



Task Difficulty Modulates Brain-Behavior Correlations in Language Production and Cognitive Control:

Behavioral and fMRI Evidence from a Phonological Go – No-Go Picture Naming Paradigm

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Introduction

- Language production involves a left-lateralized frontal-temporal-parietal brain network (Geranmayeh et al., 2012; 2014; Price, 2010; Binder et al., 2009; Visser et al., 2010; Mirman et al., 2015; Hickok & Poeppel, 2007; Indefrey & Levelt, 2000; 2004; Poldrack et al., 1999; 2001).
- Inhibitory control involves a right-lateralized fronto-parietal network (Simmonds et al., 2008; MacDonald et al., 2000; Criaud & Boulinguez, 2013).
- The interaction between language production and inhibitory control and its neuroanatomic bases has received little attention.
 - Research has shown that manipulating executive demands modulated brain activation during language processing (Kan & Thompson-Schill, 2004; Novick et al., 2010; Schnur et al., 2009; Peramunage et al., 2011).
 - Phonological Go – No-Go picture naming paradigm (Rodriguez-Fornells et al., 2002; Van Turenout et al., 1997; Schmitt et al., 2000).

The Present Study

Question

- How do different levels of inhibitory control demands affect language production?
 - Behavioral performance
 - Brain activation
 - Brain-Behavior correlations

Predictions

- Increases in difficulty will elicit poorer behavioral performance and increased activation in regions associated with language production.
- Brain-Behavior correlations will change as a function of task difficulty.

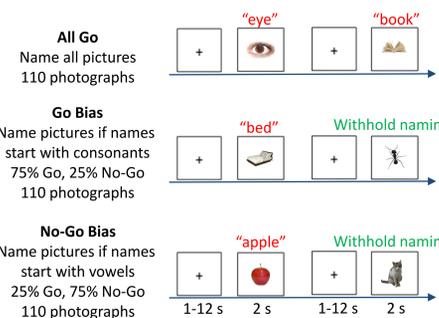
Methods

Participants

| | Mean (SD) |
|------------------------------------|-----------------|
| Demographic information | |
| N | 20 |
| Age | 22.65 (4.3) |
| Gender (M/F) | 10/10 |
| Education (Years) | 16.1 (2.36) |
| Neuropsychological testing | |
| MMSE (Score Out of 30) | 29.05 (1) |
| Vocabulary (Total # of Tokens) | 49.8 (9.6) |
| Verbal Fluency (Total # of Tokens) | 56.95 (18.67) |
| Author Recognition (Total Score) | 13.1 (8.64) |
| Magazine Recognition (Total Score) | 12.7 (7.76) |
| Immediate Recall (Total Score) | 11.25 (2.15) |
| Delayed Recall (Total Score) | 10 (2.29) |
| Simple Speed (ms) | 253.44 (27.25) |
| Digit Span Forward (# of Tokens) | 7 (0.92) |
| Digit Symbol (ms) | 1298.83 (156.4) |
| Executive Functions | |
| AX-CPT: AY RT (ms) | 386.03 (47.71) |
| AX-CPT: AY ER | 0.27 (0.20) |
| Stroop Effect (ms) | 16.98 (70.28) |
| Task Switching Cost (ms) | 56.33 (73.03) |

Tasks

Phonological Go – No-Go Picture Naming



Go Trials: Naming difficulty increases from All Go condition to No-Go Bias condition.

No-Go Trials: Inhibition Demand increases from No-Go Bias condition to Go Bias condition.

fMRI Task Parameters

MRI data were collected on a 3T Siemens Prisma Fit MRI scanner with a 20-channel head coil.

| | TR (ms) | TE (ms) | FOV (mm ²) |
|-------------------|---------|---------|------------------------|
| Structural Images | 2300 | 2.28 | 256 |
| Functional Images | 2500 | 25 | 240 |

Results

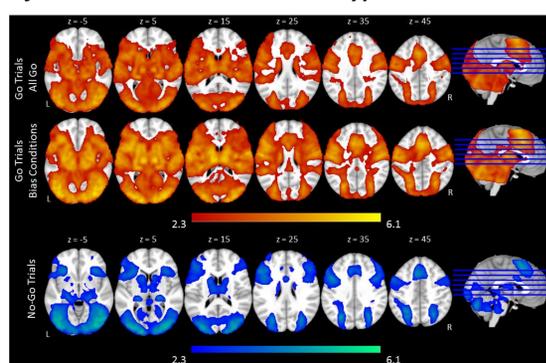
Behavioral Results

| | Overall Error Rate | Incorrect Response Rate | Commission Error Rate | Omission Error Rate | Reaction Time (ms) |
|------------|--------------------|-------------------------|-----------------------|---------------------|--------------------|
| All Go | 6.7 % (4.1 %) | 3.0 % (3.1 %) | — | 3.7 % (3.0 %) | 1217 (114) |
| Go Bias | 4.9 % (3.5 %) * | 2.5 % (1.5 %) | 4.1 % (4.1 %) *** | 1.9 % (2.6 %) ** | 1269 (119) *** |
| No-Go Bias | 4.6 % (2.7 %) | 2.6 % (2.0 %) | 0.5 % (1.1 %) | 6.4 % (6.1 %) | 1430 (150) |

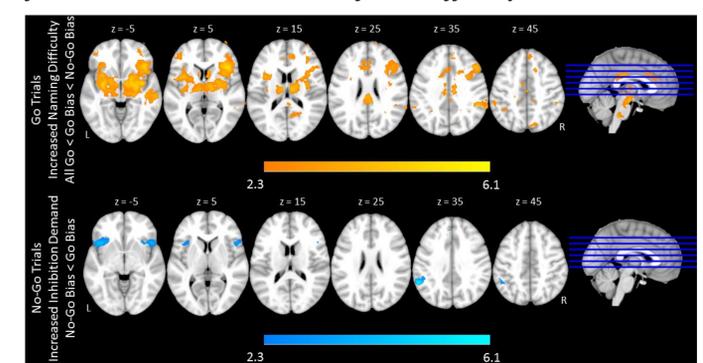
Values provided are means, with standard deviations in parentheses. **Overall Error Rate** = Total number of errors/Total number of trials, **Incorrect Response Rate** = Number of incorrect responses/Total number of trials, **Commission Error Rate** = Number of commission errors/Number of No-Go trials, **Omission Error Rate** = Number of omission errors/Number of Go trials. Because the denominator for each error rate is different, the overall error rate does not equal to the sum of three types of error rates.

- Go trials: The No-Go Bias condition elicited longer reaction times than the Go Bias condition and the All Go condition, suggesting that the No-Go Bias condition was the most difficult and had the highest language production demands.
- No-Go trials: The Go Bias condition elicited higher commission error rates than the No-Go Bias condition, suggesting that inhibition demands were higher during the Go Bias condition.

fMRI Activation to Basic Trial Types



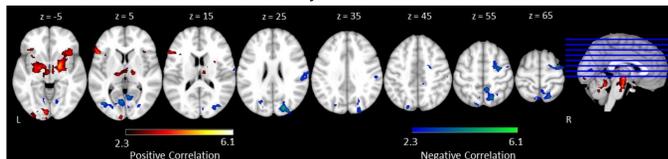
fMRI Activation as a Function of Task Difficulty



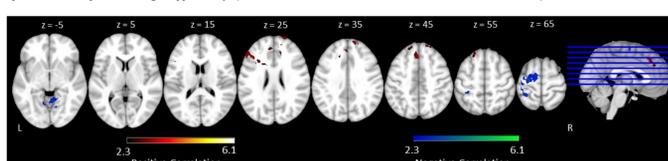
Brain-Behavior Correlation

Go Trials

Correlation between reaction time and fMRI activation across all Go trials

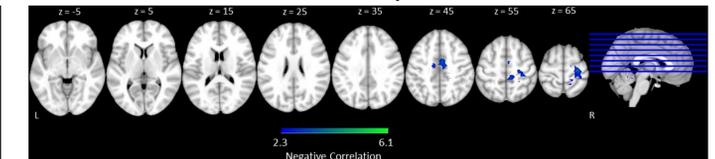


Correlation between changes in reaction time and changes in fMRI activation as a function of naming difficulty (Go trials: All Go < Go Bias < No-Go Bias)



No-Go Trials

Correlation between commission error rate and fMRI activation across all No-Go trials



- Go trials:
 - The No-Go Bias condition elicited greater activation than the All Go condition.
 - Individuals with faster RTs had more activation in regions such as right precentral and postcentral gyri, right superior frontal gyrus and right supramarginal gyrus.
 - Smaller increases in RTs correlated with larger increases in activation as a function of naming difficulty in regions such as left precentral and postcentral gyri.
- No-Go trials:
 - The Go Bias condition elicited greater activation than the No-Go Bias condition.
 - Individuals with lower commission error rates had more activation in regions such as right precentral and postcentral gyri extending to the right anterior cingulate gyrus, right supplementary motor cortex.

Discussion & Conclusions

- Increases in difficulty in both language production and inhibition elicited increases in brain activity and declines in behavioral performance.
- The greater involvement of sensory-motor regions such as right precentral and postcentral gyri and inhibitory control regions such as right superior frontal gyrus, right supramarginal gyrus and right anterior cingulate gyrus were associated with smaller declines in behavioral performance as task demands increased, for both naming trials and inhibition trials.
 - These regions are beneficial for maintaining behavioral performance.
- This study highlights the interplay of language production and inhibitory control.

References & Acknowledgments

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