Investigating the role of the brain in homeostasis: implications for physiology in older people
Interoception

- Sensations arising from inside the body

- Associated with behaviours and autonomic responses that contribute to homeostasis
Internal Signals

- Osmolality of body fluids
- Blood Volume

Interoceptive Sensation

THIRST

Behaviour

Search for and ingestion of water

Gratification

“Ah, that’s nice(ish)”

Satiation

Thirst gone
Research Agenda

- Mapping brain networks associated with interoceptive experience and control of regulatory behaviours
- Implicating brain regions in the representation of interoceptive sensations
  - discriminative processes, affective responses, modulation
- Investigating interactions between interoception and regulatory behaviours
- Exploring the interplay between interoceptive networks, pathology and disease expression
Preoptic Nucleus & Thermoregulation

Nakamura Am J Physiol 2011
Human Preoptic Anatomy

Sweating Activation Pinpoints the PO

Farrell et al. Temperature 2014
PO Network of Functional Connectivity

Farrell et al. Temperature 2014
Widely Distributed Networks

TEMPERATURE

Skin Cooling - rest
Skin Heating - rest

x = 6
x = 6

z = 54
z = 48

c

d

y = -28
y = -28

z = 0
z = -2

Egan et al. PNAS 2005

PAIN

Control Group
AS Patient Group

Medial

(b)

% Signal Change

Time (seconds)

9
24
39
51

Lateral

(c)

(d)

Cole et al. Brain 2006

THIRST

Maximum Thirst
Post Drink

A
B

x = 8

C
D

x = 12

E
F

x = 12

G
H

Farrell et al. PNAS 2008

URGE-TO-COUGH

E

A

B

C

D

E

F

G

Z-score

2

z = -18

z = -9

z = -2

z = 20

z = 66

z = 6

Mazzone et al. Am J Respir Crit Care Med 2007

Thirst

Urge

- to

Cough

Mazzone et al. Am J Respir Crit Care Med 2007
Deconstructing Networks: Urge-to-Cough

Stimulus/Response Function

capsaicin dose (log_{10} \mu M/L) vs urge-to-cough

8th September 2015 | 10
Urge-to-Cough Coding

Farrell et al. Neuroimage 2012
Urge-to-Cough Coding

Farrell et al. *Neuroimage* 2012

![Graph showing urge-to-cough ratings for different runs and levels of leakage.](image)
Urge-to-Cough Coding

Farrell et al. *Neuroimage* 2012
Mid Cingulate Cortex & Interoception

**URGE-TO-COUGH**

Farrell et al. Neuroimage 2012

**THERMAL COMFORT**


**THIRST**

Farrell et al. PNAS 2008
Regulatory Behaviours & Autonomic Responses

SUDOMOTOR ACTIVITY

Farrell et al. *Temperature* 2014

COUGH SUPPRESSION

Mazzone et al. *J Neurosci* 2011

THERMODEFENSIVE VASOCONSTRICTION

McAllen et al. *PNAS* 2006

“OVER” DRINKING

Saker et al. *PNAS* 2014
Coughing Control & Interoception

<table>
<thead>
<tr>
<th></th>
<th>Don’t Cough</th>
<th>Cough</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saline Inhaled</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Capsaicin Inhaled</td>
<td>C</td>
<td>D</td>
</tr>
</tbody>
</table>
Mazzone et al. *J Neurosci* 2011
B + D > A + C
Cough Activation

C + D > A + B
Capsaicin Activation

Don’t Cough

Cough

A

B

Saline Inhaled

Capsaicin Inhaled

C

D

Mazzone et al. J Neurosci 2011
COUGH Suppression Network

Mazzone et al. J Neurosci 2011
Cough Hypersensitivity = $\downarrow$ Suppression
Thirst, Water & Gratification

A

Warm-up Exercises

Cool-Down Exercises

Exercise

5 mins

60 mins

Cool-Down

5 mins

60 mins

Scanning

60 mins

Weight Temperature Rating

Weight Temperature Rating

Weight Temperature Rating

Weight Rating

mins

Rating

B

Thirsty

Run 1

Run 2

Satiated

Run 3

Run 4

Structural Scan

Single trial

10 trials per run

Drink to satiation Overdrinking

Removed from scanner

Saker et al. PNAS 2014
Water Pleasantness

Saker et al. PNAS 2014
Water Unpleasantness

Saker et al. PNAS 2014
Water Unpleasantness/Effort to Swallow

Saker et al. PNAS 2014
Thirst, Satiation and Ageing

- Young, Isotonic
- Young, Hypertonic
- Old, Isotonic
- Old, Hypertonic

**Plasma osmolality (mosm/kg)**

**Water intake (ml/kg)**

Farrell et al. *PNAS* 2008
Conclusions

- Widely distributed brain networks code responses to interoceptive signals in humans
- Constituent regions within interoceptive networks fulfill functional roles in discriminative, affective, cognitive and behavioural processes
- The function of interoceptive networks can be influenced by disease and ageing
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