Networks underlying top-down enhancement and suppression of visual processing

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Why study networks that support top-down modulation?

- Top-down modulation serves at the interface of perceptual, attentional and memory processes.

- Alterations in top-down modulation may underlie the diverse cognitive deficits associated with normal aging, neurological and psychiatric diseases.

- Critical details concerning the neural interactions that support top-down modulation, notably differences between enhancement and suppression networks, as well as aspects of causality, remain poorly understood.
endogenous, goal-directed

Top-down Modulation

Perception

Short-term Memory

Long-term Memory

exogenous, stimulus-driven

Attention
Top-down enhancement and suppression are dissociable processes
Age-related changes are selective

<table>
<thead>
<tr>
<th>cue stimuli</th>
<th>delay</th>
<th>probe</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 ms</td>
<td>800 ms</td>
<td>800 ms</td>
</tr>
<tr>
<td>9 sec</td>
<td>2 sec</td>
<td></td>
</tr>
</tbody>
</table>

Remember Scenes  
Ignore Faces

Passively View

Remember Faces  
Ignore Scenes

Scene-selective area
Age-related changes are selective to deficits in top-down suppression

Working memory performance is selectively influenced by suppression in older adults.

**fMRI**


**EEG**

Does enhancement and suppression differentially influence WM performance in young adults?

Zanto & Gazzaley, Journal of Neuroscience 2009
EEG markers of modulation

Overall Modulation: Motion

Overall Modulation: Color

Remember Motion
Ignore Color

Remember Color
Ignore Motion

cue stimuli
delay
probe

800 ms  800 ms  800 ms  800 ms
4 sec  2 sec

X

X
Neural-behavioral relationship
Neural-behavioral relationship

Motion trials

Remember Motion

Ignore Color

Attend Motion: Fast vs. Slow Trials, PO8

Time (ms)

Fast
Slow

Ignore Motion: Fast vs. Slow Trials, PO8

Time (ms)

Fast
Slow

Ignore Color: Fast vs. Slow Trials, IZ

Time (ms)

Fast
Slow

Attend Color: Fast vs. Slow Trials, IZ

Time (ms)

Fast
Slow

Remember Color

Ignore Motion

Cue Stimuli

Delay
Probe
Response Time

Remember — Ignore

Motion trials

Color trials
Top-down enhancement and suppression are dissociable processes

• Age-related changes are selective to top-down suppression.

• Working memory performance is selectively influenced by suppression in both younger and older adults.
Networks supporting top-down enhancement and suppression

Top-down modulation
Functional Connectivity: Beta series correlation

Cue Period Correlation (r=.668)

Rissman, Gazzaley & D’Esposito, Neuroimage 2004
Gazzaley, Rissman & D’Esposito, CABN 2004
The strength of MFG--VAC coupling correlates with the magnitude of attentional enhancement and suppression of visual cortical activity.
## Top-down modulation networks

### Simultaneous Presentation

<table>
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<tbody>
<tr>
<td>800 ms</td>
<td>4 sec</td>
<td>500 ms</td>
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</table>

### Scene-selective area modulation

- **Remember Scenes**
- **Ignore Faces**
- **Passively View**
- **Remember Faces**
- **Ignore Scenes**
- **Remember Faces**
Top-down modulation networks
Simultaneous Presentation

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Remember Scenes
Remember Scenes Ignore Faces
Passively View
Remember Faces Ignore Scenes
Remember Faces

Scene-selective area modulation

BOLD Signal

Overlap conditions: Scene, scene passive, face, Face

Top-down modulation networks
Simultaneous Presentation
Sequential vs. Simultaneous presentation

Sequential Presentation

Younger

- Remember Scenes: Enhancement
- Passive View: Suppression
- Ignore Scenes: 

Older

- Remember Scenes: Enhancement
- Passive View: 
- Ignore Scenes: No Suppression

Simultaneous Presentation

Younger

- Remember Scenes: Enhancement
- Passive View: Suppression
- Ignore Scenes: 

Older

- Remember Scenes: Enhancement
- Passive View: 
- Ignore Scenes: No Suppression


Chadick & Gazzaley (in preparation)
Top-down modulation networks
Simultaneous Presentation

Enhancement Network

PPA seed - Remember Scenes (Overlap)
FFA seed - Remember Faces (Overlap)

Suppression Network

PPA seed - Remember Faces (Overlap)
FFA seed - Remember Scenes (Overlap)
A Default Mode of Brain Function

Resting State Network
adapted from Fransson et al., HBM 2005

Default mode
Independent Localizer Task (rest > attention)
Default Mode & Suppression Network (PPA-seed)

Default Mode (Independent localizer task)

Suppression Network (PPA seed - Remember Faces/Overlap)

Significant Overlap
Default Mode & Suppression Network (FFA-seed)

Default Mode (Independent localizer task)

Suppression Network (FFA seed - Remember Scenes/Overlap)

Significant Overlap
mPFC & Suppression Network

Remember Faces

Faces
Enhancement network (FFA seed)

Faces/Scenes

Suppression network (PPA seed)

Remember Scenes

Scenes
Enhancement network (PPA seed)

Faces/Scenes

Suppression network (PPA seed)

Faces/Scenes

Suppression network (FFA seed)

Scenes
(PPA seed)

(FFA seed)
mPFC & Suppression Network

Remember Faces

- FFA seed
- Suppression
- PPA seed
- Enhancement

Remember Scenes

- FFA seed
- Suppression
- PPA seed
- Enhancement

Faces/Scenes

Default mode ROI

0 0.20 0.40 0.60 0.80 1.00
0 0.18 0.37 0.55 0.73 0.92 1.10
Remember Faces & Suppressions Network

Remember Faces

PPA seed Suppression

FFA seed Enhancement

Faces/Scenes

Default mode ROI

PPA seed Enhancement

FFA seed Suppression
Relationship between suppression network and magnitude of suppression

Greater functional connectivity between the PPA and mPFC is associated with greater suppression indices.

Whole-brain, across-participant, regression analysis between suppression index and the suppression network

• Greater functional connectivity between the PPA and mPFC is associated with greater suppression indices.
What does this mean?

Default mode regions related to self-referential mental activity...

...related to “self projection”

... related to “mind-wandering”
What does this mean?

**Question:**
Why are brain areas that are associated with an introspective, self-referential mode of mental activity functionally and dynamically connected with suppressed visual cortical areas?

**Interpretation:**
- There is a coupling between inhibition of internal distraction & external distraction.
- This coupling is related to the effective suppression of processing irrelevant information.
Suppression Network in Healthy Aging

Scene-selective area seed / Remember Faces (overlap)

Younger vs. Older

Younger vs. Older

Chadick & Gazzaley In Preparation
Anticipation involves a decrease in connectivity of visual cortical areas with medial PFC.

Face selective area (FFA- seed) Connectivity

Passive View        | Remember Faces | Passive > Remember

Bollinger & Gazzaley In Preparation
Causal influences in top-down networks

fMRI-guided rTMS-EEG

Zanto & Gazzaley In Preparation
Causal influences in top-down networks

fMRI functional connectivity
(Attend > Ignore)

Color ROIs (V4)  Motion ROIs (V5)

Right inferior frontal junction (IFJ); p < 0.01
Bilateral inferior frontal junction (IFJ); p < 0.05

Cue Stimuli (Encode)  Delay (Maintain)  Probe (Retrieve)

800 ms  800 ms  800 ms  800 ms  4000 ms  800 ms

Remember Color
Ignore Motion

Remember Motion
Ignore Color
Causal influences in top-down networks

Experimental design

- rTMS to right IFJ prior to each task (1 Hz for 10 minutes)
- Each participant received rTMS and sham control rTMS
- rTMS target defined by individual participant fMRI data
- TMS intensity: 65% MSO (~110% motor threshold)
- 64-electrode EEG recorded during task.
- Each task = 15 minutes; TMS effects should be greater in first half
Causal influences in top-down networks

Working memory performance

**First Half: Accuracy**

- Color: Sham = 0.8, Stim = 0.7
- Motion: Sham = 0.8, Stim = 0.7

* p < 0.05

**Second Half: Accuracy**

- Color: Sham = 0.7, Stim = 0.7
- Motion: Sham = 0.7, Stim = 0.7
Causal influences in top-down networks

Color evoked response potentials
Causal influences in top-down networks

Color evoked response potentials
Causal influences in top-down networks

Color evoked response potentials

*
Causal influences in top-down networks

Color evoked response potentials

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[Graphs showing color ROI with different conditions: Attend Sham, Ignore Sham, Attend Stim, Ignore Stim. The graphs illustrate amplitude (uV) over time (ms) with peaks at different times for each condition.]

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[P1 modulation bar chart comparing Sham and Stim conditions for the 1st and 2nd half with an asterisk indicating a significant difference.]
Causal influences in top-down networks

Motion evoked response potentials

![Graph showing motion ROI: PO8 O2 with different conditions: Attend Sham, Ignore Sham, Attend Stim, Ignore Stim.](image)

![Graph showing P1 modulation with bar graphs for 1st and 2nd half for Sham and Stim conditions.](image)
Causal influences in top-down networks

- Decline in WM accuracy for color
- Decline in top-down modulation for color

Correlation between TMS-induced modulation changes and performance changes

\[ \Delta = \text{Stim} - \text{Sham rTMS} \]
Causal influences in top-down networks

- Why are some individuals more susceptible to TMS effects?

Correlation between TMS-induced modulation changes and IFJ-V4 functional connectivity

\[ r = -0.47 \]
\[ p < 0.05 \]

\( \Delta = \text{Stim} - \text{Sham rTMS} \)
Causal influences in top-down networks

Conclusions

• IFJ is a source of feature-based top-down modulation of activity in visual association cortex.

• The degree of functional connectivity relates to the magnitude of the causal influence.

• This role in top-down modulation has an influence on working memory performance.
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