A functional and structural connectivity view of switching dynamics in aging

Pauline Baniqued
Beckman Institute & Department of Psychology
Approach

Control processes involve brain networks
functional phenomena in grey matter
structural changes in white matter

Age-related changes in behavioral control and brain structure
Why is this important?

Everyday we switch between tasks
  • several paradigms to study task-switching
Switching experiment

Trial n

CUE
H: respond with hand
V: respond with voice

Trial n+1

REACTION STIMULUS
L: respond left
R: respond right
Why is this important?

Everyday we switch between tasks

There are **costs** to switching

- More errors, slower responses
- Even when given time to prepare

There is evidence we can be **more efficient**

- given cue, optimize preparatory period
- recruitment of frontal and parietal regions
Coactivation led to FPN “network”

Important for **controlling** attention in a wide array of tasks

How do these FPN-dependent control processes interact with regions that carry out the task?

*Corbetta & Shulman, 2002; Hopfinger, Buonocore, Mangun, 2000; Weissman, Warner, Woldorff, 2004; Gratton, Low, & Fabiani, 2008; Baniqued, Low, Fabiani & Gratton, 2013*
Spatiotemporal dynamics of preparation

Lagged cross-correlations
- “functional connectivity” with timing info
- LAGS, relative order of activation
- Can detect patterns of activity with different onsets

Rykhlevskaia, Fabiani & Gratton, 2006
Event-related optical signal (EROS)

- Measures changes in **optical scattering** in neural tissue (active vs. rest)
- Reaches ~3cm below scalp
- Spatial resolution ~5 mm
- Temporal resolution ~10 ms
- Recorded concurrently with **event-related potentials (ERPs)**, which measure scalp voltage changes due to neural activity

Gratton & Fabiani, 2010
Modality Switching Experiment

YOUNG ADULTS, N=15, 4 runs of 20 blocks with 24 trials each

Bimodal Precue
H: respond with hand
V: respond with voice
400 ms

Preparatory Period
Interaction of frontal control and modality-specific* mechanisms

Reaction Stimulus
Visual or Auditory
L: respond left
R: respond right
400 ms

*well-characterized response regions
Greater Frontal & Parietal Activity for Switch vs Repeat Trials

230 ms
Switch Main Effect:
Switch > Repeat

358 ms
Switch Main Effect:
Switch > Repeat

Baniqued, Low, Fabiani & Gratton, JoCN 2013
Switch-related frontal activity predicts task-specific **downregulation** and **upregulation**

Baniqued, Low, Fabiani & Gratton, 2013
Switch-related frontal activity predicts task-specific downregulation and upregulation

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Part 1 Summary: Connectivity in young adults

- **Connectivity** between frontal control areas and task-specific regions (e.g., motor areas) is important for preparation, especially in more demanding switch trials.

- **Frontal activity** predicted downregulation of task-irrelevant processes then upregulation of task-relevant processes.

- **QUESTION:** What happens in older age, when frontal and parietal areas undergo age-related decline?
Spatial Stroop: Switching task sensitive to age, highly involves frontal regions

Older adult participants (aged 55-85), n=40

Gratton et al., 2009
Spatial Stroop Switching task

Trial n

M + M

CUE
M: MEANING
P: POSITION

Trial n+1

P + P

Preparatory Period
Interaction of frontal control and modality-specific mechanisms

BELOW +

REACTION STIMULUS
ABOVE BELOW

BELOW +
Switch-related frontal negativity, important for behavior?

55-67 yrs

68-85 yrs

F3

μv

μv

Meaning

SWITCH

REPEAT

Position

time in milliseconds, time-locked to precue
Switch-related activation in **left frontal cortex** during preparatory period predicts smaller switch costs

**ERP:** greater F3 negativity, smaller costs

$r = .479, p = .007$

$r_p = .455, p = .013$

$r = .439, p = .015$

$r_p = .512, p = .005$
Switch-related activation in **left MFG** during preparatory period predicts smaller switch costs.

**ERP:** greater F3 negativity, smaller costs.

**EROS**

**SWITCH > REPEAT**

at 384 ms
Cross-correlations: **Left middle frontal gyrus** predicts task-specific activations

- **Meaning**
  - Lag: 0 ms
  - Lag: 230 ms
  - Lag: 256 ms

- **Position**
  - Lag: 0 ms
  - Lag: 153 ms
  - Lag: 256 ms
Larger switch costs, reduced switch modulation in frontal areas in older adults

Gratton et al., 2009
Anterior corpus callosum shrinks with age

$r = -0.60, p < 0.001$

Overall, larger switch costs for those with smaller CC, especially in right-hemisphere dependent position task.
Large CC group: more lateralized switch modulation

MEANING switch effect

POSITION switch effect

large CC  small CC  large CC  small CC
White matter matters for grey(ing) areas

- **Grey areas:** *Functional* connectivity between frontal control areas and task-specific regions is important in attention-demanding tasks.

- **White matter matters:** In older adults, difficulty engaging preparatory control due to weaker *structural connections* may lead to sub-optimal performance.

- **Work in progress**
  - Probe EROS-behavioral relationships
  - Investigate cross-correlation (functional) differences as a function of corpus callosum size (structural)
Target health of frontal white matter with **exercise**?

Gordon et al., 2008; Johnson et al., 2012; Zimmerman et al., 2014; Tan et al., In Preparation

**Voss et al., 2013**

**Burzynska et al., In Preparation**

Gordon et al., 2008; Johnson et al., 2012; Zimmerman et al., 2014; Tan et al., In Preparation
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