Differences of Functional Connectivity Associated with Response and Numerical Magnitude Conflict

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Abstract

One goal of cognitive neuroscience is to understand neural mechanisms involved in cognitive control. A task often used in the study of cognitive control is the size congruency task, which employs two forms of conflict: response conflict and numerical magnitude conflict. Past research suggests that detection of response conflict by the anterior cingulate cortex (ACC) is involved in recruiting cognitive control via functional connectivity with the dorsolateral prefrontal cortex (dlPFC). What remains to be seen is if the two forms of conflict engage the same neural network or by two different networks. This thesis will attempt to answer this question by employing a psychophysiological interaction (PPI) analysis to compare changes of functional connectivity within participants performing the size congruency task.

Introduction

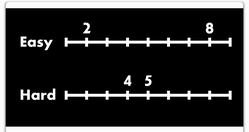
Size Congruency Task is frequently used to assess cognitive control and conflict processing.

- Individuals are presented with two digits (1 - 9) of different values and sizes, and must select the numerically larger digit, regardless of physical size. Trials may be *Congruent* (numerically larger digit is physically larger), or *Incongruent* (numerically larger digit is physically smaller).

Fig. 1: Two trial types.

2 forms of conflict

Response conflict:
Encountered only on incongruent trials, the individuals are primed by two mutually-exclusive sources of information; numerical value and physical size.



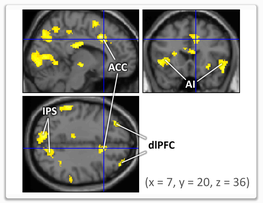
Numerical magnitude conflict:
Can be encountered on either congruent or incongruent trials.
Easier to tell numbers apart when they are far from each other than when they are closer in value.

Neural Processing of Response Conflict

Dorsolateral Prefrontal Cortex (dlPFC)
Anterior Cingulate Cortex (ACC)
Anterior Insula (AI)

Neural Processing of Numerical Magnitude Conflict

Intraparietal Sulcus (IPS)



Functional Connectivity

- When two regions covary with each other in their activation, the regions are said to have functional connectivity.
- Cortical networks establish functional connectivity between brain regions in order to complete a certain process (e.g., the Size Congruency Task).
  - For example, the ACC engages in functional connectivity with the dlPFC in order to resolve response conflict (Kerns et al., 2004).

Research Question

Are dynamic changes in functional connectivity associated with response conflict to comparable to those associated with magnitude conflict?

Methods

This thesis will analyze data from a previous study by Wilk et al. (2011).

Participants

- 26 right-handed individuals (12 male)
- Age: 21 - 35

Imaging

- 3T Siemens
- 36 slices
- TR = 2s, 743 volumes per run
- Motion constrained to 2mm

Task

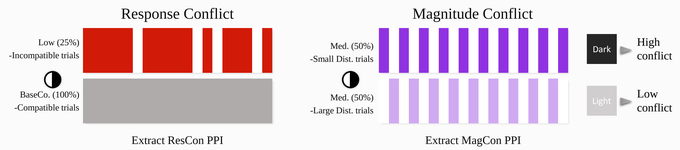
- Task given in 3 block conditions varying in congruency:
  Low (25%), Medium (50%), High (75%),
  & Base Co. (100%).
- 24 blocks per run (separated by 10s), 16 trials per block
- 2 runs each subject, each lasting 18 minutes.
- Short distance = 1-4
  Long distance = 5-8

- Note: for the data analyses, blocks will be collapsed and treated as individual trials

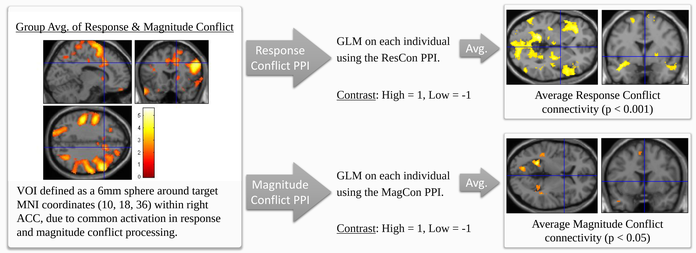
Two digits differing in physical size and numerical magnitude were presented. Trials were administered as three 16-trial blocks, which could be 25%, 50%, 75%, or 100% compatible.

Analysis

- Data preprocessing
  - Data were preprocessed in SPM8; 3D motion-corrected, linear trend removal, spatial smoothing with 8 mm Gaussian kernel
- GLM:



- Psychophysiological Interaction (PPI)



Avg. Response Conflict – Avg. Magnitude Conflict = Functional connectivity when Response > Magnitude Conflict

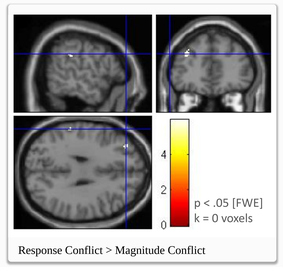
Avg. Magnitude Conflict – Avg. Response Conflict = Functional connectivity when Magnitude > Response Conflict

References

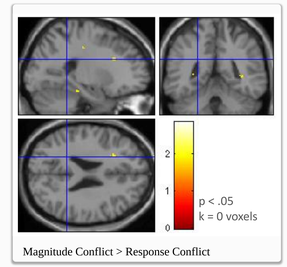
Kerns, J. G., Cohen, J. D., MacDonald III, A. W., Cho, R. Y., Stenger, V. A., & Carter, C. S. (2004). Anterior cingulate conflict monitoring and adjustments in control. *Science, 303*, 1023-1026.

Wilk, H. A., Ezekiel, F., & Morton, J. B. (2011). Brain regions associated with moment-to-moment adjustments in control and stable task-set maintenance. *NeuroImage, 59*, 1960-1967.

Results



Response Conflict > Magnitude Conflict



Magnitude Conflict > Response Conflict

Region	BA	Hemisphere	X	Y	Z	Peak voxel stat.
Response Conflict > Magnitude Conflict (p < 0.05, FWE)						
Dorsolateral prefrontal cortex	46	L	-36	40	36	t(42) = 5.95
Supramarginal gyrus (SMG)	40	L	-58	-33	28	t(42) = 5.75
Magnitude Conflict > Response Conflict (p < 0.05)						
Inferior frontal gyrus (IFG)		L	-28	22	28	t(42) = 2.05
Cuneus (Cu)	17	L	-28	-46	6	t(42) = 1.84
	17	R	34	-46	2	t(42) = 1.96
Middle frontal gyrus (MFG)		R	22	-6	40	t(42) = 2.61
		R	22	-10	42	t(42) = 2.18
		R	20	-2	36	t(42) = 2.13
Postcentral gyrus (pre-CG)	1/3	L	-28	-22	44	t(42) = 1.92
Precentral gyrus (post-CG)	4	L	-8	-22	64	t(42) = 1.82

X, Y, and Z are MNI coordinates of peak voxels at each region

Discussion

- *Research question*: Found dynamic changes in functional connectivity associated with response conflict, compared to those associated with magnitude conflict.

Response Conflict

- dlPFC: May be due to the greater demands on cognitive control (inhibiting prepotent response; overcoming tendency to select physically larger number; supressing more salient stimulus features- i.e., size; re-evaluating numerical values of stimuli; etc.).
  This may also be related to the greater saliency of visual size, and the ACCs role in salience processing.
- SMG: Probably to supress irrelevant task information (i.e., physical size)

Magnitude Conflict

- Cu: Possibly due to greater uncertainty when comparing number stimuli of small numerical distance. Cu has been found to be involved in processing uncertainty in visual discrimination, as well as character reading. ACC may top-down regulate Cu to resolve uncertainty.