

# Maturation of Widely Distributed Brain Function Subserves Cognitive Development

Luna et al.

2001

## Introduction

- ❖ Traditional Believes
- ❖ Today's View

## Methods

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## Results & Discussion

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## Conclusion

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# Introduction

# *Traditional Believes*

Introduction

❖ Traditional Believes

❖ Today's View

Methods

Results & Discussion

Conclusion

- Elementary cognitive processes are in place by early childhood.
- But cognitive and brain maturational changes continue until adulthood.
- These were believed to be subserved primarily by the incorporation of the prefrontal cortex.

# Today's View

Introduction

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❖ Traditional  
Believes

❖ Today's View

Methods

---

Results &  
Discussion

---

Conclusion

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- High-order cognitive functions are subserved by widely distributed and integrated brain systems.
- Developmental improvements in frontal cortex *may* lead to increased integration with other brain regions.
- Maturation of the functional integration of widely distributed circuitry still unexplored.

Introduction

**Methods**

❖ The Antisaccade Task

❖ Prosaccade vs Fixation Task

❖ Functional MRI

❖ Subjects

Results & Discussion

Conclusion

# Methods

# *The Antisaccade Task*

Introduction

---

Methods

❖ The Antisaccade Task

❖ Prosaccade vs Fixation Task

❖ Functional MRI

❖ Subjects

Results & Discussion

---

Conclusion

---

- The ability to voluntarily suppress responses to irrelevant information is essential to adult-level cognition.
- The antisaccade task requires a subject to stop a reflexive eye movement to a visual stimulus and fixate the mirror location.

# *The Antisaccade Task*

Introduction

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Methods

❖ The Antisaccade Task

❖ Prosaccade vs Fixation Task

❖ Functional MRI

❖ Subjects

Results & Discussion

---

Conclusion

---

antisaccade.eps

# Prosaccade vs Fixation Task

Introduction

Methods

❖ The Antisaccade Task

❖ Prosaccade vs Fixation Task

❖ Functional MRI

❖ Subjects

Results & Discussion

Conclusion

- Used as comparison condition for the antisaccade task.
- Allows to differentiate between the cognitive component and the motor and sensory components.

fixation.eps

# Functional MRI

Introduction

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Methods

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❖ The Antisaccade Task

❖ Prosaccade vs Fixation Task

❖ **Functional MRI**

❖ Subjects

Results & Discussion

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Conclusion

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- fMRI measures changes in blood flow related to neural activity.
- Standard data-analysis approaches.
- High spatial resolution (typical: 2–3 mm).
- Poor temporal resolution.
- Correlation does not imply causation.

# Subjects

Introduction

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Methods

---

❖ The Antisaccade Task

❖ Prosaccade vs Fixation Task

❖ Functional MRI

❖ **Subjects**

Results & Discussion

---

Conclusion

---

- Eleven 8–13 year-old (mean 10.9; females = 8)
- Fifteen 14–17 year-old (mean 15.7; females = 6)
- Ten 18–30 year-old (mean 24.2; females = 6)
- All right-handed except one adult.

Introduction

Methods

**Results &  
Discussion**

❖ The Antisaccade Task

❖ Basic Circuitry

❖ Activation in Adults

❖ Regions Active only in Adults

❖ Interpretation of the Results

❖ Activation in Children

❖ Activation in Adolescents

❖ Dorsolateral Prefrontal Cortex

Conclusion

# Results & Discussion

# The Antisaccade Task

Introduction

---

Methods

---

Results &  
Discussion

---

❖ The Antisaccade  
Task

❖ Basic Circuitry

❖ Activation in  
Adults

❖ Regions Active  
only in Adults

❖ Interpretation of  
the Results

❖ Activation in  
Children

❖ Activation in  
Adoloscents

❖ Dorsolateral  
Prefrontal Cortex

Conclusion

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- Significant decrease in prosaccade error rate with age in the antisaccade task.
- Antisaccades showed no significant changes in:
  - ❖ peak velocity
  - ❖ accuracy
  - ❖ amplitude
  - ❖ duration
  - ❖ latency

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# Basic Circuitry

Introduction

---

Methods

---

Results &  
Discussion

---

❖ The Antisaccade  
Task

❖ **Basic Circuitry**

❖ Activation in  
Adults

❖ Regions Active  
only in Adults

❖ Interpretation of  
the Results

❖ Activation in  
Children

❖ Activation in  
Adoloscents

❖ Dorsolateral  
Prefrontal Cortex

Conclusion

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- Both great overlap and qualitative differences in the pattern and extent of brain activation across age groups.
- Results indicate that SEF, insula, precuneus and anterior cingulate are elements of basic oculomotor and attention circuitry.
- These regions are associated with basic sensory and motor control as well as some cognitive functions.

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# Activation in Adults

Introduction

---

Methods

---

Results &  
Discussion

---

❖ The Antisaccade  
Task

❖ Basic Circuitry

❖ Activation in  
Adults

❖ Regions Active  
only in Adults

❖ Interpretation of  
the Results

❖ Activation in  
Children

❖ Activation in  
Adoloscents

❖ Dorsolateral  
Prefrontal Cortex

Conclusion

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- Adults showed more activation in the superior FEF, IPS, thalamus.
- These regions are mainly associated with generation and directing of eye movements.

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# Regions Active only in Adults

Introduction

---

Methods

---

Results &  
Discussion

---

❖ The Antisaccade  
Task

❖ Basic Circuitry

❖ Activation in  
Adults

❖ Regions Active  
only in Adults

❖ Interpretation of  
the Results

❖ Activation in  
Children

❖ Activation in  
Adolescents

❖ Dorsolateral  
Prefrontal Cortex

Conclusion

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- In comparison to children and adolescents adults showed additional activation in the lateral cerebellum, dentate nucleus of the cerebellum and the superior colliculus (SC).
- These regions are responsible for:
  - ❖ a broader number of cognitive functions like attention
  - ❖ planning, initiation and control of volitional movements
  - ❖ inducing saccadic eye movements

# Interpretation of the Results

Introduction

---

Methods

---

Results &  
Discussion

---

❖ The Antisaccade  
Task

❖ Basic Circuitry

❖ Activation in  
Adults

❖ Regions Active  
only in Adults

❖ Interpretation of  
the Results

❖ Activation in  
Children

❖ Activation in  
Adoloscents

❖ Dorsolateral  
Prefrontal Cortex

Conclusion

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- The cerebellum may be involved in establishing the inhibitory activity to suppress automatic responses<sup>1</sup>.
- Activation in SC and FEF probably reflects metabolic demands of the inhibitory processes.<sup>2</sup>
- Integration of these regions may be important for the ability to suppress prepotent responses.

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<sup>1</sup>Deiber *et al.*, 1996

<sup>2</sup>Compare with Munoz *et al.* (1998).

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# Activation in Children

Introduction

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Methods

---

Results &  
Discussion

---

❖ The Antisaccade  
Task

❖ Basic Circuitry

❖ Activation in  
Adults

❖ Regions Active  
only in Adults

❖ Interpretation of  
the Results

❖ Activation in  
Children

❖ Activation in  
Adoloscents

❖ Dorsolateral  
Prefrontal Cortex

Conclusion

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- In contrast to the other groups children showed increased activation in the supramarginal gyrus (SMG).
- May be reflecting a reliance on visuospatial processing to compensate for the immature brain regions.

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# Activation in Adolescents

## Introduction

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## Methods

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## Results & Discussion

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### ❖ The Antisaccade Task

### ❖ Basic Circuitry

### ❖ Activation in Adults

### ❖ Regions Active only in Adults

### ❖ Interpretation of the Results

### ❖ Activation in Children

### ❖ Activation in Adolescents

### ❖ Dorsolateral Prefrontal Cortex

## Conclusion

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- In adolescent and older subjects activation in the basal ganglia (and striatum) were observed.
- May be a first step in the maturation of structures generating voluntary behavior.
- Adolescents had the highest activation in the DLPFC.
- Indicating greater reliance on executive prefrontal behavior control systems.

# Dorsolateral Prefrontal Cortex

Introduction

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Methods

---

Results &  
Discussion

---

❖ The Antisaccade  
Task

❖ Basic Circuitry

❖ Activation in  
Adults

❖ Regions Active  
only in Adults

❖ Interpretation of  
the Results

❖ Activation in  
Children

❖ Activation in  
Adoloscents

❖ Dorsolateral  
Prefrontal Cortex

Conclusion

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- Last area to develop in the human cerebrum.
- Connected to the thalamus, basal ganglia and other brain areas.
- Highest cortical area responsible for motor planning, organization and regulation.
- Activation of DLPFC could provide inhibitory input to FEF and SEF until the maturation of widely distributed function.

Introduction

---

Methods

---

Results &  
Discussion

---

Conclusion

❖ Conclusion

# Conclusion

# Conclusion

Introduction

Methods

Results &  
Discussion

Conclusion

❖ Conclusion

- New evidence indicating that the ability to voluntarily initiate and suppress behavior is influenced by the maturation of integrated function.
- The maturation occurs among the neocortex, striatum, thalamus and cerebellum.
- Immature functional connectivity makes it difficult to integrate distant brain regions.