressive and receptive language functions and, therefore, better identifies language-related areas than paradigms which focus on only one of these faculties (e.g., word generation or passive story listening tasks). Second, language faculty requires an interaction of multiple mechanisms on several levels including phonology, orthography, syntax, morphology and semantics (Middlebrooks et al., 2017). The design of our paradigm engages multiple linguistic processes, as words have to be combined into larger units to allow comprehension of the sentence and its completion with a plausible word. Third, we examined two active baselines to determine the better one. Previously, language localizer tasks were often contrasted against resting baselines. However, more selective contrasts tailored to the experimental conditions can better highlight higher-level language processes (Bradshaw et al., 2017).

18 right-handed healthy native speakers of Russian (MAge= 41, range 30–53; 14 females) participated in the study on two separate occasions. Each session consisted of two paradigms (15 min each) that always included reading sentences aloud and completing them with a plausible word as an experimental condition but differed with regard to the baseline. In the syllable (syll) baseline, participants read aloud and overtly repeated the visually presented syllable. In the pseudowords (ps) baseline, participants read aloud a string of pseudowords and were instructed to overtly repeat one of them. MRI data were acquired on a Siemens 3T scanner and processed using SPM12. The results show that our task allows to assess the hemispheric lateralization of language processing, with the following mean values of the lateralization index: 0.42 with syll and 0.45 with ps baseline in the crucial 1st session in the frontal-temporal-parietal (ftp) region. Values for separate lobes are provided in the Table 1 and are also comparable in both baseline conditions. We also investigated the reliability of our paradigm. Individual activation maps (FWE-corrected) from 2 sessions were compared using the Dice index, illustrating the degree of overlap in significantly activated voxels across two images. The mean Dice indices in the whole ftp region (0,49 – syll, 0,54 - ps) as well as in individual lobes did not differ between syll and ps baselines (see Table 1). Using the cutoff of min. 100 voxels to treat a region as activated, we argue that the paradigm elicits reliable activation in frontal language-related areas, especially in the triangular part of inferior frontal gyrus (1st session: syll – 15, ps – 18 participants), as well as in the temporal region, especially in the middle temporal gyrus (1st session: 17 participants in both syll and ps baselines). Percentage of participants showing activation in each region is presented in Table 2. The present data do not strongly favor syll or ps baselines. Group-level activation maps are presented in Figure 1 also showing strong activation in the frontal language-related regions with more activation in the ps baseline condition.

We argue that the proposed sentence completion paradigm efficiently engages multiple language processes and activates receptive and expressive language-related areas in individuals in a single task. Thus, the examined paradigm can be used in clinical environments with both baselines as a tool for the lateralization and mapping of functionally crucial brain areas. In clinical practice, though, syll baseline may be more advantageous as ps baseline appears more demanding for patients.

References

Bradshaw, A. R., Thompson, P. A., Wilson, A. C., Bishop, D. V. M., & Woodhead, Z. V. J. (2017). Measuring language lateralisation with different language tasks: A systematic review. *PeerJ*, *5*. https://doi.org/10.7717/peerj.3929

Middlebrooks, E. H., Yagmurlu, K., Szaflarski, J. P., Rahman, M., & Bozkurt, B. (2017). A contemporary framework of language processing in the human brain in the context of preoperative and intraoperative language mapping. *Neuroradiology*, *59*(1), 69–87. https://doi.org/10.1007/s00234-016-1772-0

Table 1. Lateralization indices (calculated using adaptive thresholding) and Dice overlap values between two sessions

		ftp	frontal	temporal	parietal
LI (1st session)	syll	0.42	0.46	0.41	0.25
	ps	0.45	0.5	0.44	0.3
Dice value	syll	0.49	0.46	0.45	0.29
	ps	0.54	0.5	0.48	0.45

Table 2. Percentage of participants with activated regions and the average number of activated voxels per region in the first and second experimental sessions (G. – gyrus, P. - Pars)

Percentage of participants with activated regions

		Inferior Frontal G.			Middle Temporal G.	Superior Temporal G.
		P opercularis	P orbitalis	P triangularis		
syll	1	55.56	66.67	83.33	94.44	27.78
	2	66.67	72.22	94.44	88.89	33.33
ps	1	66.67	72.22	100.00	94.44	16.67
	2	72.22	77.78	100.00	100.00	27.78

Averaged activation (number of voxels*)

syll	1	249	265	684	630	179
	2	325	335	988	818	249
ps	1	228	307	851	781	221
	2	256	361	974	869	174

*calculated using AAL3 toolbox (available at https://www.gin.cnrs.fr/en/tools/aal/)

Figure 1

Group-level activation maps with syllables and pseudowords as baseline conditions