Comparison between event-related and block-periodic fMRI data from a story processing task in children

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Introduction

The ability to process an aurally-presented story is supported by a specific network of auditory and language-processing brain regions that changes during development. Multiple aspects of language processing are engaged during this naturalistic speech task, including speech perception, word recognition, syntactic processing and discourse coherence.

Our previous fMRI studies (Karunanayaka et al 2007) have examined this network in children, using a block-periodic (BP) design contrasting short stories with tone sequences. The present study compares the BP story paradigm to an event-related (ER) version that includes on-line performance monitoring and a sparse acquisition paradigm that eliminates scanner noise during auditory presentation.

Method

Participants

19 children ages 11-13 (8 females), native speakers of English, no history of neurological or language disorders.

Procedure

Participants completed two versions of a story processing task during fMRI scanning.

Block-Periodic Design:

5 cycles of aurally-presented, 10-sentence stories (30 seconds each) followed by 30 seconds of random tones. Participants completed comprehension questions after the fMRI scan.

Event-Related Design:

• two sentences presented during a 5s no-scan interval
  • 6-second data acquisition.
  • question during another 5s no-scan interval and another acquisition period;
  • 5s of random tones (with no scanning) and an additional acquisition period
  • 15 cycles x 36 seconds/cycle
  • Scanning was performed on a 3T Bruker MRI scanner (fMRI parameters: 32 axial planes, TR = 2 sec, flip angle = 77.6 degrees).

Data Analysis

A general linear model was used to identify voxels activated in each story processing task (relative to tone listening) for each participant.

• Laterality indices (LIs) were calculated in 2 functionally-defined regions of interest (ROIs) designed based on the intersection of block-periodic and event-related areas of activation:
  • One ROI included activated voxels in the left inferior frontal gyrus (LIFG)
  • The second ROI included activated voxels in the left inferior, middle and superior temporal gyri.

• These ROI’s, defined in the left hemisphere, were mirrored onto the right hemisphere for purposes of laterality calculation.

• Voxels above the median value in each ROI were counted for each participant, and LI was defined as:
  • the difference in the number of activated voxels between left and right ROIs, divided by the sum of active voxels in the left and right ROIs.
  • This yields Lis ranging from -1 (right) to 1 (left).

Results

Event-Related Task Design:

<table>
<thead>
<tr>
<th>Auditory</th>
<th>Frontal</th>
<th>Temporal</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL task 18</td>
<td>2.21, p&lt;0.05</td>
<td>AR task 18 = 3.38, p&lt;0.01</td>
</tr>
</tbody>
</table>

Both paradigms evoked consistent left-lateralized activation:

•增加了 activation in DLPFC during the ER task was due to cognitive strategic aspects of the two tasks.

• Increased activation in DLPFC during the ER task was likely associated with maintenance of sentence segments in working memory across acquisition intervals in order to construct the complete story (Smith et al., 1998; Mason and Just 2004) and semantic retrieval which may be more actively engaged when comprehension questions are included in the task.

• Activation in cingulate cortex during the ER task may relate to increased attention during the segmented stories (Hahn et al., 2008), as well as error/performance monitoring in response to interspersed questions (Botvinick et al 2004).

• The two versions of the story processing task did not differ in their degree of left-lateralization in specific frontal and temporal lobe language processing areas.

• The ER task showed a significantly larger effect size in the frontal ROI only, and may be a more effective method for eliciting activation in this region. This may also be due to cognitive strategic factors.

Conclusions

• Both BP and ER story processing paradigms are effective methods for activating eloquent cortex in children.

• For children that are able to perform the ER task, mapping this more extensive network may be beneficial, along with increasing effect size in LIFG.

• A passive story listening task also reveals brain regions involved in language processing, producing the same degree of lateralization and an equally large effect size in the temporal language area.

• This suggests that the lateralization pattern and corresponding LI derived from the passive story listening paradigm when no responses are recorded is accurate.

Acknowledgements

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Effect Size Analysis: Results

The ER task showed a larger effect in the frontal ROI than the BP task \((t(18) = 3.39, p<0.05)\). The two tasks did not differ in effect size the temporal ROI \((p>3)\).

Discussion

• Activation differences observed between block-periodic and event-related versions of a story processing task are likely due to cognitive strategic aspects of the two tasks.

• Increased activation in DLPFC during the ER task was likely associated with maintenance of sentence segments in working memory across acquisition intervals in order to construct the complete story (Smith et al., 1998; Mason and Just 2004) and semantic retrieval which may be more actively engaged when comprehension questions are included in the task.

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