Introduction
In light of the debate on neural modularity of cognitive domains, we used fMRI to investigate neural activation levels associated with high-load processing in different domains.
• **Language (Syntax):** garden-path (vs non-GP), noncanonical (object-cleft vs subject-cleft) and ungrammatical sentences.
• **Music:** ‘deceptive’ chord sequences (including a low-probability chord) and anomalous sequences (including a discord), compared to harmonious chord sequences.
• **General cognitive control:** Stroop task, incongruent vs congruent.

To the extent that cognitive load in language and music relies on shared neural substrates for qualitatively similar processes, the garden-path contrast was expected to show overlap with the deceptive musical contrast, while sentence-ungrammaticality should reveal overlap with musical anomaly. Activation patterns within Inferior Frontal Gyrus were of specific interest, due to the association of IFG with syntactic processing as well as general cognitive control.

• Analyses: 1) whole-brain classic subtraction; 2) ROI analyses on bilateral IFG; 3) Network analysis (see Fedorenko & Thompson-Schill, 2014)

Methods
Participants: 20 Speakers of English (12 females; mean age 22.5)

**Language task:** Auditory picture verification. Five sentence types (40 per condition): garden-path, late-closure, object-cleft, subject-cleft and ungrammatical. Valid data for 18 subjects.

**Music task:** 8-chord piano sequences (35 trials each): harmonious, deceptive and anomalous. Participants responded by button press to a tub sound inserted in 15 trials. Valid data for 20 subjects.

**Cognitive Control:** Stroop task, participants responded by button press to the color of a visually presented color word, with a choice of red, green, yellow and blue, congruent or incongruent with the presentation color (40 trials each). Valid data for 18 subjects.

**fMRI Analysis:** For the language and Stroop tasks, erroneous responses modeled separately and trial-specific RTs entered as regressors. For music, response stimuli (tuba) modeled separately. Language and music contrasts tested in one-way repeated-measures ANOVAs. Stroop contrasts examined with paired t-test. In addition to whole-brain analyses, we performed ROI analyses in bilateral IFG.

**Network analyses:** For contrasts of interest, subject-specific (n=16) average beta-values extracted from 12 bilateral regions-of-interest (5mm radius). Regions selected based on their hypothesized role in language processing and/or cognitive control. In principle, full functional connectivity was assumed between the 24 nodes of the resulting network (see Figure 1).

Results: Behavioral
• **Music:** Participants’ ratings of music trials from the three conditions (outside of the scanner; 10 trials per condition) shows they are sensitive to the musical anomaly manipulation (F(1,26)=21.85; p<.001).

• **Language (Syntax):** Main effects of condition: RTs (F(1,50)=10.39; p<.005). GP>NGP > Ungramm > OCS; Accuracy (F(1,50)=31.71; p<.002). OCS>Ungramm > GP>NGP (95%–100%).

• **Stroop:** Average accuracy: 91.12% (SD 5.60; 70.64–99.17)

Results: Network Analyses

**Methods**
**Network analyses (continued)**

<table>
<thead>
<tr>
<th>Region</th>
<th>Network</th>
<th>ROC</th>
<th>T statistic</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior Cingulate Cortex (ACC)</td>
<td>1-2, 14, 46</td>
<td>0.9</td>
<td>1.05</td>
<td>0.005</td>
</tr>
<tr>
<td>Anterior insula</td>
<td>2-4</td>
<td>0.9</td>
<td>1.05</td>
<td>0.005</td>
</tr>
<tr>
<td>Anterior IFG</td>
<td>3-4, 46</td>
<td>0.9</td>
<td>1.05</td>
<td>0.005</td>
</tr>
</tbody>
</table>

Subtraction contrasts: multiple correlations to investigate functional connectivity specific to high cognitive load in different cognitive domains ➝ maps thresholded at p<.00018 (Bonf. corr.)

• Main effects: multiple correlations to compare network activity across domains and high-load conditions (unthresholded)

• Fischer’s r to z transform:

• Matrices vectorized

• paired t-tests and paired correlations between networks (p<.00033, Bonf. corr.)

• Calculation of RV coefficient for each network (matrix) comparison

Results: Network Analyses

**Visual comparisons:** Thresholded network maps (Figure 5) suggest functional connectivity associated with the high-load vs. lower-load contrasts varies between domains, with high levels of interhemispheric functional connectivity in general.

• Unthresholded patterns for main FX (Figure 6) suggest greater similarity between Stroop and Music than between Music and Syntax.

• Pairwise comparisons:

• Paired t-tests: networks are largely different, even within domains.

• Paired correlations: networks are similar, even between domains.

• Ranking by RV coefficients: largely in line with hypotheses, with greatest similarity within modules (dark blue), followed by similarity between Deceptive Music ↔ Stroop and Garden-Paths ↔ Stroop.

• Except: Decept. Music more similar to Ungramm. Syntax than to GPs.

Discussion & Conclusions
Evidence suggestive of both shared and unique neural substrates:

• Within LH IFG, the high-load contrasts between domains and conditions overlap only minimally, with general cognitive control associated with activation anterior and posterior to the thresholded activation clusters associated with OCS and GP>NGP.

• The activation patterns within our hypothetical full-connectivity network differ between domains (and conditions) wrt strength of between-node correlations (paired t-tests), but are very similar wrt the patterns of between-node correlations (paired correlations).


Thanks: Grigory Younganov and Eve Bayram