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The development of interoceptive information processing across adolescence

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University of California, Santa Barbara

May 29<sup>th</sup>, 2010

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Aristotle      René Descartes      Baruch Spinoza

Charles Darwin      William James      Walter Cannon

May 29<sup>th</sup>, 2010

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Interoception

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**Interoception:** the current homeostatic condition of the entire body

Sherrington, 1906

the ability for homeostatic information to reach conscious awareness

Craig, 2003

the initiation of motivated action to regulate the internal state of the body

Craig, 2007

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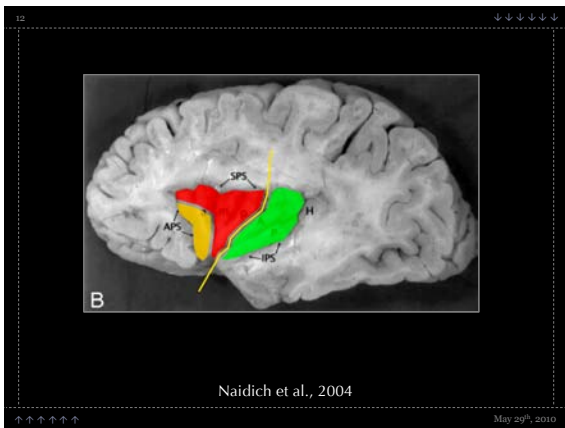
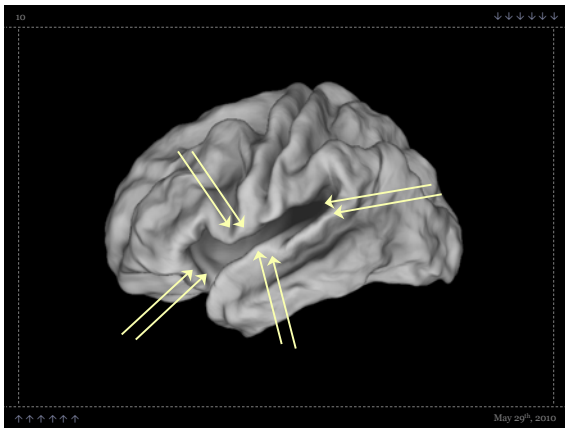
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Craig, 2004

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- Interoception is understudied
- The development of interoception is understudied
- The dysfunction of interoception is understudied
- The function(s) of the insula are not well understood

## The Insula

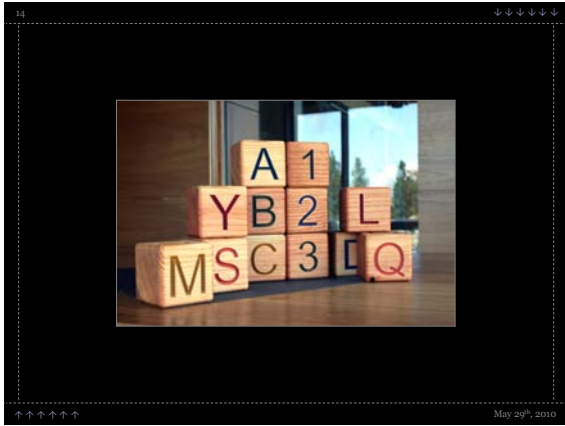


Naidich et al., 2004

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# Insula Function

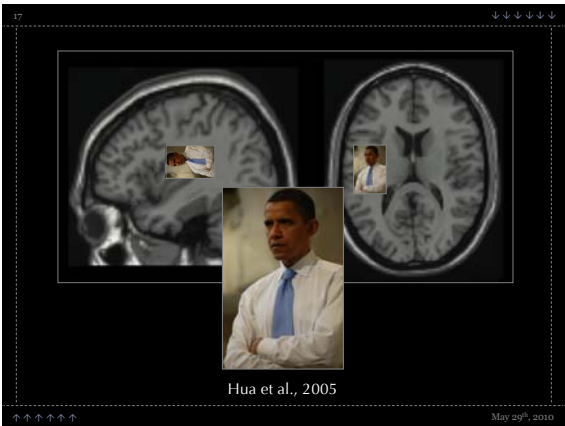
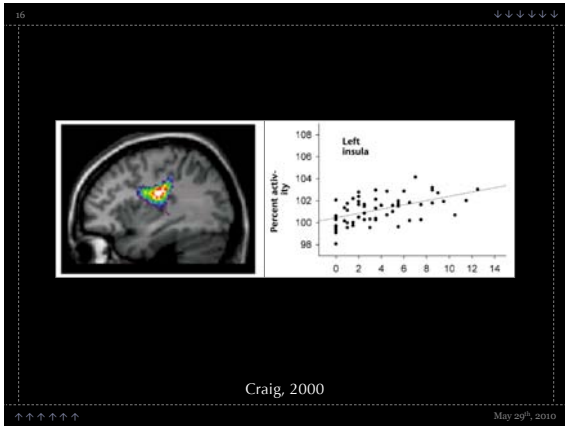
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AFFERENT INTEROCEPTION

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AFFERENT INTEROCEPTION

TEMPORAL PROCESSING

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Hadjikhani et al., 1998      Banati et al., 2000      Bushara et al., 2001

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**(D) Activity covarying with EDA**  
**Right anterior insula / orbitofrontal**

Critchley, 2005

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Sympathetic activity:  
 HF power orthogonalized  
 with respect to LF power

Critchley, 2003

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COHERENT  
 FEELING STATES

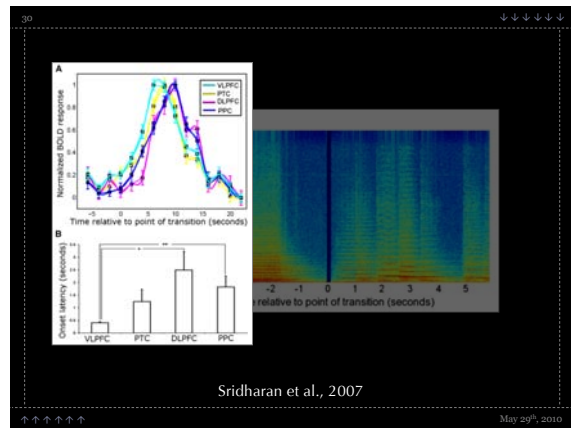
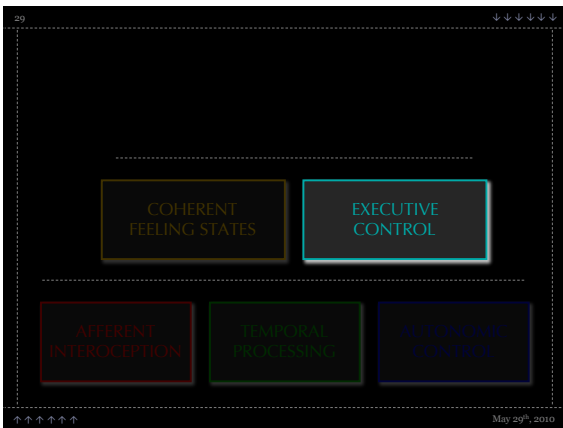
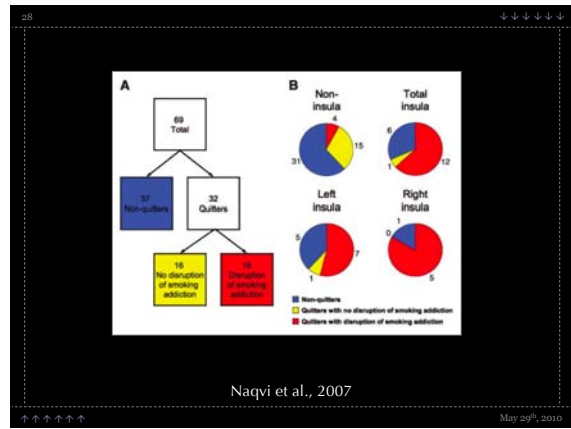
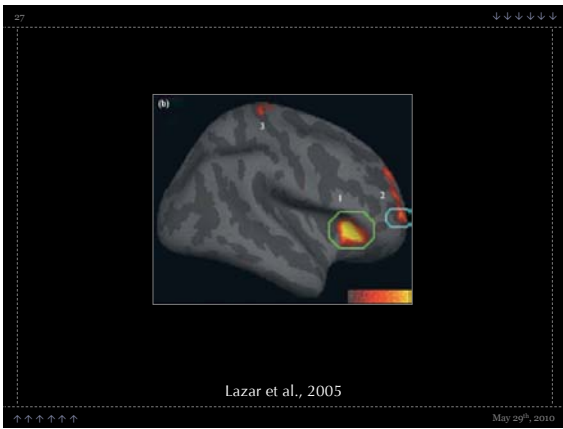
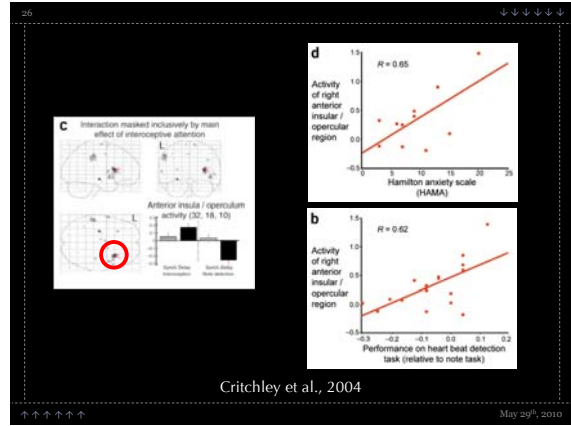
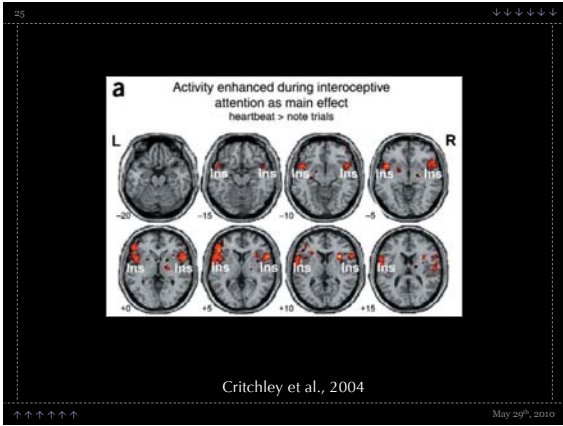
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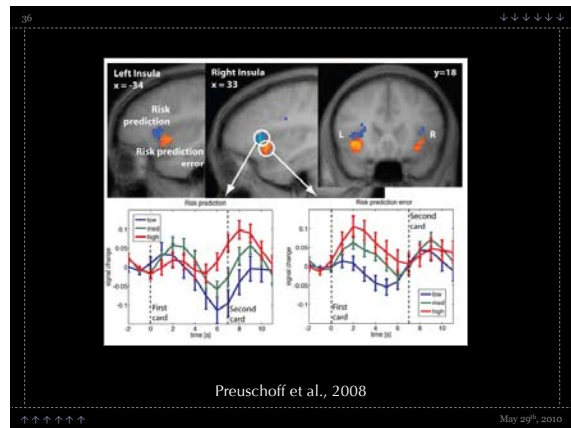
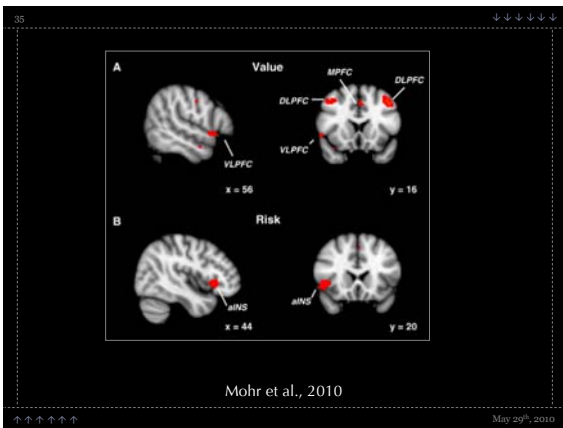
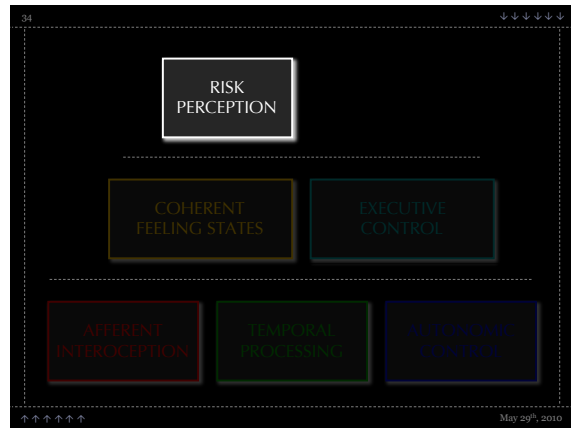
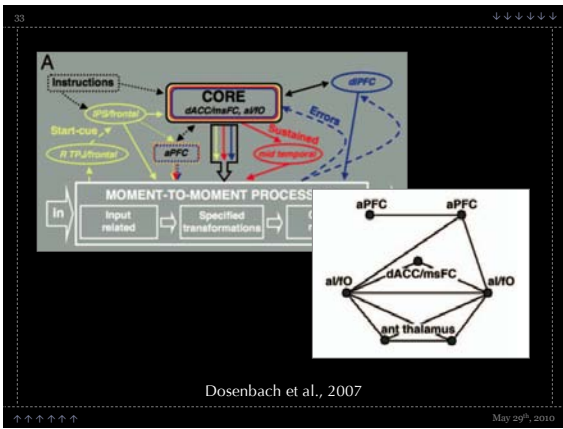
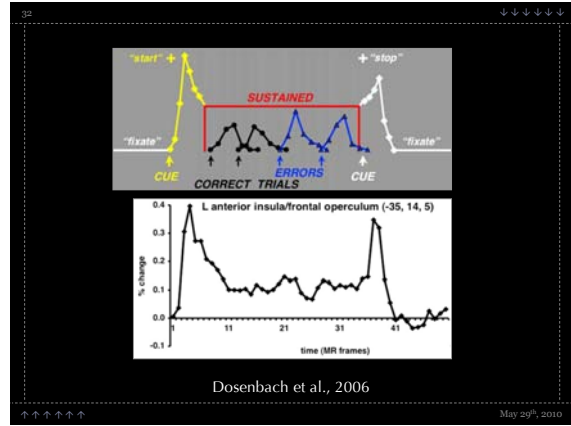
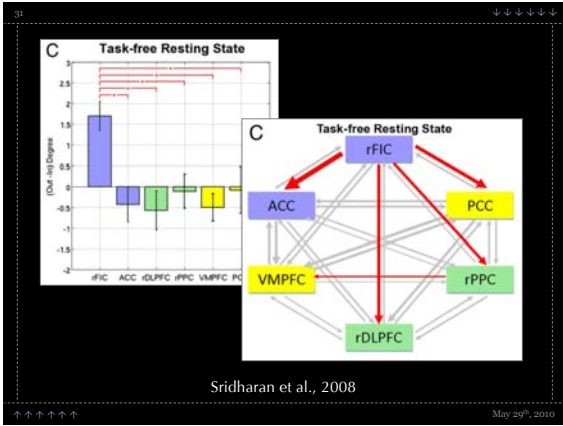
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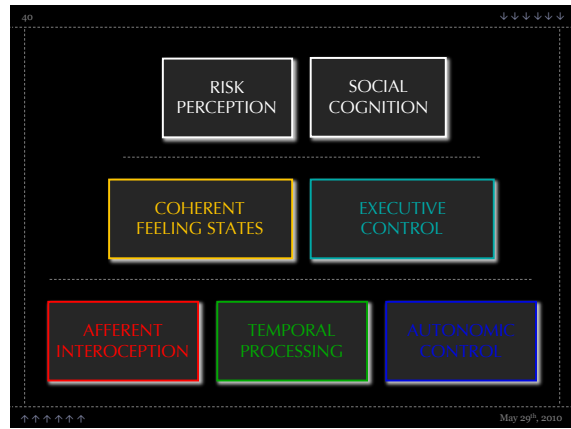
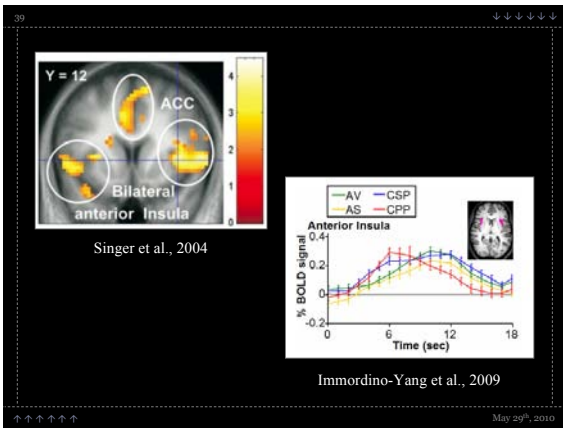
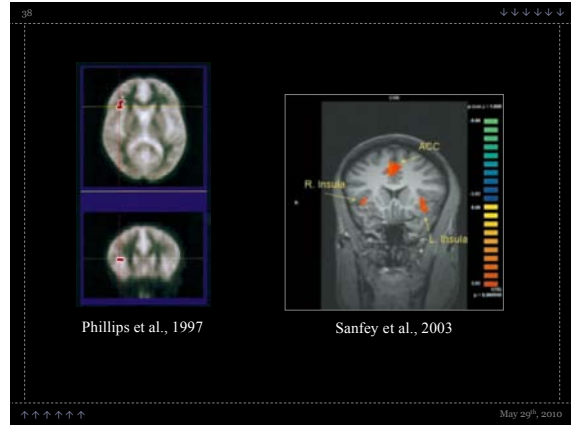
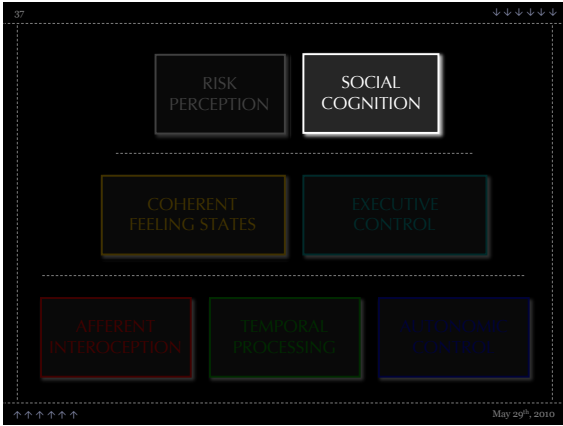
Rating regression,  
 right anterior insula  
 (14, 12, 20)

Craig, 2000

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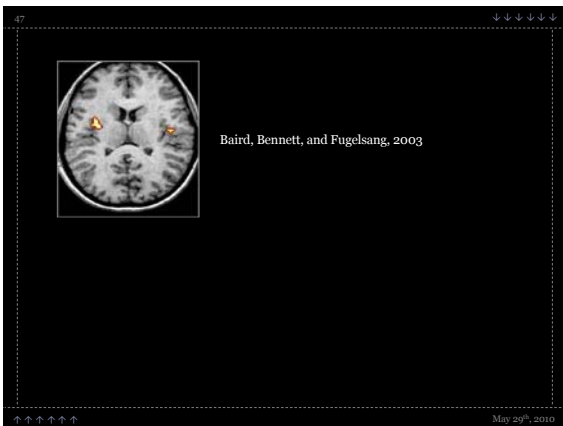
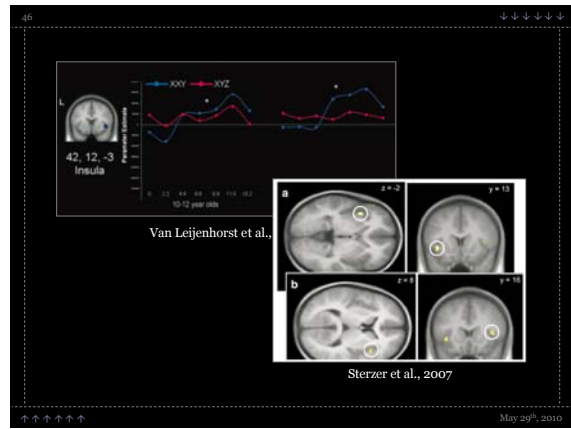
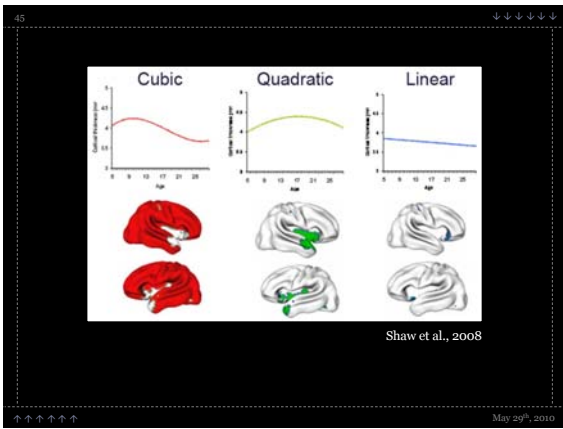
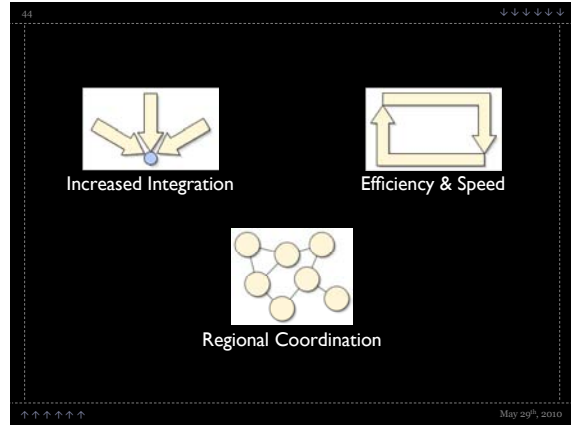
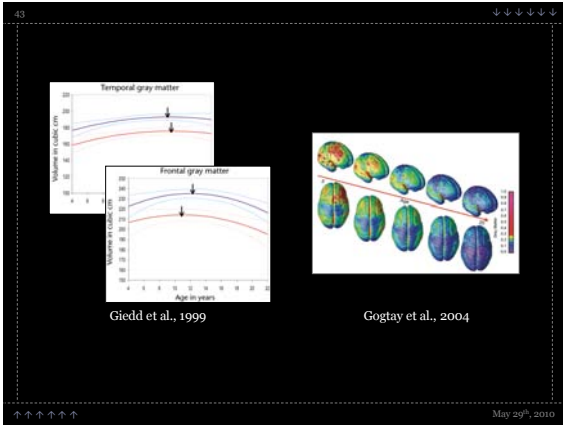


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- Better heartbeat detectors were better decision makers (Werner et al., 2009)
  - Temperature of beverage primes social proximity (Ijzerman and Semin, 2009)
  - The perception of time changes with anger (Hauser et al., 2009)
  - Music and dance enhance social bonding
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Development

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Our Data

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# Exp 1: Simple Stimulation

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AFFERENT INTERCEPTION

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Molavi, 1997

Craig, 2004

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van Westen et al., 2004

Craig et al., 2000

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Top View

4"

May 29<sup>th</sup>, 2010

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Hot  
Warm  
Neutral  
Cool  
Cold

5 Pegs  
4 Pegs  
3 Pegs  
2 Pegs  
1 Peg

May 29<sup>th</sup>, 2010

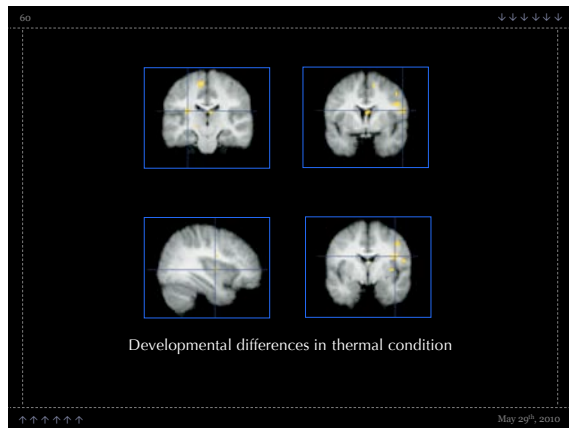
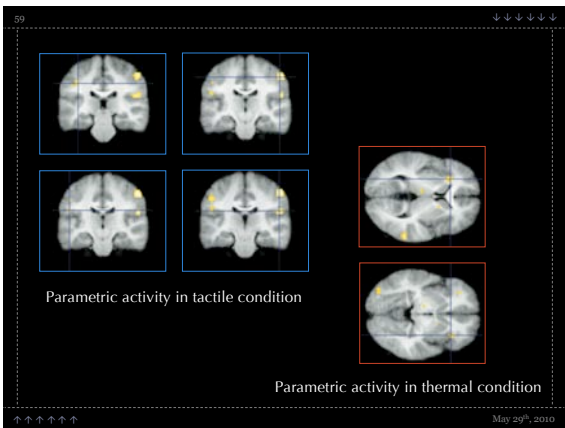
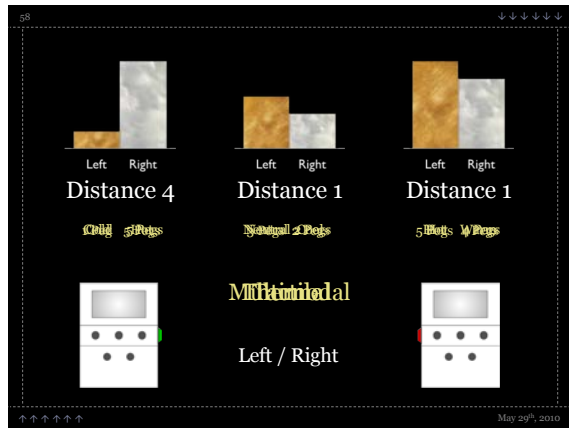
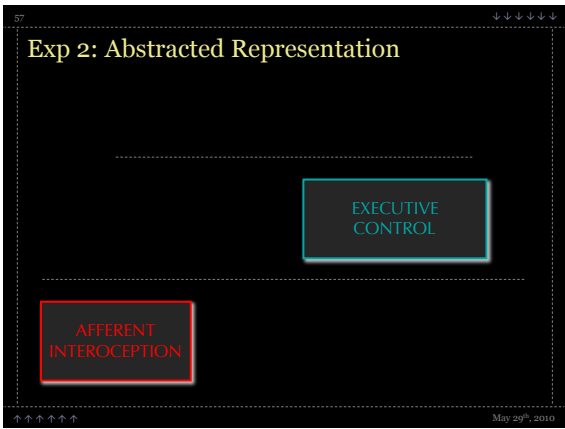
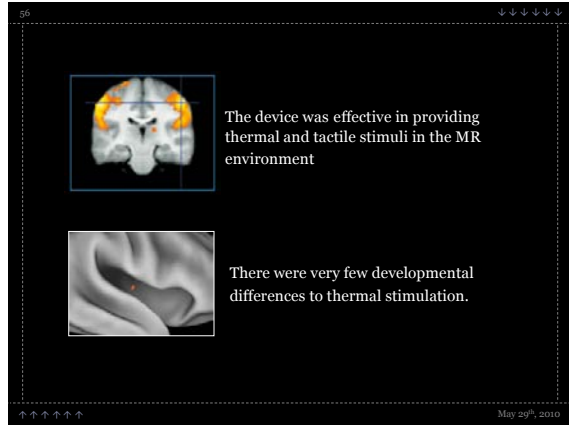
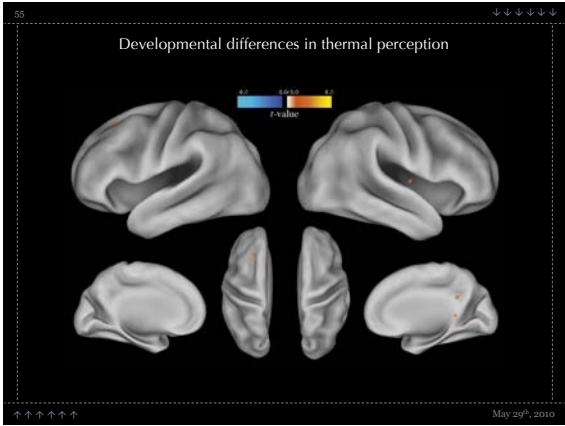
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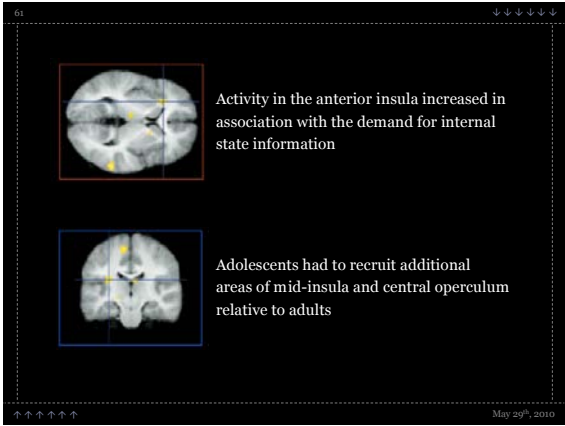
### Activity to both thermal and tactile stimuli

F-Value

0.01 0.05

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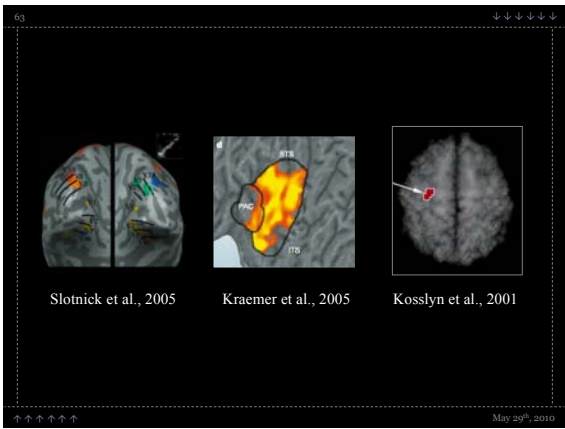


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### Exp 3: Top-Down Interoception

COHERENT  
FEELING STATES

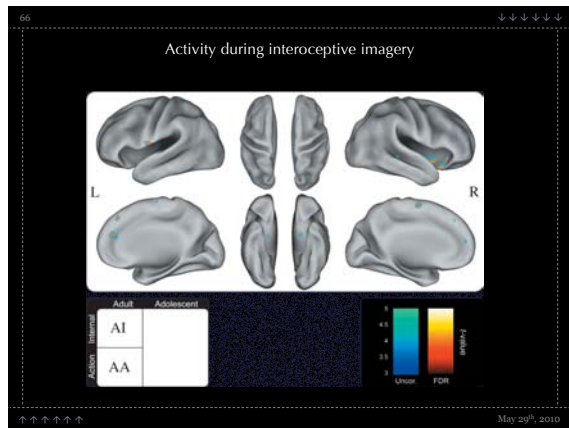
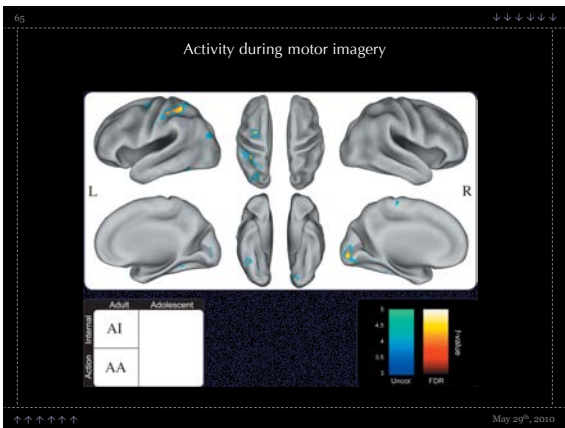
May 29<sup>th</sup>, 2010



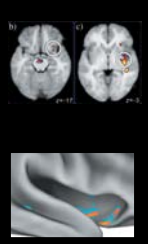
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<p>Freezing Cold Sweltering Hot Starving Nauseous Itchy Rash</p> <hr/> <p>Internal States</p>	<p>Tie shoes Pour Water Wash Hands Lock Door Answer Phone</p> <hr/> <p>Everyday Actions</p>
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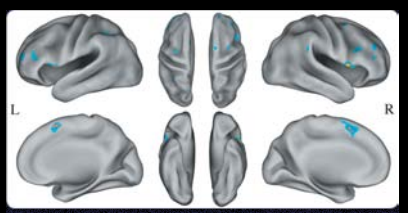
The interoceptive system *can* be driven in a top-down manner through mental imagery

Only secondary areas of interoceptive cortex showed significant activity

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Developmental differences in activity, regardless of modality

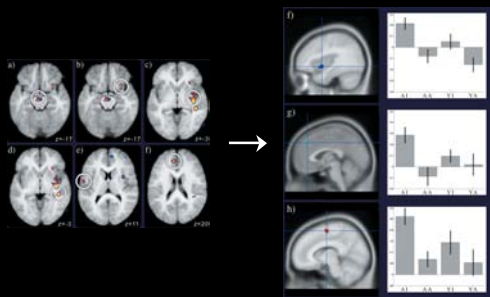


	Adult	Adolescent
Action Intensity	AI	YI
Imagery	AA	YA

Linear FDR

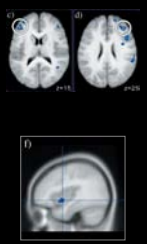
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Regions of higher-order cortex show developmental differences in activity during mental imagery

Certain regions active during internal imagery in adults were hypoactive in adolescents

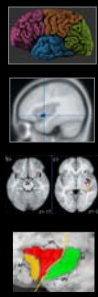
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# Wrap Up

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- Interoceptive sensory processing is separable, unique
- Areas supporting this processing are still developing
- Interoceptive function is developing during adolescence
- These differences could have wide-ranging implications

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## Acknowledgements

Abigail Baird    Mike Miller  
George Wolford    Daniel Ansari


Paul Whalen    Donna Coch    Megan Steven  
Scott Gerlach    Emily Cross    Ken Munsey

↑↑↑↑↑↑    May 29<sup>th</sup>, 2010

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## Thank You

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bennett @ psych.ucsb.edu  
<http://prefrontal.org>

↑↑↑↑↑↑    May 29<sup>th</sup>, 2010