Linguistics meets advanced neuroimaging methods to help optimize the navigation of brain surgeries around the language cortex

Functional magnetic resonance imaging (fMRI) is a non-invasive method that allows us to identify eloquent language areas in surgical candidates to minimize the risk of new language deficits after brain surgery (Benjamin et al. 2018). Language tests used during fMRI remain an underexplored research topic. Specifically, studies in preoperative language mapping have mainly focused on assessing language at the word level (Fernández Coello et al. 2013), failing to account for grammar processes (Rofes & Miceli 2014). Assessing grammar preoperatively has been demonstrated to be an effective way to localize language functions within the language-dominant hemisphere in surgical candidates (Połczyńska et al. 2017). However, based on clinical practice, we learned that the original grammar battery used in Połczyńska et al. (2017) required shortening for appropriate clinical use. The goal of this work was to create an optimized, shorter grammar battery for pre-surgical fMRI that maximally identifies the language network. We recruited 20 healthy right-handed individuals (10 females, mean age 41 years [SD=17.4]). All subjects performed ten fMRI tasks: three standard lexico-semantic tasks used as the gold standard (object naming, auditory, and visual responsive naming), seven tasks from the CYCLE-N fMRI battery (Połczyńska et al. 2017; Curtiss & Yamada 2013) and finally a resting-state fMRI. The CYCLE-N battery consisted of: (1) the comprehension and (2) production of active and passive voice, (3) the comprehension and (4) production of relativized subject and object relative clauses, (5) the comprehension and (6) production of inflectional morphology (past tense marking), and (7) the comprehension of "wh"-subject and object questions. We selected 12 language regions of interest (ROIs) in the left hemisphere. To reduce the number of necessary tasks to draw from the CYCLE-N, we assessed which tasks produced the least signal percent change in every ROI using one-way ANOVA. The ROIs were also used to derive a language network from resting-state and task-based fMRI. We calculated global (e.g., modularity), and local (clustering coefficient) Graph Theory metrics (Monti et al. 2013). The analyses allowed us to remove three grammar tasks from the CYCLE-N battery for our objectives. First, the task evaluating the comprehension of active and passive voice produced lower percent signal change than all the other grammar tasks and two of the standard tasks ($p<0.05$, Bonferroni corrected). Based on the metric correlation using Graph Theory (modularity and small worldness), we found a high task-based correlation within the language ROIs ($r \geq 0.7$) between the following grammar tasks: 1 and 2, 1 and 6, and 7 and 6. Further, among all the language tasks (including the standard tasks), task 6 displayed the highest correlation with the resting-state fMRI language network (modularity; $r=0.6$). We thus kept this task and removed the two tasks that highly correlated with it (i.e., task 1, 2 and 7). Finally, comparisons between the three removed CYCLE-N tasks, and the four remaining tasks showed that the former tasks generated significantly lower percent signal change than the latter tasks ($t(19)=-2.8$, $p=0.04$). In sum, we optimized grammar tasks for preoperative fMRI in a group of healthy volunteers.

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