Understanding Variation in Food Preference

Sally Eldeghaidy
and
Martha Skinner

Presentation Overview

- Sensory evaluation and perception
- Taste phenotypes
- Functional Magnetic Resonance Imaging (fMRI)
- Current research at Nottingham
- Discussion and questions

Sensory Evaluation

"A scientific method used to evoke, measure, analyse and interpret those responses to samples as perceived through senses"

- Humans are your 'instrumental measure'
- Robust experimental design & statistical analysis

Divided into 2 categories

- Objective (trained panellists)
  Measure sample attributes
- Subjective (untrained consumers)
  Measure preference & acceptance

Combined practices

- Understand how sensory properties drive consumer preference

(Kemp *et al*, 2009)

Demand for Multidisciplinary Research

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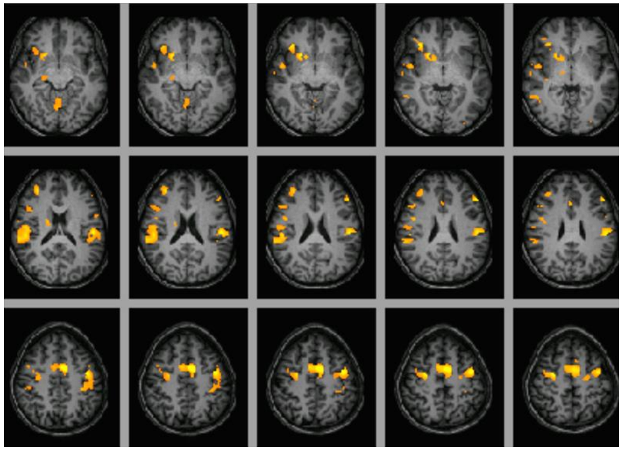
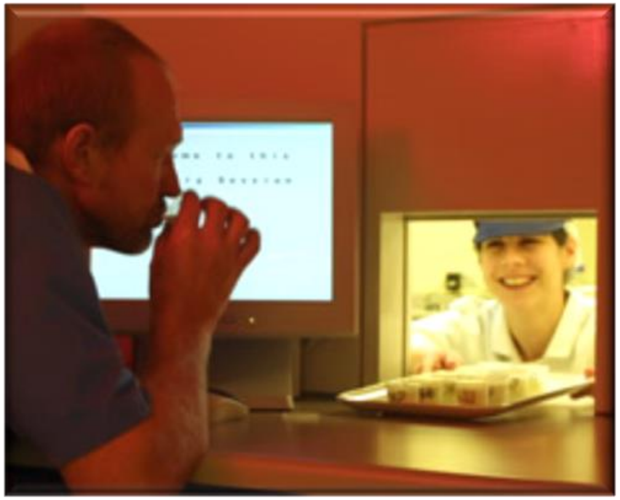


- Investigational gap between peripheral stimulation and conscious perception

- Neuroimaging allows the brain response to stimuli to be measured



- Multidisciplinary research approach:
  - Sensory Evaluation
  - Functional MRI

Taste Perception

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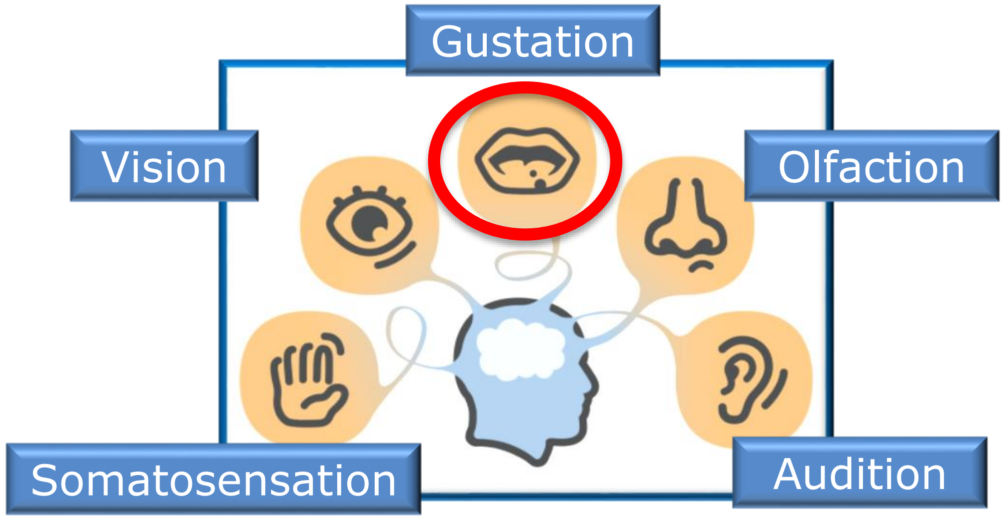
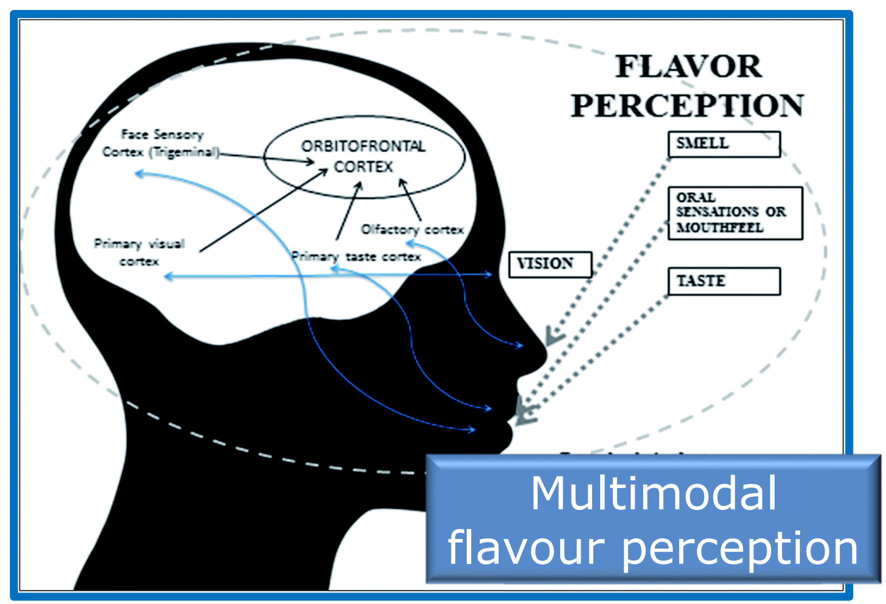
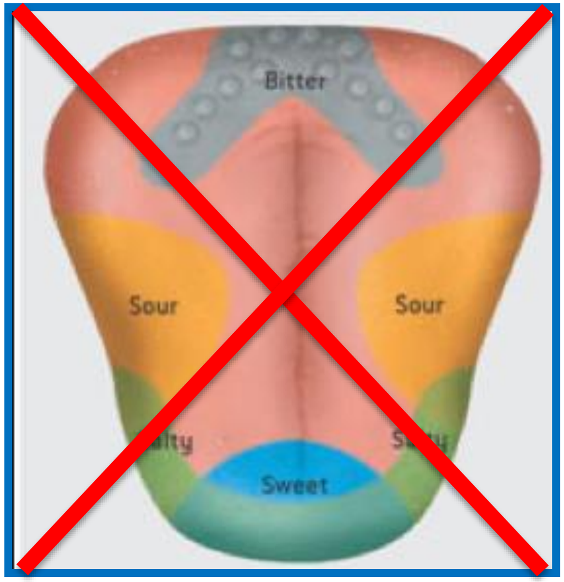
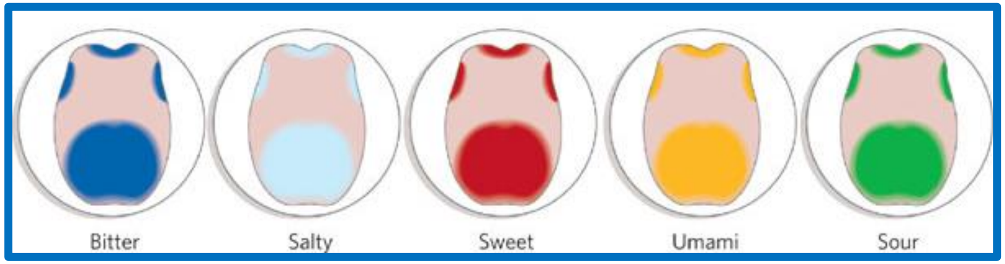




Taste Processing





Tastant dissolved in saliva

↓

Papillae

↓

Taste bud

↓

Taste receptor cell

↓

Cell depolarises & action potential

↓

Peripheral nervous system

↓

Central nervous system

(Chandrashekar *et al*, 2006)

Variation in Food Preference

Gender

Age

Culture

Food availability

Societal factors

Economic factors

Health/disease

Taste/aroma disorders

PROP taster status

Thermal taster status

Nutritional status

PROP Taste Phenotype

Varied sensitivity to bitter tasting compounds

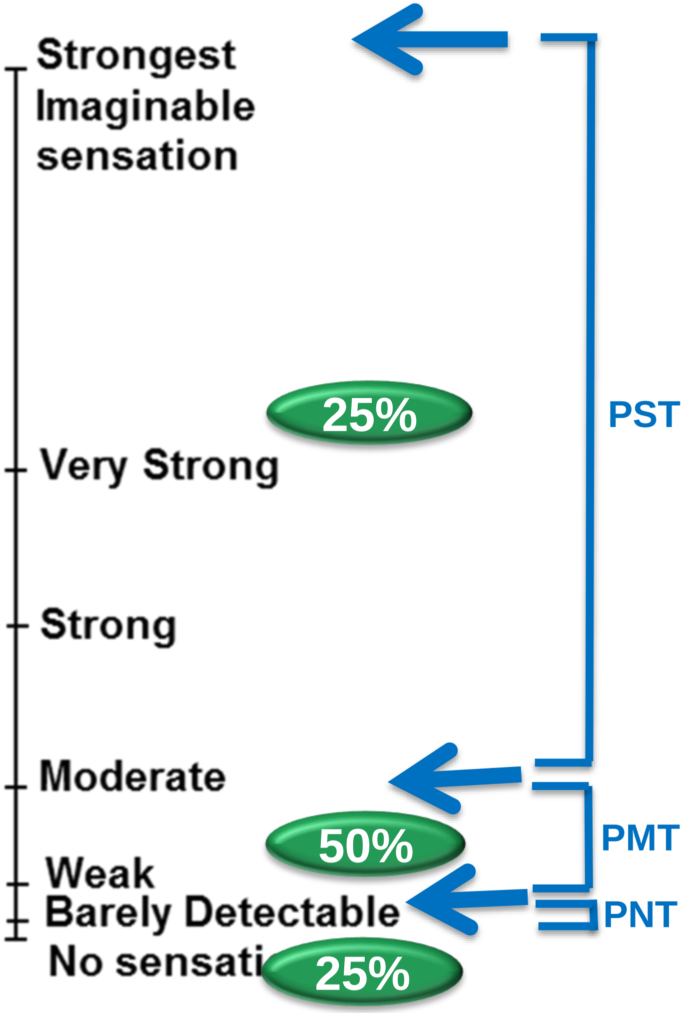
- Phenylthiocarbamide (PTS)
- 6-n-propylthiouracil (PROP)

PROP taster status groups

- PROP non taster (PnT)
- PROP taster

  -Medium taster (PMT)

  -Supertaster (PST)



General labelled magnitude scale (gLMS)

(Blakeslee & Fox, 1932; Bartoshuk et al, 2004a; Bartoshuk, 2004b)

Factors Influencing PROP Sensitivity

PROP sensitivity
(Duffy & Bartoshuk, 2000)

Genotype TAS2R38 (Duffy *et al*, 2004)

PROP Taster Status and Oral Sensitivity

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Sweet

Bitter

Sour

Salt

Umami

(Bajec & Pickering, 2008; Yang *et al*, 2014)

Astringency

(Bajec & Pickering, 2008)

Ethanol

(Prescott *et al*, 2000)

Capsaicin

(Tepper & Nurse, 1997)

Linoleic acid

(Tepper *et al*, 2014)

PROP Taster Status and Food Choice

PST ↓ preference for bitter vegetables
↓ vegetable consumption?

PNT ↑ preference fat
↑ consumption energy dense foods

Inverse correlation between PTS and calorie intake/BMI

PST ↓ alcohol preference
↓ consumption?

PNT less discrimination between fat concentration
↑ fat consumption

(Reviewed by Tepper *et al*, 2014)

Thermal Taste Phenotype

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WARMING TRIAL

Sweet

20-50%

Bitter

COOLING TRIAL

Sour

Salty

Umami

Metallic

Spicy

Menthol/Mint

Thermal taster (TT)

Thermal non taster (TnT)

(Cruz & Green, 2000; Yang *et al*, 2014; Bajec & Pickering, 2008; Bajec & Pickering, 2010)

Thermal Taster Status and Oral Sensitivity

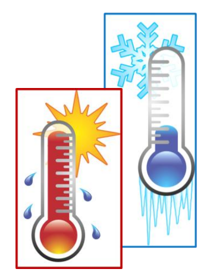
TTs have heightened sensitivity to oral stimuli

Taste

Metallic

Astringency

Temperature



(Bajek & Pickering, 2008; Cruz & Green, 2000; Green & George, 2004; Yang, 2014; Hort *et al*, 2016)

Thermal Taster Status and Food Choice

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TTs

- ↑ attribute intensity ratings
- No difference in overall liking

Sensitivity did not translate into different preference

(Pickering *et al*, 2010a; 2010b)

TTs

- ↓ preference 'mushy' and 'creamy' food group
- ↑ preference 'grainy' food group

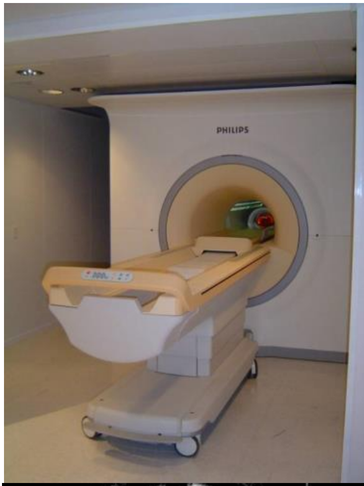
FOOD CHOICE

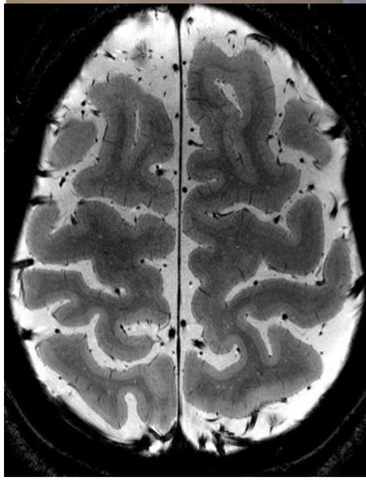
Predicted to be driven by texture

(Bajec & Pickering, 2010; Pickering & Klodnicki, 2016; Pickering *et al*, 2016)

What can MRI assess?

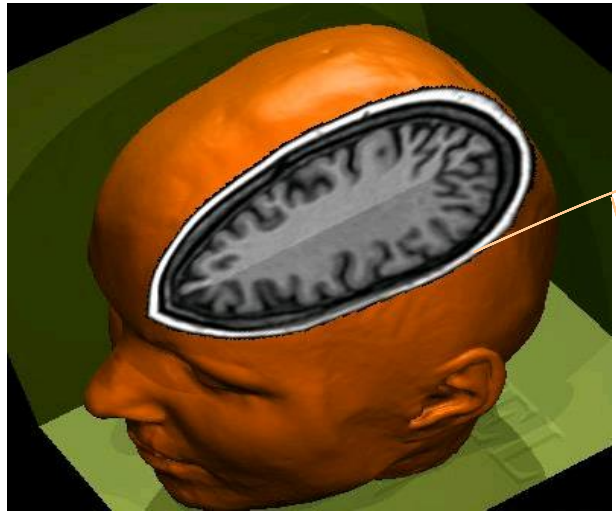
- Structure- anatomy, DTI
- Brain metabolites
- Haemodynamic changes (fMRI)
  - **<u>1- BOLD</u>** (ratio of oxyhaemoglobin to deoxyhaemoglobin)
  - **2. <u>Cerebral Blood Flow (CBF)</u>** (using Arterial Spin Labelling (ASL))

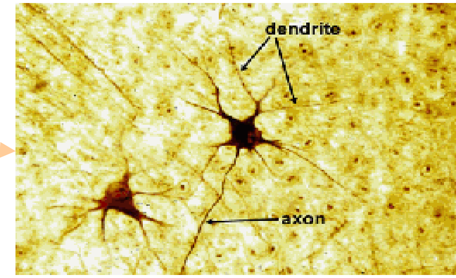




fMRI – How it works

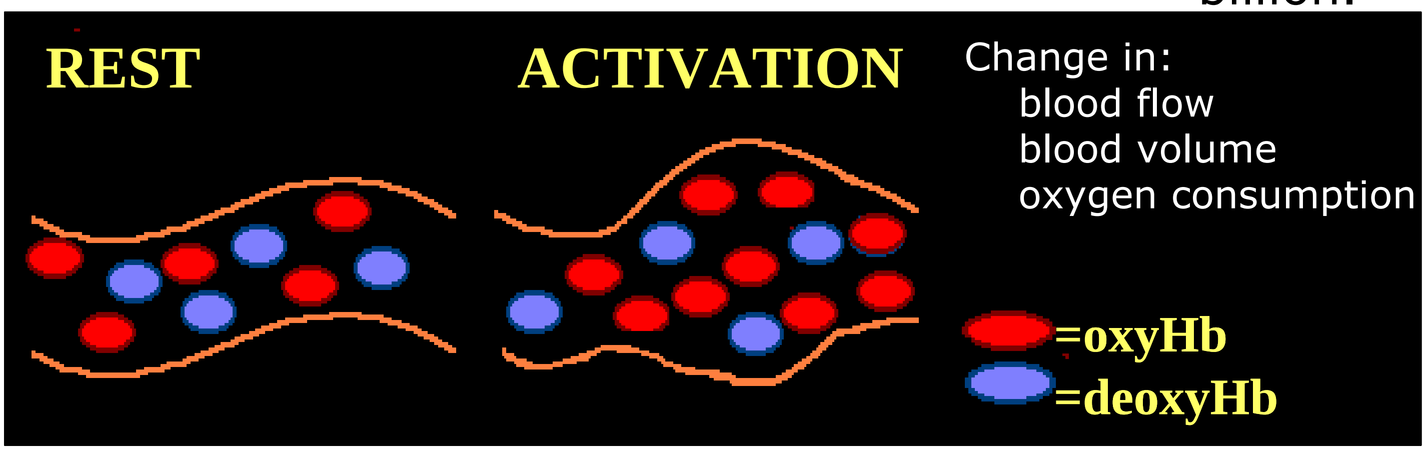
Brain separated into grey and white matter-Grey matter contains neurons





The average number of neurons in the brain = 100 billion.

When neurons are active they consume more energy and need more oxygen.

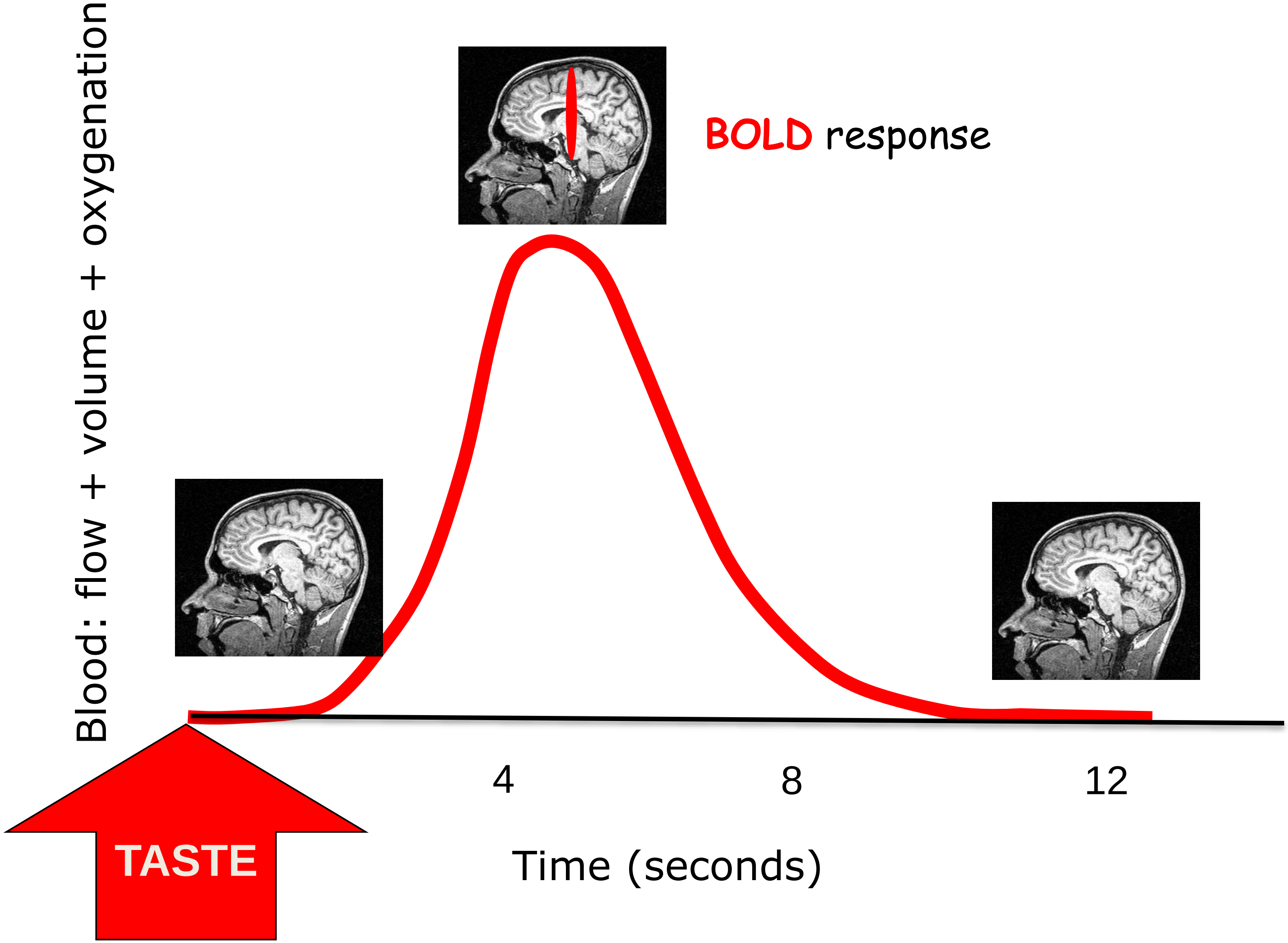


INCREASE IN BLOOD OXYGEN LEVEL IN ACTIVE AREAS

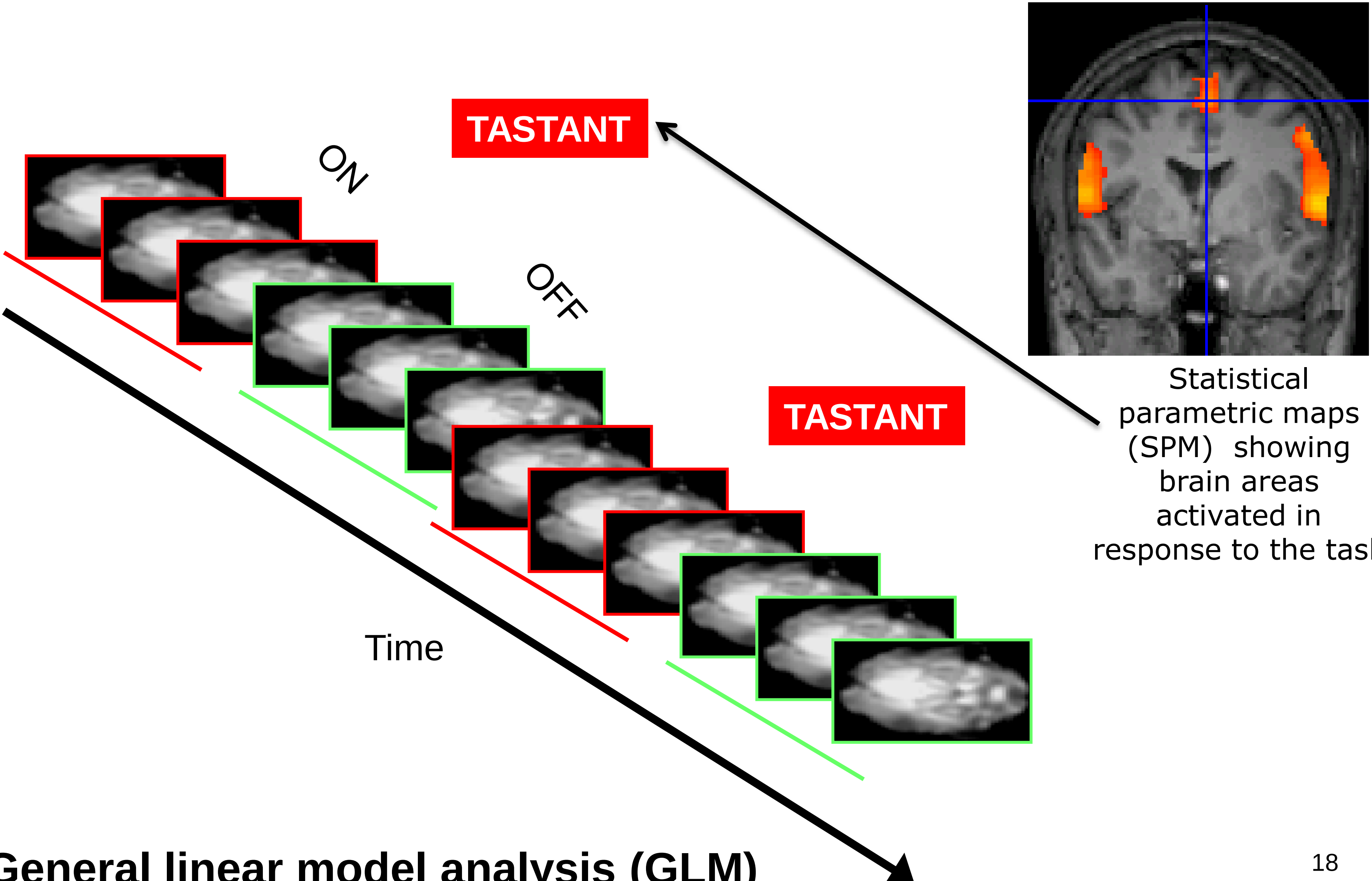
Blood Oxygen Level Dependent = BOLD response = 1-2% increase in image intensity in active brain areas

Measure with functional Magnetic Resonance Imaging (fMRI).

fMRI – How it works



fMRI – How it works



General linear model analysis (GLM)

fMRI protocols in nutrient research

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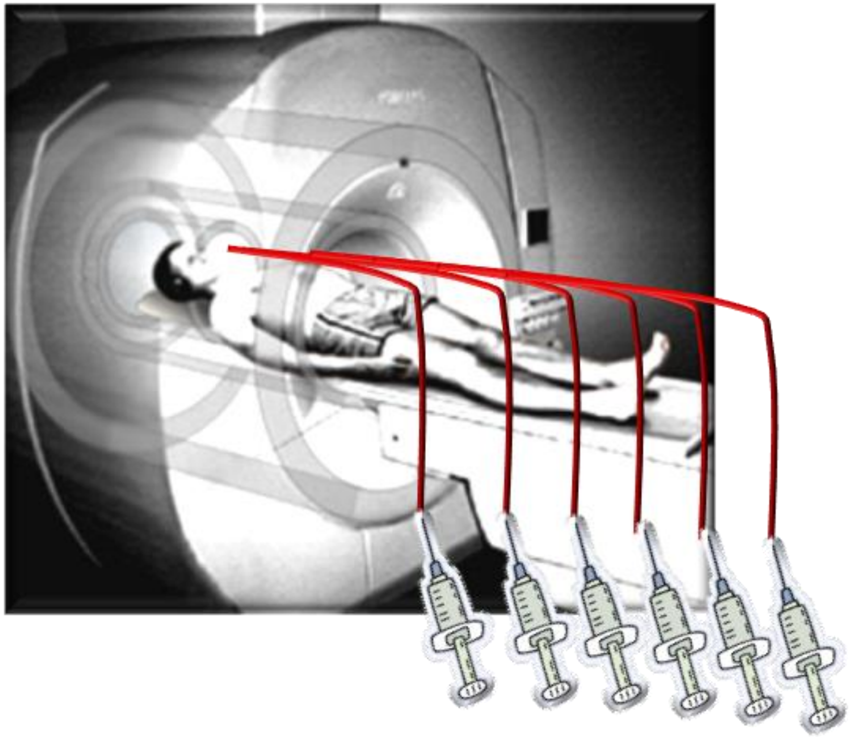
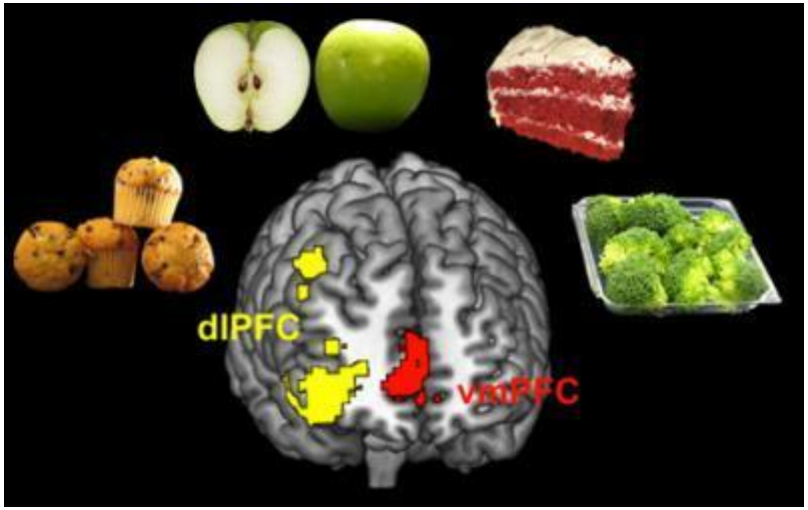
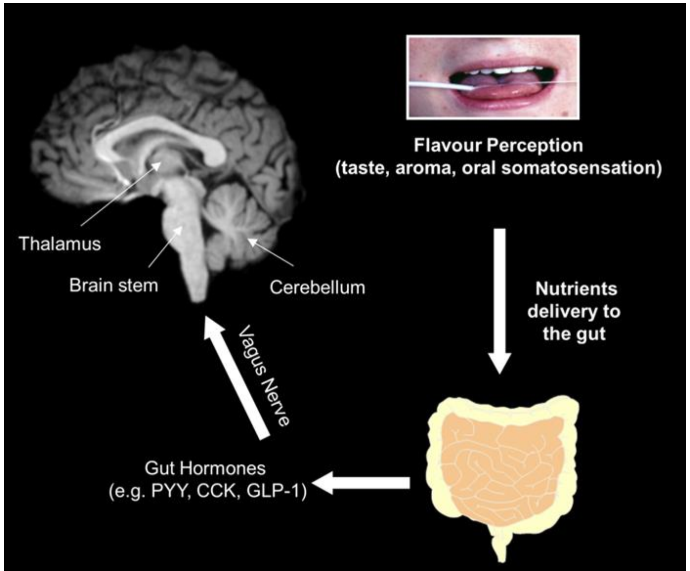
Delivering taste, aroma, flavour samples



Food images

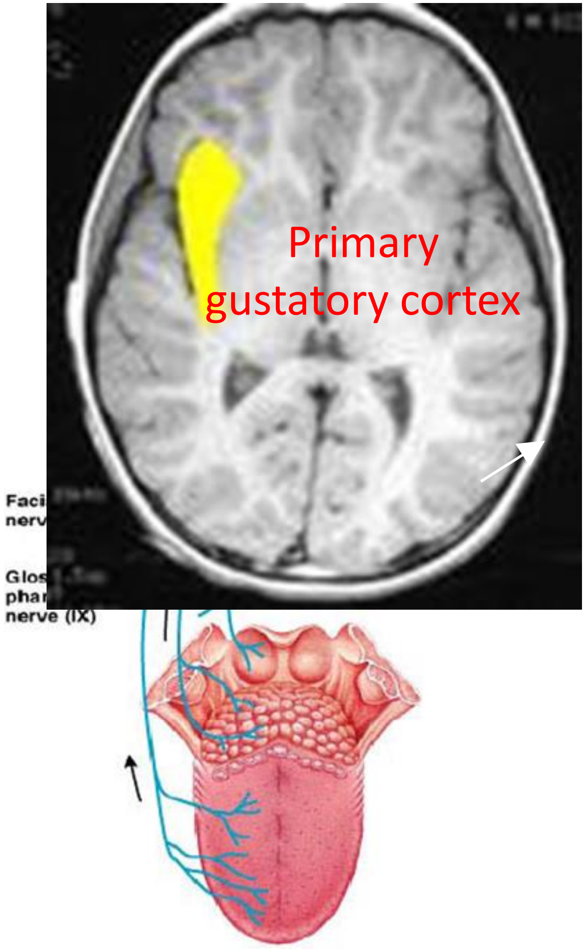


Gut – brain axis

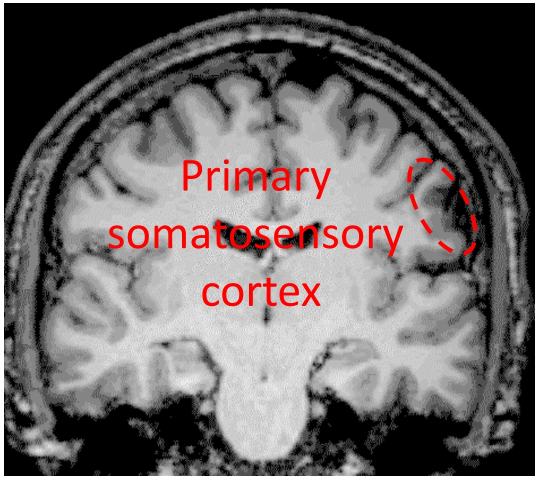


Brain areas involved in food processing

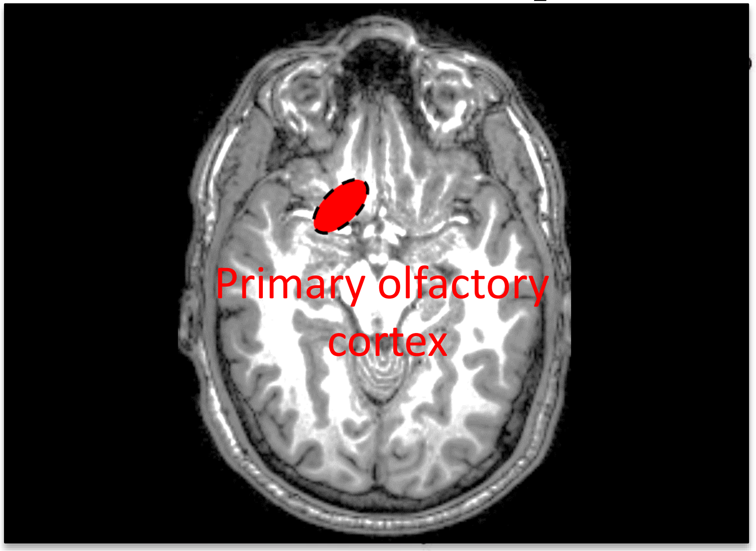
Taste



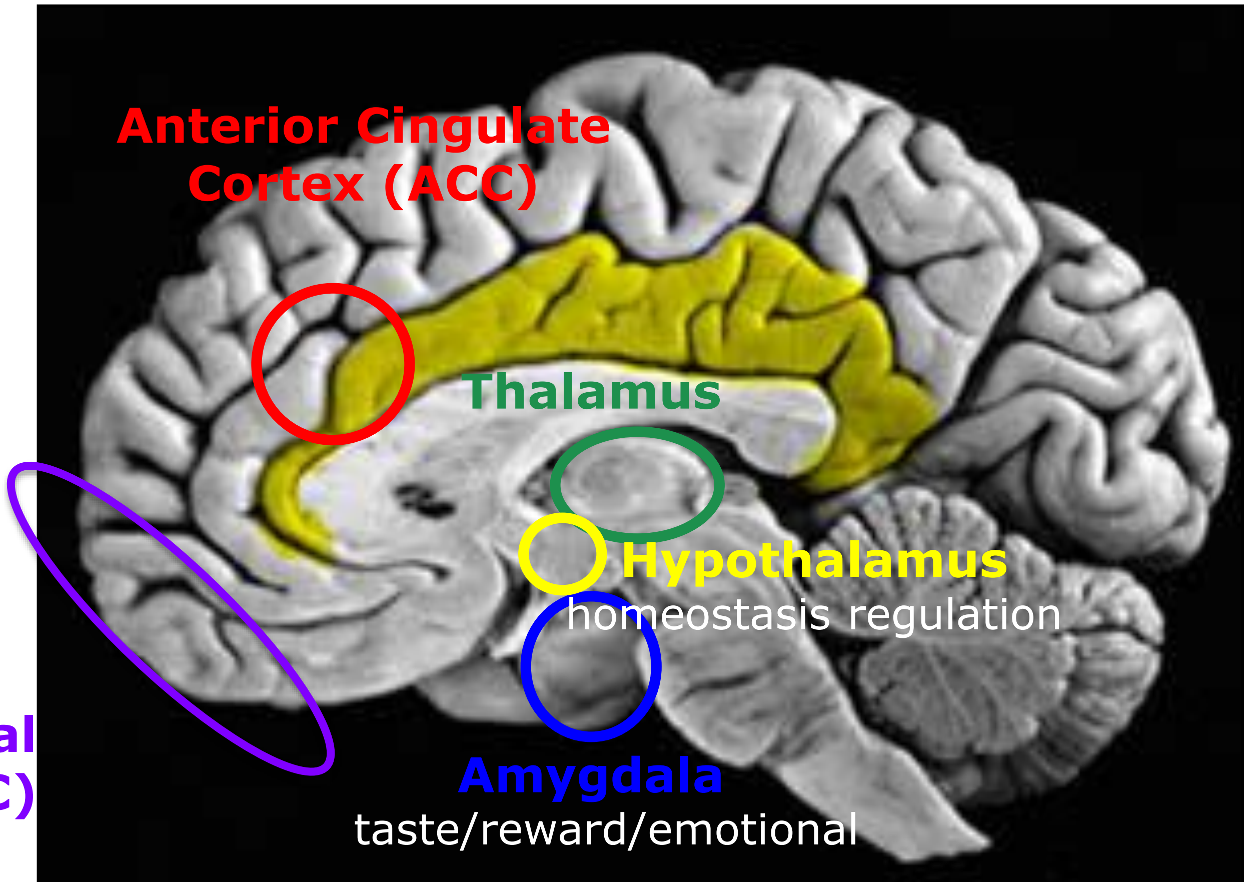
Somatosensory



Olfactory



Brain areas involved in food processing



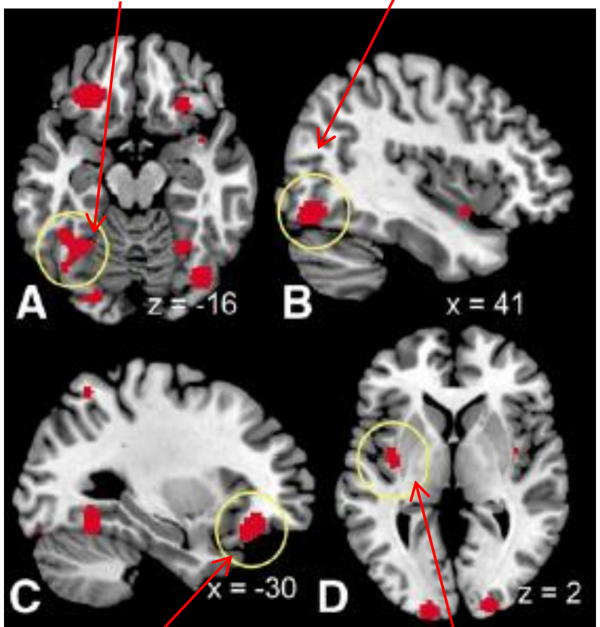
Orbitofrontal Cortex (OFC)
Multimodal Integration area

Brain response to food picture

Food > non food

Fusiform-occipital (Visual)

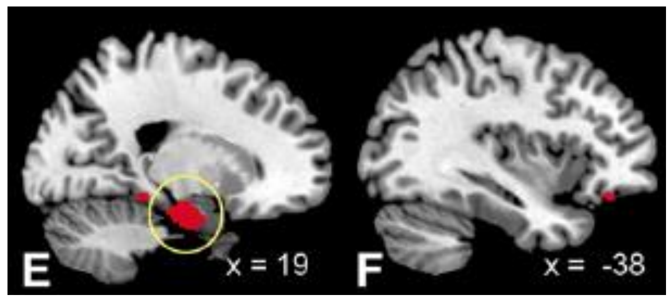
Fusiform



Lateral OFC (pleasantness)

Mid insula (Mouthfeel)

Hungry>satiated



Amygdala (reward/pleasantness)

Lateral OFC (Pleasantness)

High>low energy food

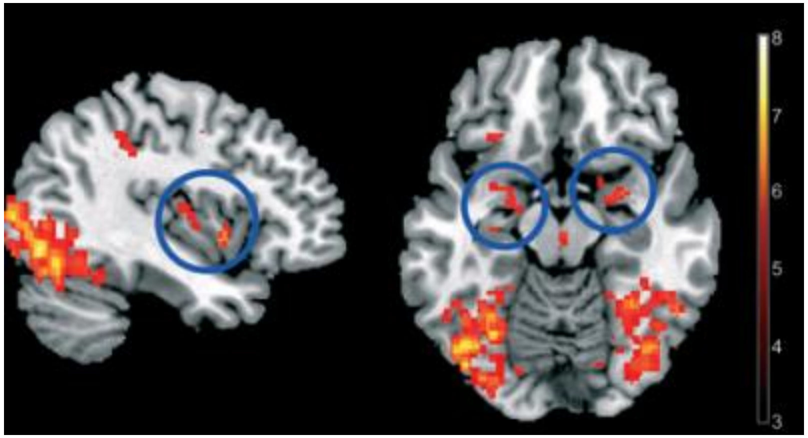
hypothalamus to striatum (Food regulation and reward)

van der Laan et al. The first taste is always with the eyes: a meta-analysis on the neural correlates of processing visual food cues. *NeuroImage 55 (2011) 296–303*

Brain activity in lean and obese subjects: Sweet drink prior to food images

Sucrose or non-nutrient sweetened beverage prior to viewing food or neutral images.

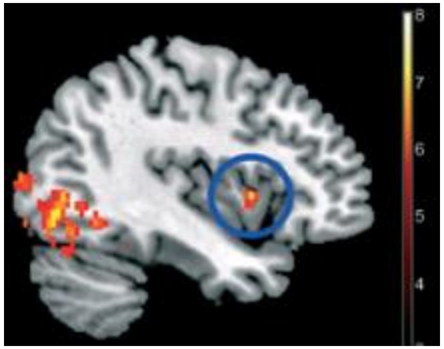
Obese > lean
food images



Taste areas (Insula)

Hedonic areas (Amygdala)

Obese > lean
High calorie sucrose c.f no nutrient



Insula

Obese women demonstrated greater hedonic brain response, although they report reduced hedonic behavioral responses to sweet drink. This response pattern is similar to drug addiction.

Connolly et al . Differences in brain responses between lean and obese women to a sweetened drink. Neurogastroenterol Motil (2013) 25, 579–e460

Cortical response to oral fat

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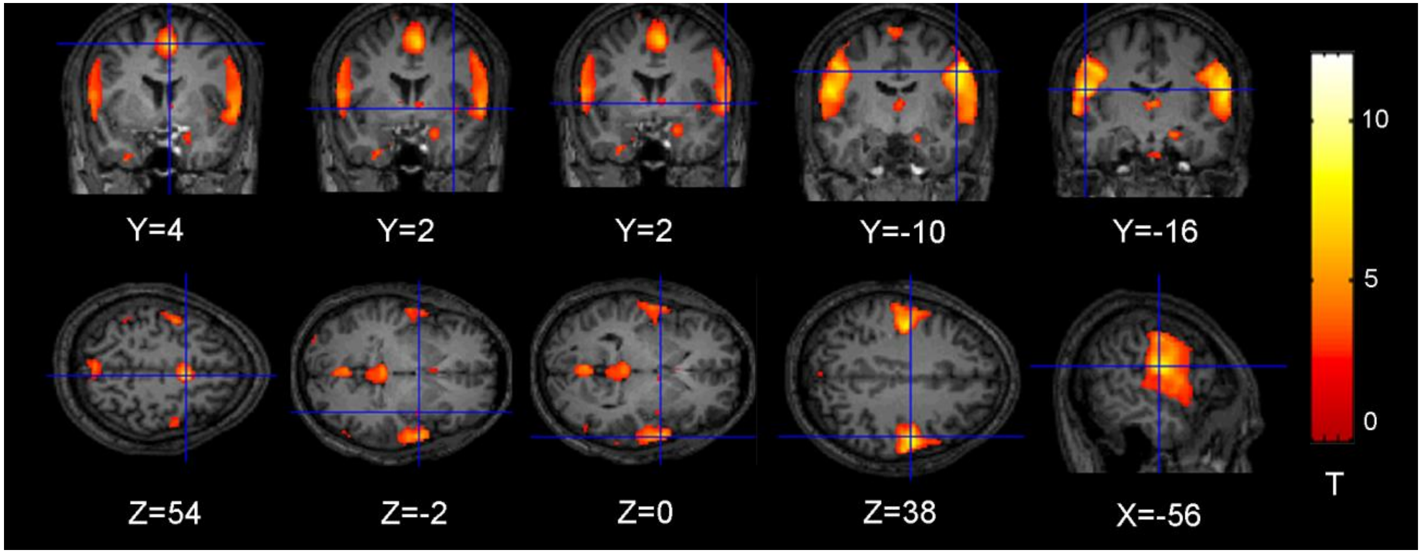
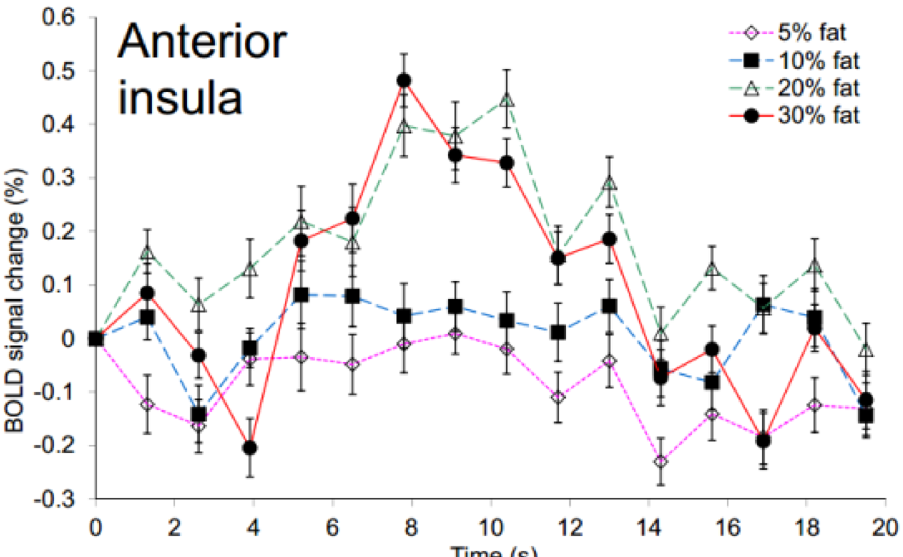


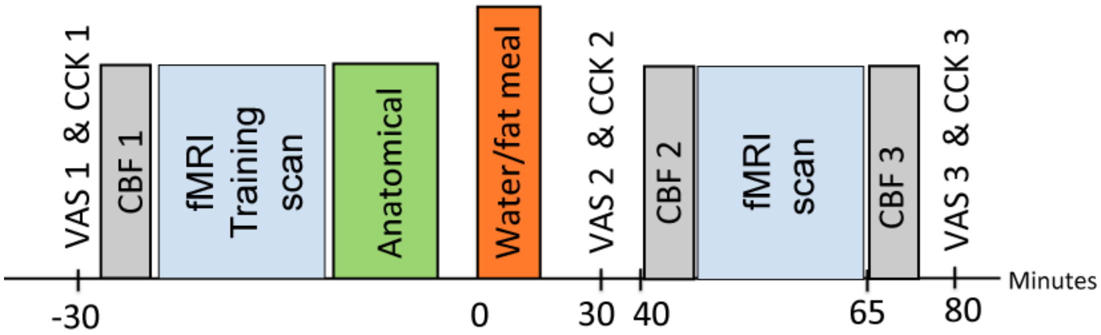
Fat emulsion samples:
Fully characterised in sensory lab using sensory evaluation techniques

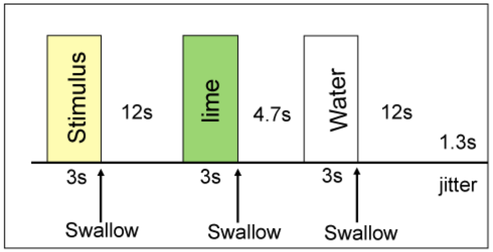
Iso-viscous: 5% fat
10% fat
20% fat
30% fat



Eldeghaidy S et al., J Neurophysiol. 2011;105(5):2572-81.

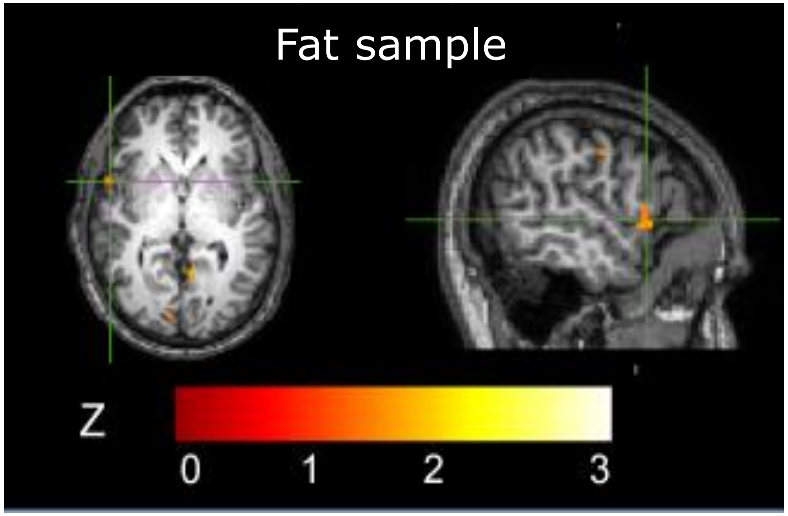
Hormonal interaction of gut and brain: effect of prior feeding of fat meal





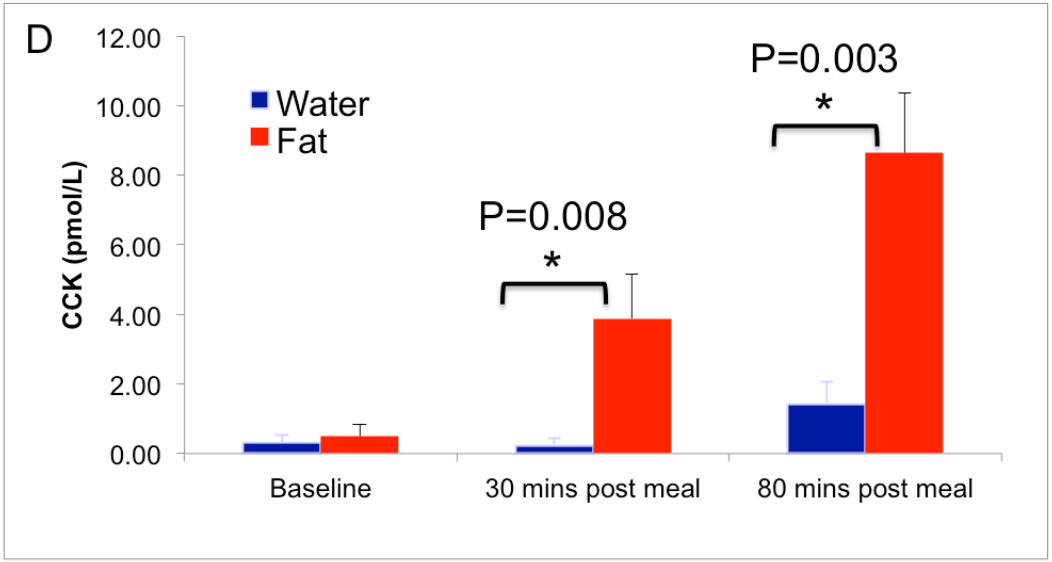
Water meal > fat meal

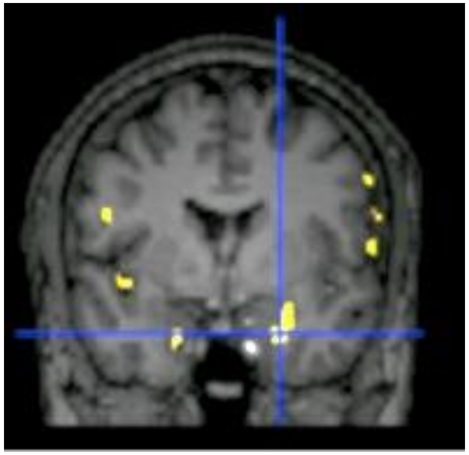
Suspression in taste areas following fat meal



Eldeghaidy et al., *Prior consumption of a fat meal by healthy adults modulates the brain's response to fat.*, J Nutrition, (2016) 146, 2187-2198.

CCK correlation with BOLD response





BOLD negative correlation with CCK following the fat meal in amygdala, anterior, mid- and posterior insula, SI.

Cerebral blood flow (CBF) changes to fat/water meal

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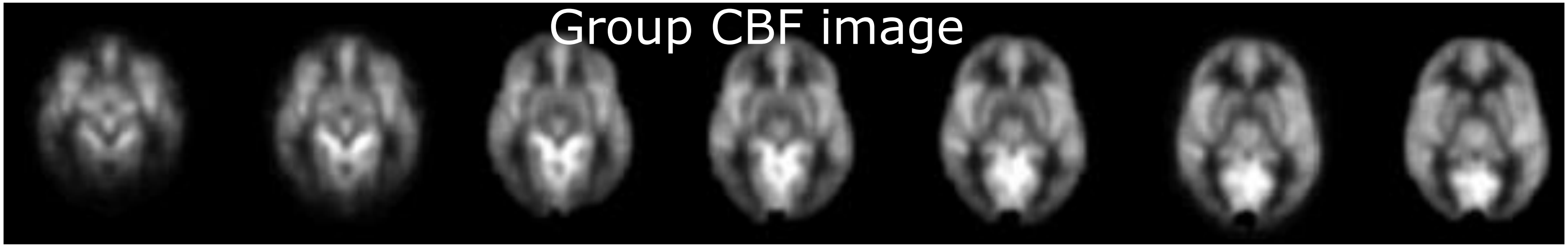
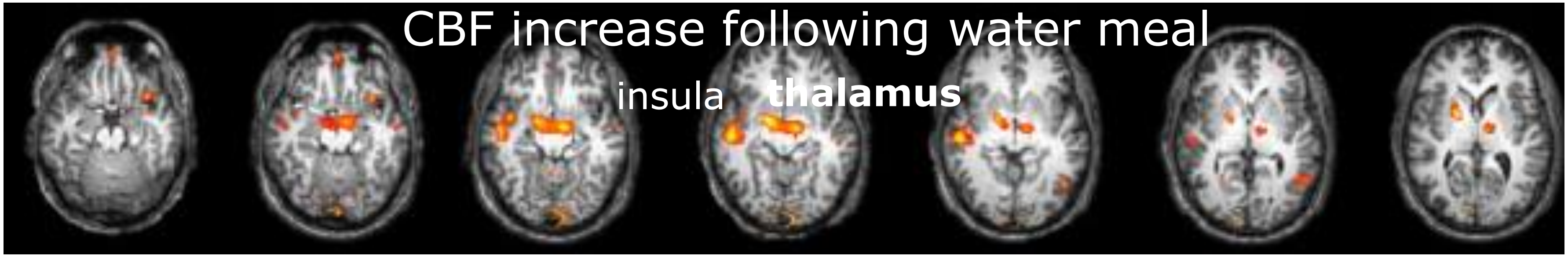


These results aid in understanding the role appetite regulatory hormones to control food intake and obesity.



See also: Frank S et al., Olive oil aroma extract modulates cerebral blood flow in gustatory brain areas in humans. Am J Clin Nutr. 2013 Nov;98(5):1360-6; Frank S et al. Fat intake modulates cerebral blood flow in homeostatic and gustatory brain areas in humans. Am J Clin Nutr. 2012 Jun;95(6):1342-9; Page KA et al. Effects of fructose vs glucose on regional cerebral blood flow in brain regions involved with appetite and reward pathways. JAMA. 2013 Jan 2;309(1):63-70.

Effect of Taster Status on cortical response to fat

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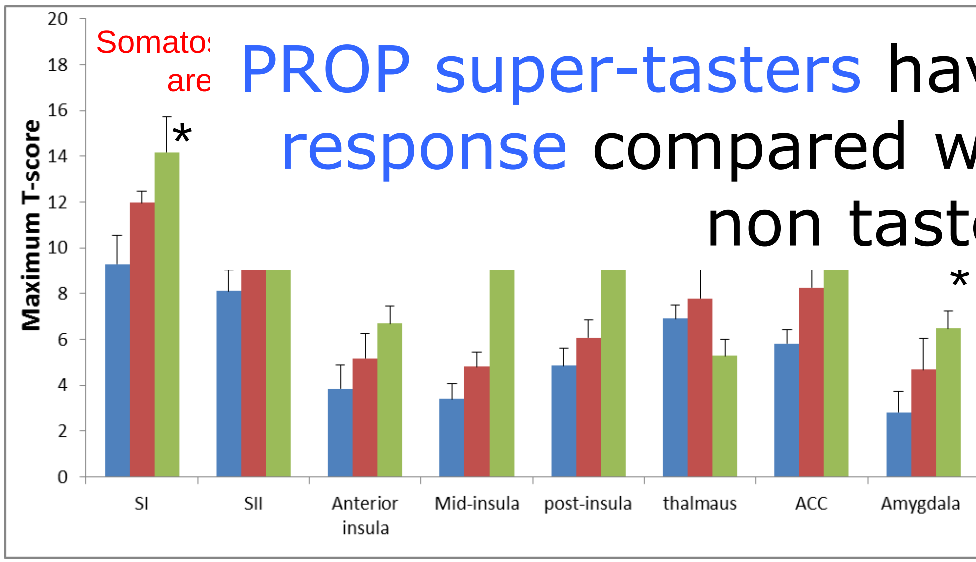
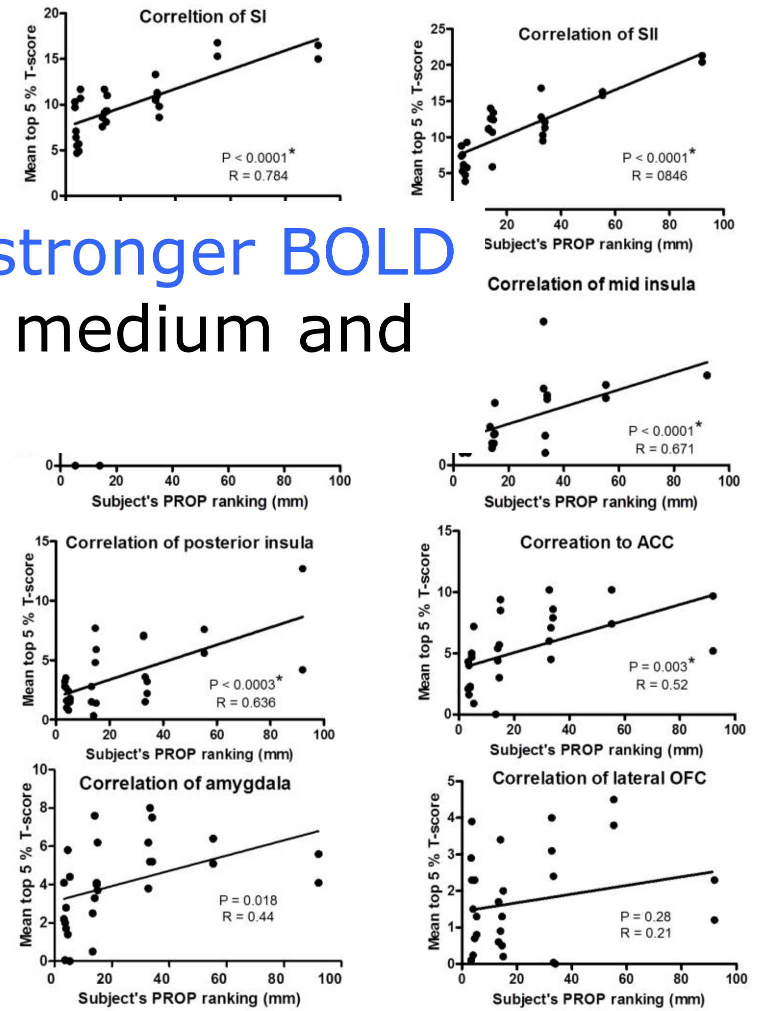
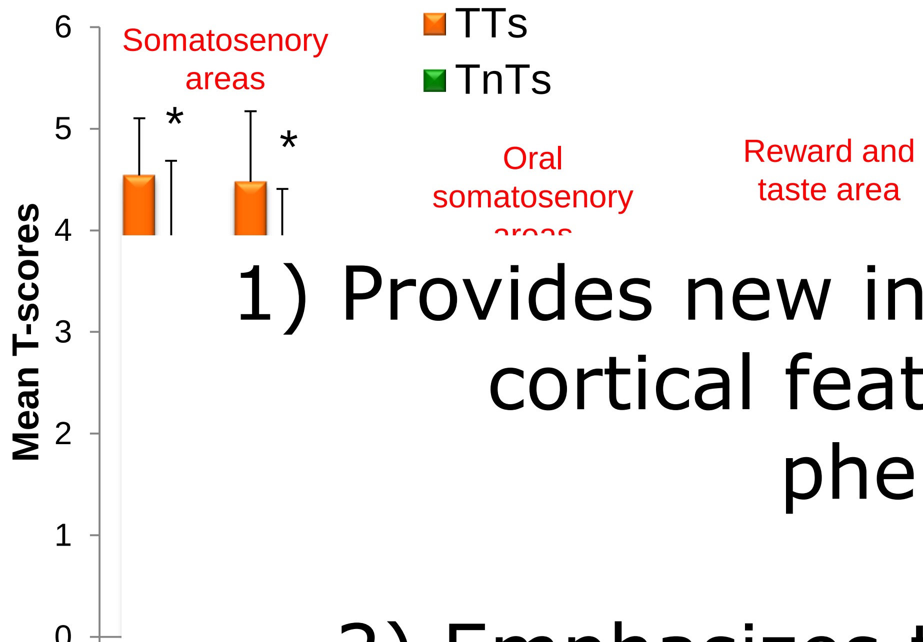


PROP super-tasters have stronger BOLD response compared with medium and non tasters



Eldeghaidy S et al., J Neurophysiol. 2011;105(5):2572-81.

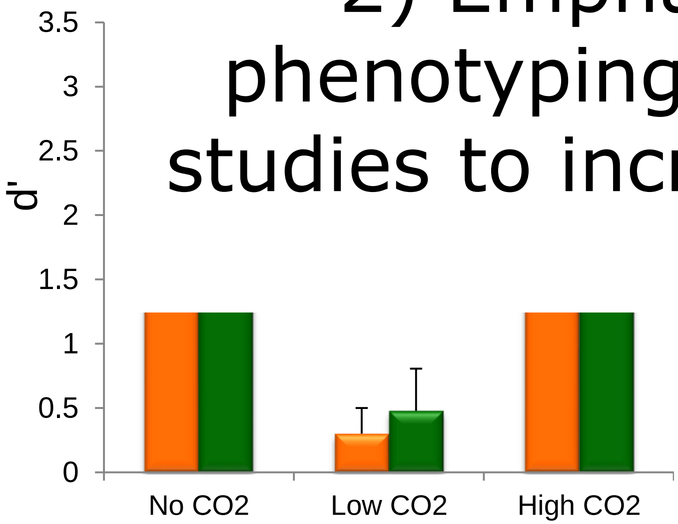
Effect of Thermal Taster status on cortical response to carbonation



TT > TnT for taste sample (No CO_2)

1) Provides new information about the cortical features of different phenotypes.

2) Emphasizes the importance of phenotyping participants for fMRI taste studies to increase the statistical power of group analyses



Hort, J et al., submitted to journal of HBM

Taste Perception: meta-analysis

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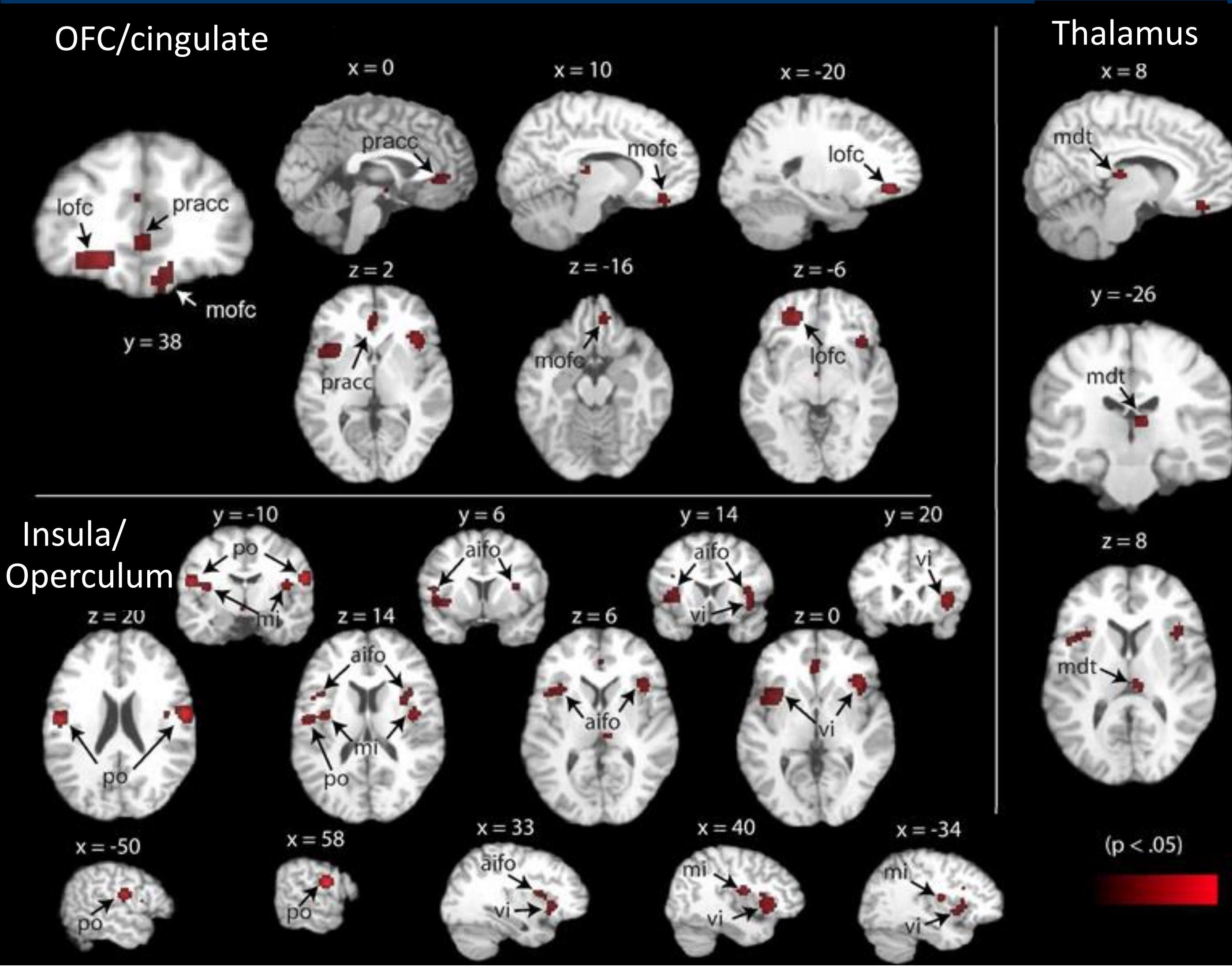

Contrasts (stimuli)*
taste (sucrose/citric acid/NaCl) -tasteless
taste(NaCl/aspartame/quinine hydrochloride/hydrocholic acid)-tasteless
sucrose-tasteless
sucrose-tasteless
sucrose-tasteless, citric acid-tasteless, saccharin-tasteless, caffeine-tasteless, GMP-tasteless, NaCl-tasteless
NaCl-tasteless
MSG-tasteless, NaCl-tasteless
glucose-tasteless, NaCl-tasteless
glucose-tasteless, NaCl-tasteless
NaCl-tasteless
citric acid - water
sucrose-tasteless, quinine sulfate-tasteless
taste (citric acid/sucrose/quinine sulfate/NaCl) - tasteless
NaCl-tasteless
quinine hydrochloride-tasteless, sucrose-tasteless

Veldhuizen et al. Identification of Human Gustatory Cortex by Activation Likelihood Estimation. Hum Brain Mapp. (2011); 32 (12): 2256-2266

Can we identify a gustotopic map in the human brain?

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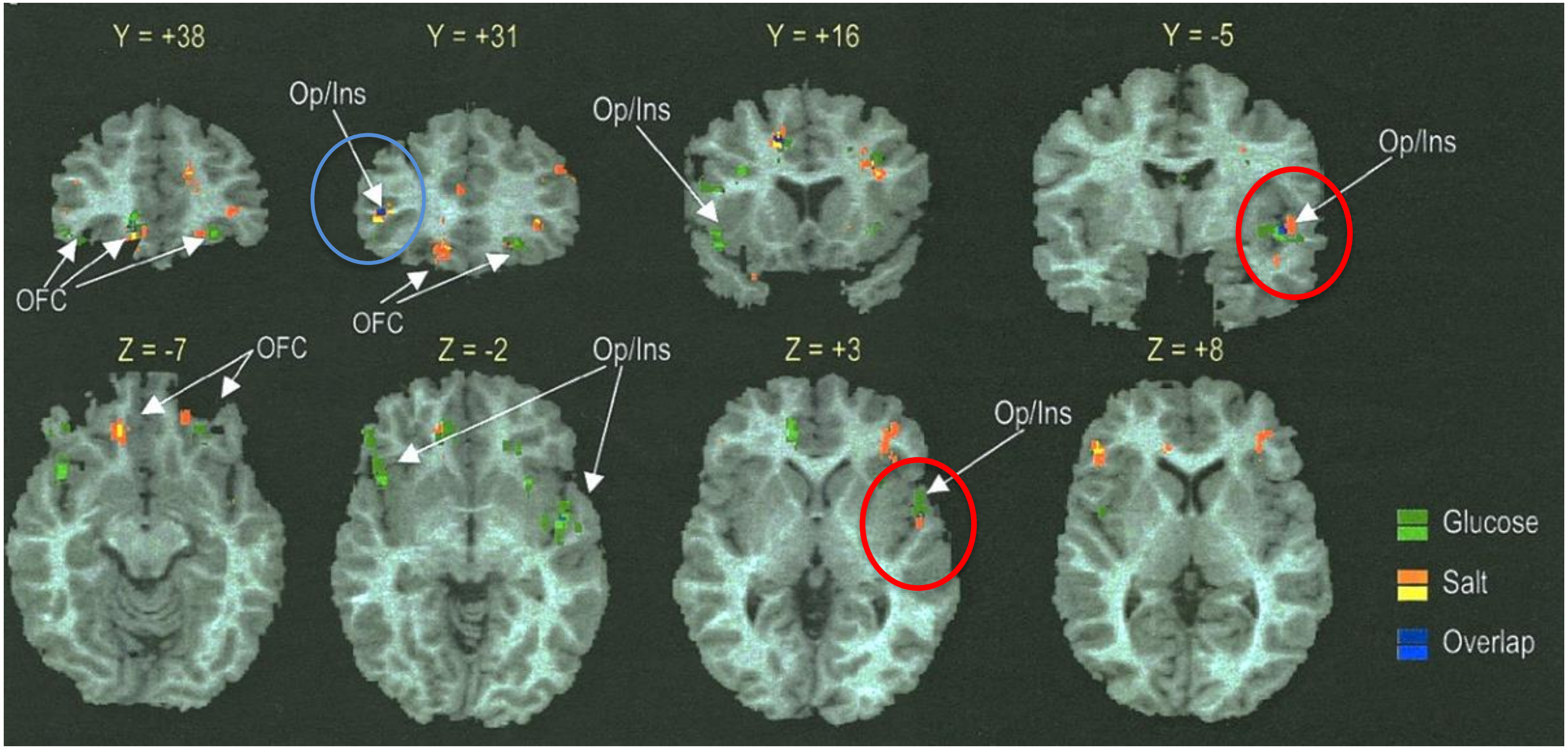
Evidence of topographic representation of sweet and salt sensation in the insula/FO and OFC

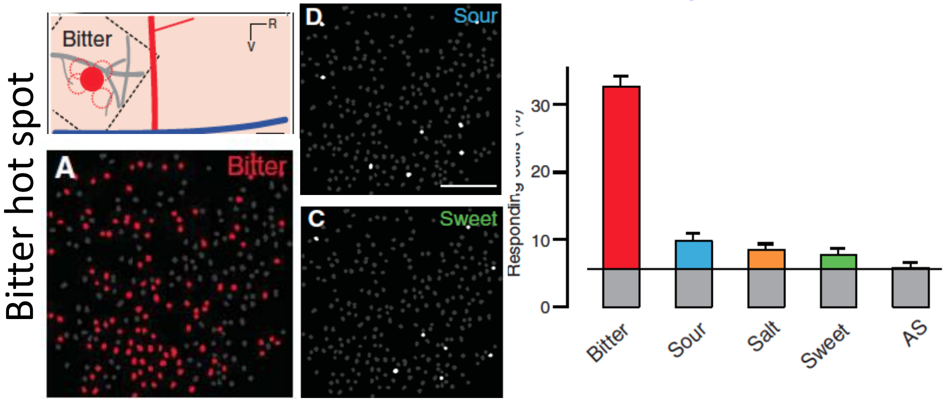


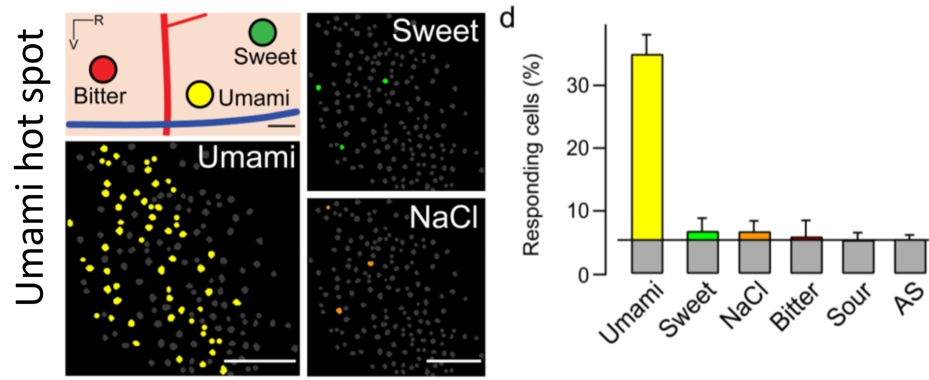
O'Doherty J. et al., J. of Neurophysiol. 2001;85 (3): 1315-1321

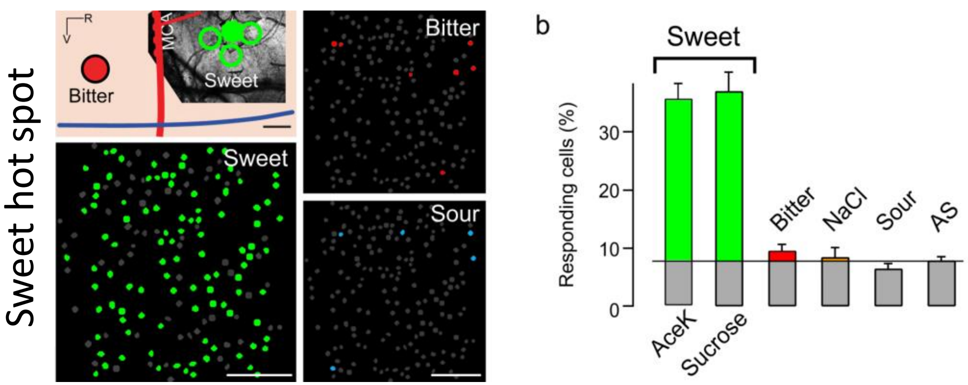
Can we identify a gustotopic map in the human brain?

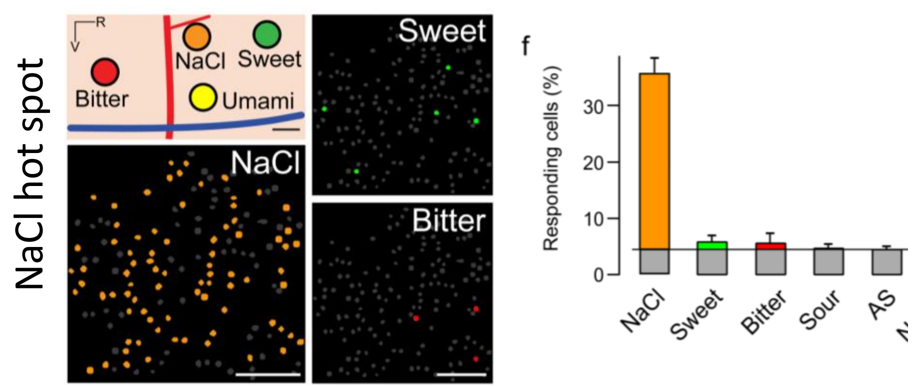
Gustotopic map in insula

Two photon imaging









Chen et al., Science, 2011; 333 (6047):1262-1266

Can we identify a gustotopic map in the human brain?

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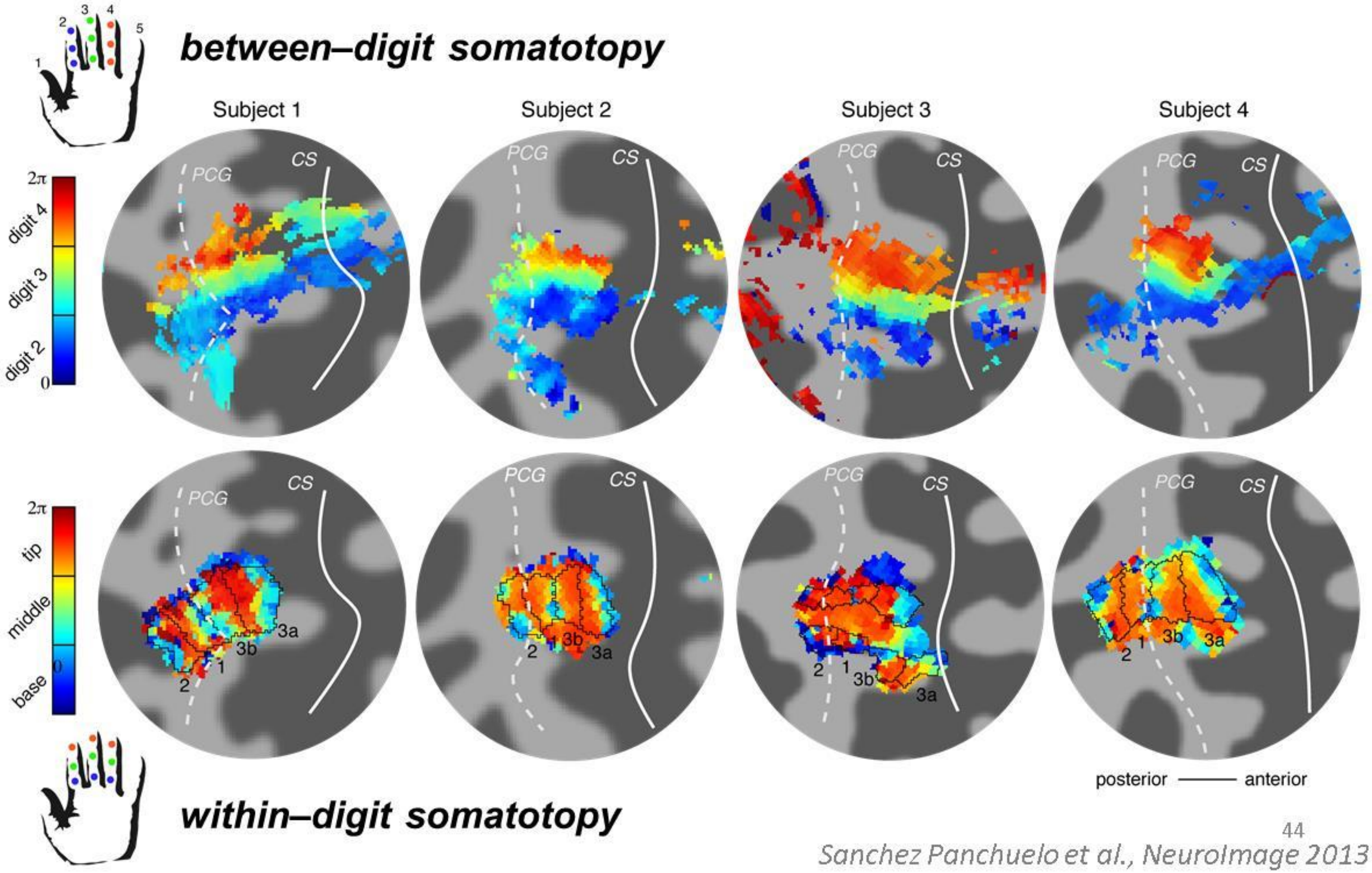
Ultra-high field fMRI (7 T)



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Sanchez Panchuelo et al., NeuroImage 2013

Current research at Nottingham: Gustotopic mapping

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Aim

- Explore both the perceptual and brain response to taste using sensory science and fMRI

Objectives

- Identify gustotopic map of tastants in the human brain
- Determine if the gustotopic map varies across taste phenotypes

- Discover how phantom taste is represented in the brain of thermal taster phenotypes

Gustotopic Mapping: Stimuli Development

Aim

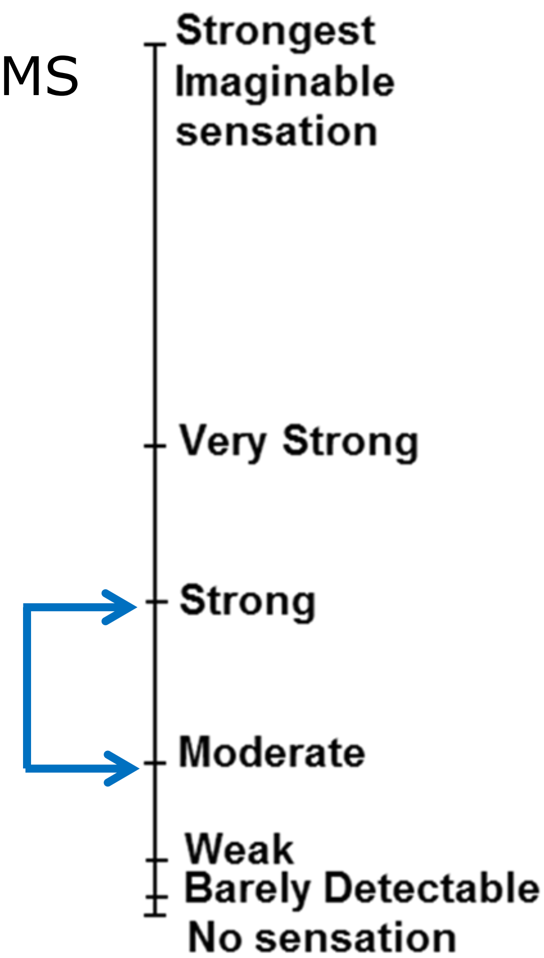
- Equi intense tastants moderate/strong on gLMS
- Palatable across different taste sensitivities

Tastants

- Sweet (glucose)
- Sour (citric acid)
- Salty (sodium chloride)
- Bitter (quinine sulphate)
- Umami (monosodium glutamate)
- Metallic (iron sulphate) (Lawless *et al*, 2004)

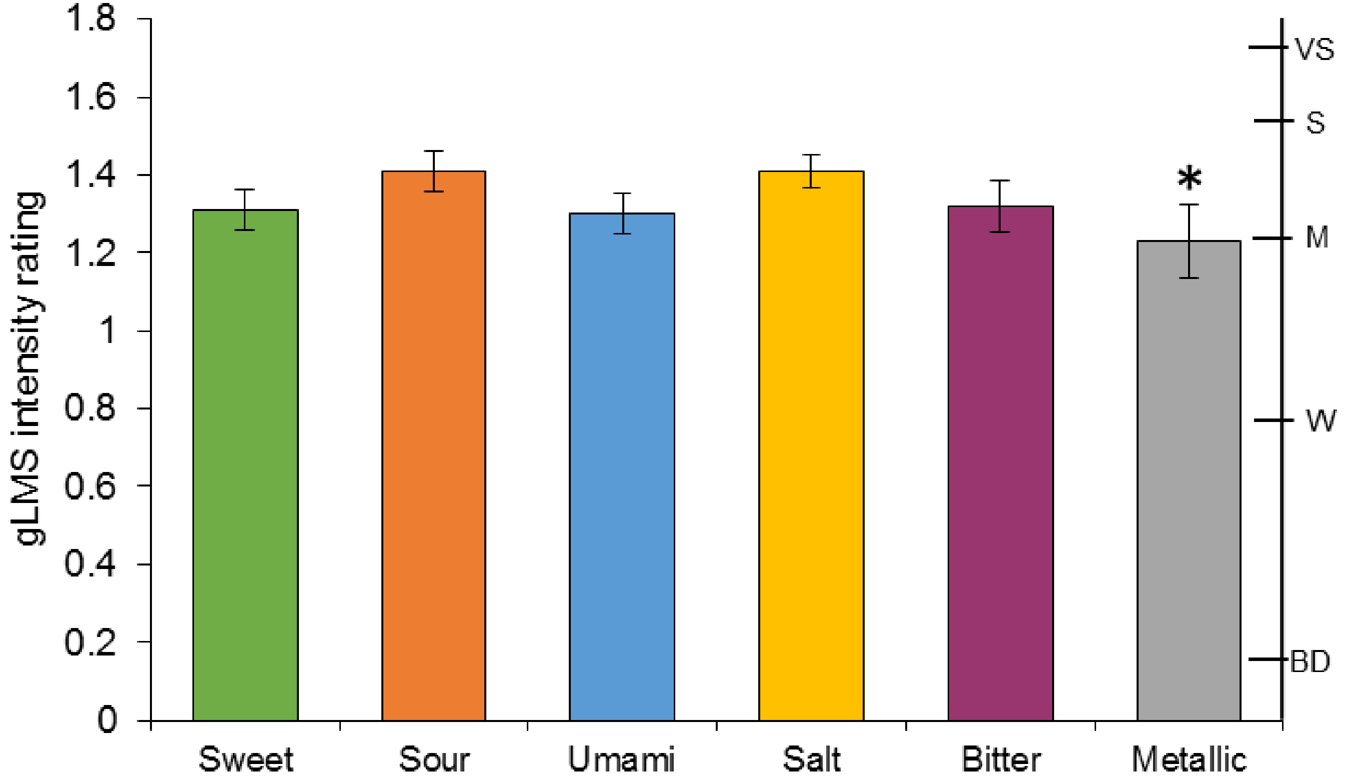
Objectives

- Sensory panel recruited (n = 10)
- Training of panel
- Sample assessment, statistical analysis, adapt concentrations



Gustotopic Mapping: Stimuli Development

Samples rated equi-intense at moderate-strong intensity



Bars represent log mean intensity rating, ± SE.
Word descriptors showing barely detectable-BD, weak-W, Moderate-M, strong-S, very strong-VS.

Gustotopic Mapping: Perceptual Testing

PROP taste testing

PROP

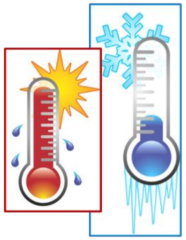
PROP taste groups

10 PNT

10 PMT

10 PST

TT status



Thermal taste groups

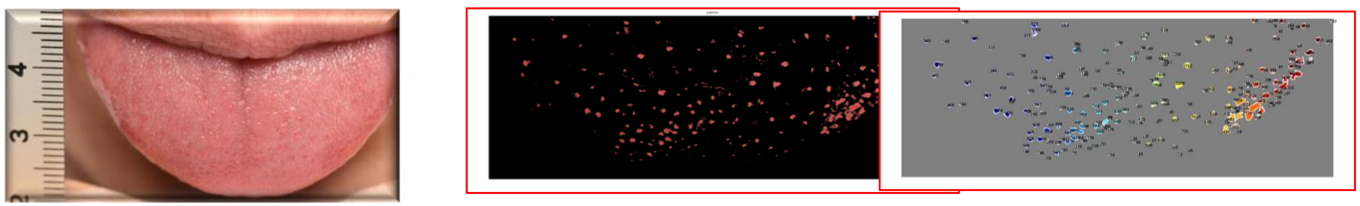
12 TT

12 TnT

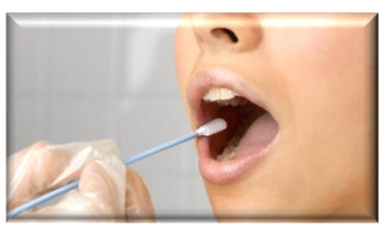
Gustotopic Mapping: Perceptual Testing

Taste sensitivity

Tongue imaged



Collect saliva swab



TAS2R38 genotype

Gustotopic mapping fMRI paradigm

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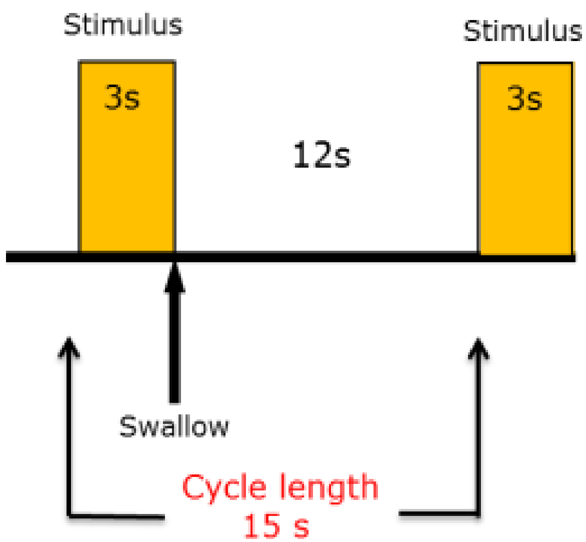
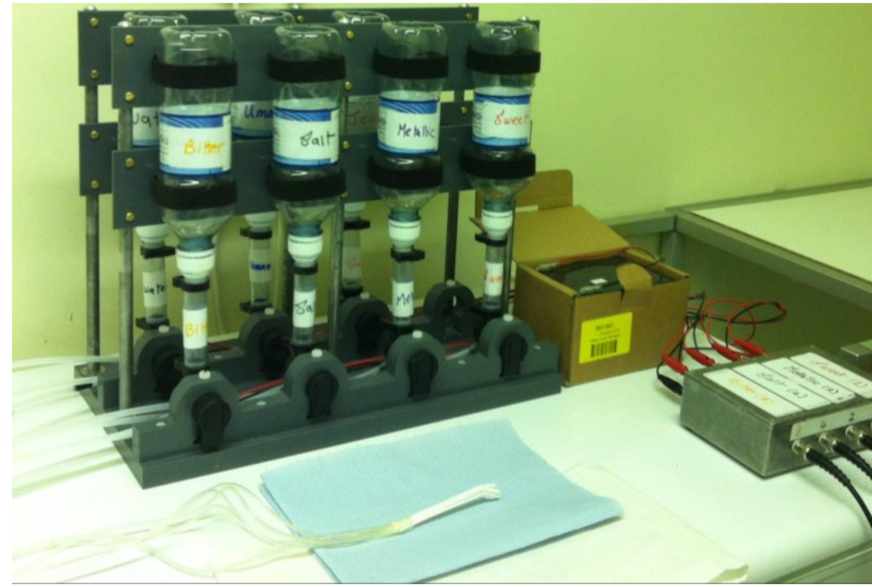
- Sweet
- Sour
- Salty
- Bitter
- Umami
- Metallic
- Deionised water (control)

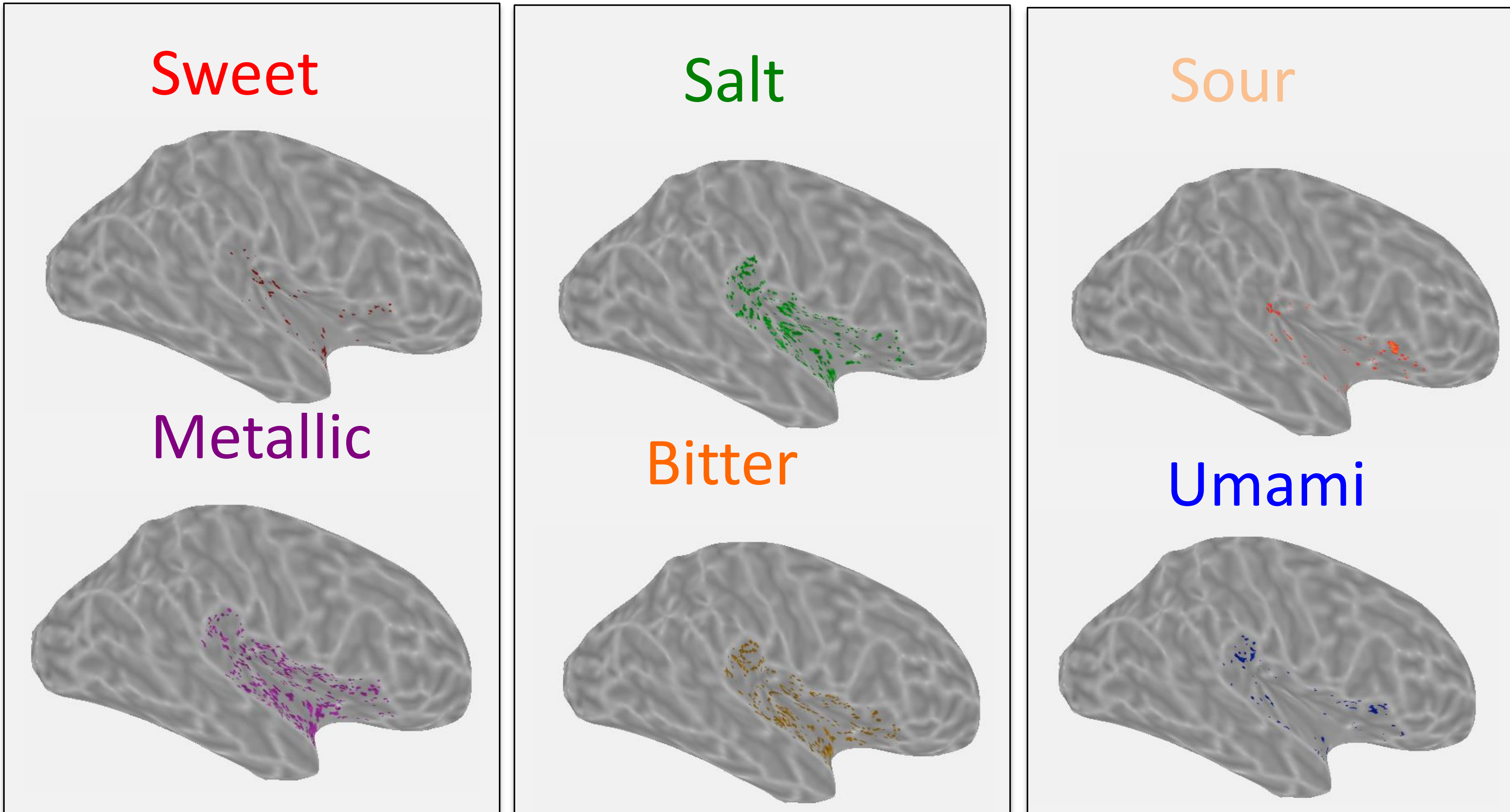




Marciani L. et al. J. *of Neuroscience Methods.* 2006; 158:186-194.

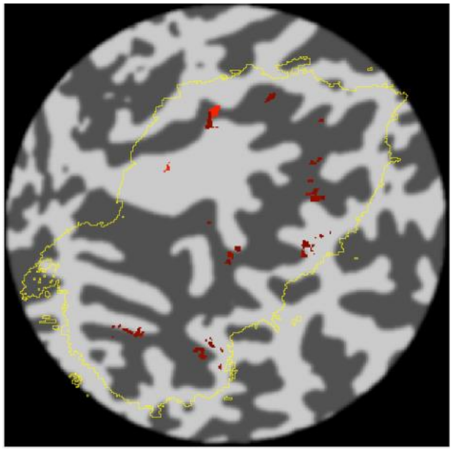
10 repetition of each taste

7 Tesla: Gustotopic mapping

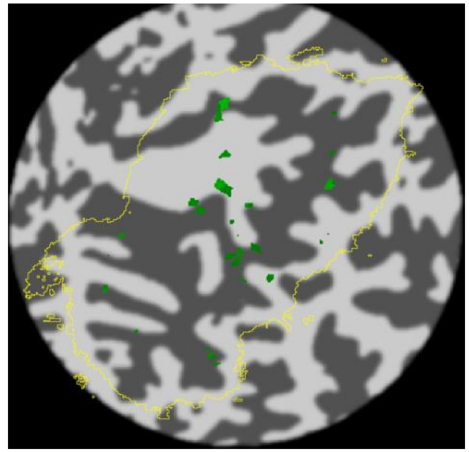


7 Tesla: Gustotopic mapping

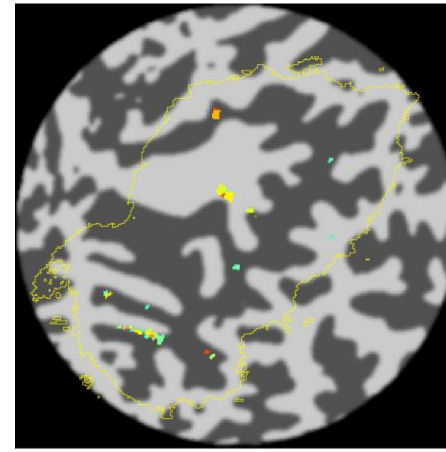
Sweet



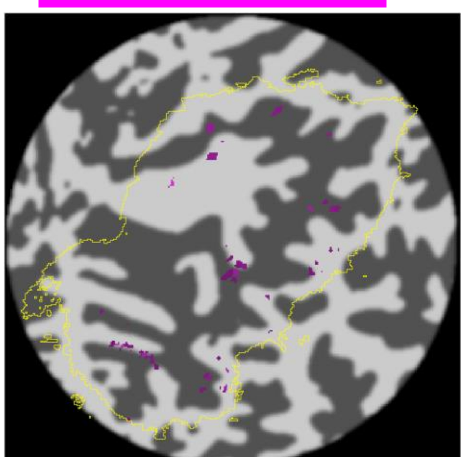
Salt



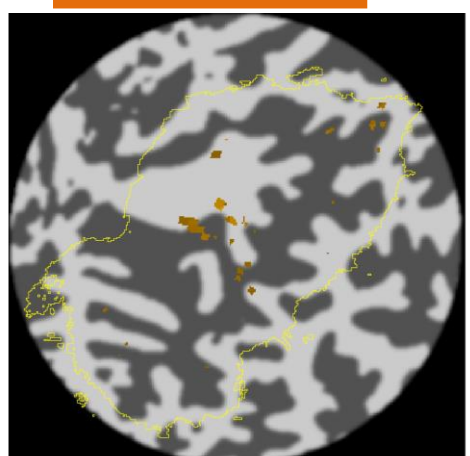
Sour



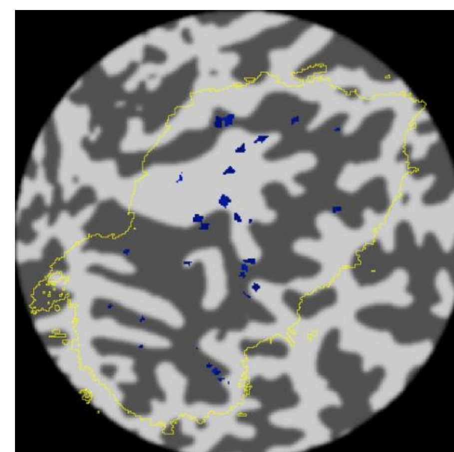
Metallic



Bitter



Umami



Mapping Phantom Taste

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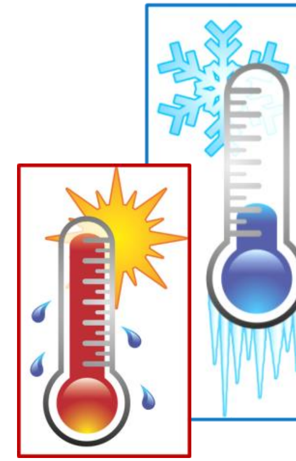


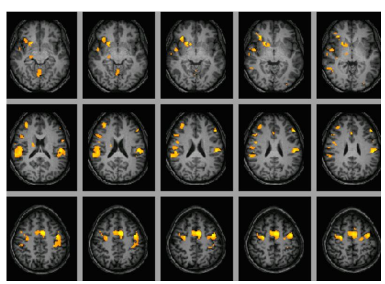
Aim

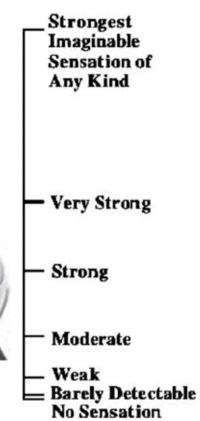
- Measure phantom taste related brain activity in thermal tasters

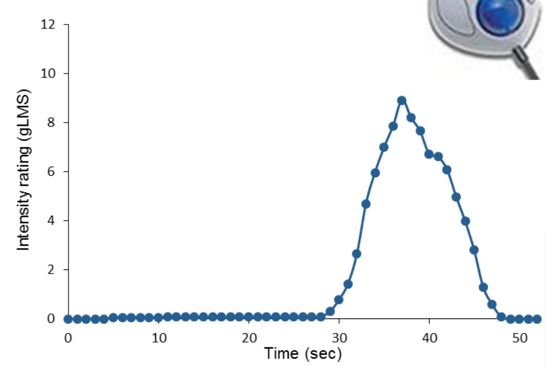
Objectives

Thermally stimulate the tongue:

- TTs rate phantom taste intensity
- Imaging the brain using fMRI

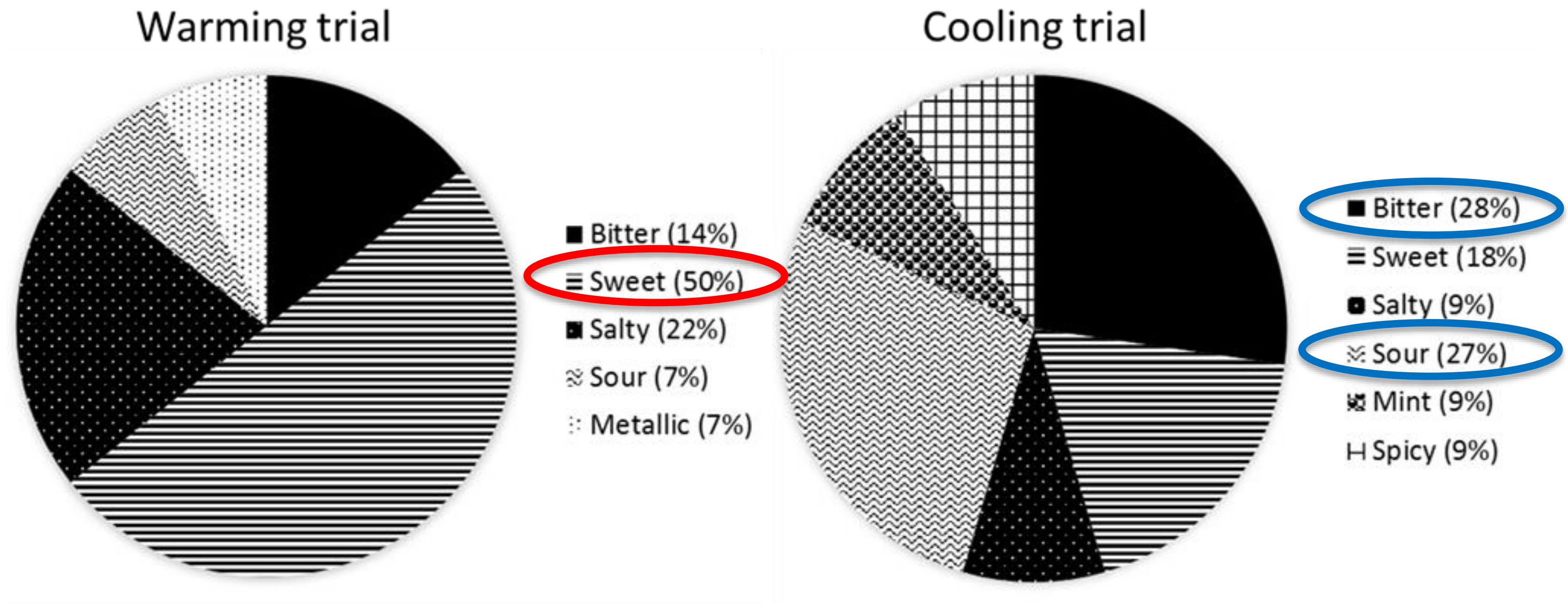






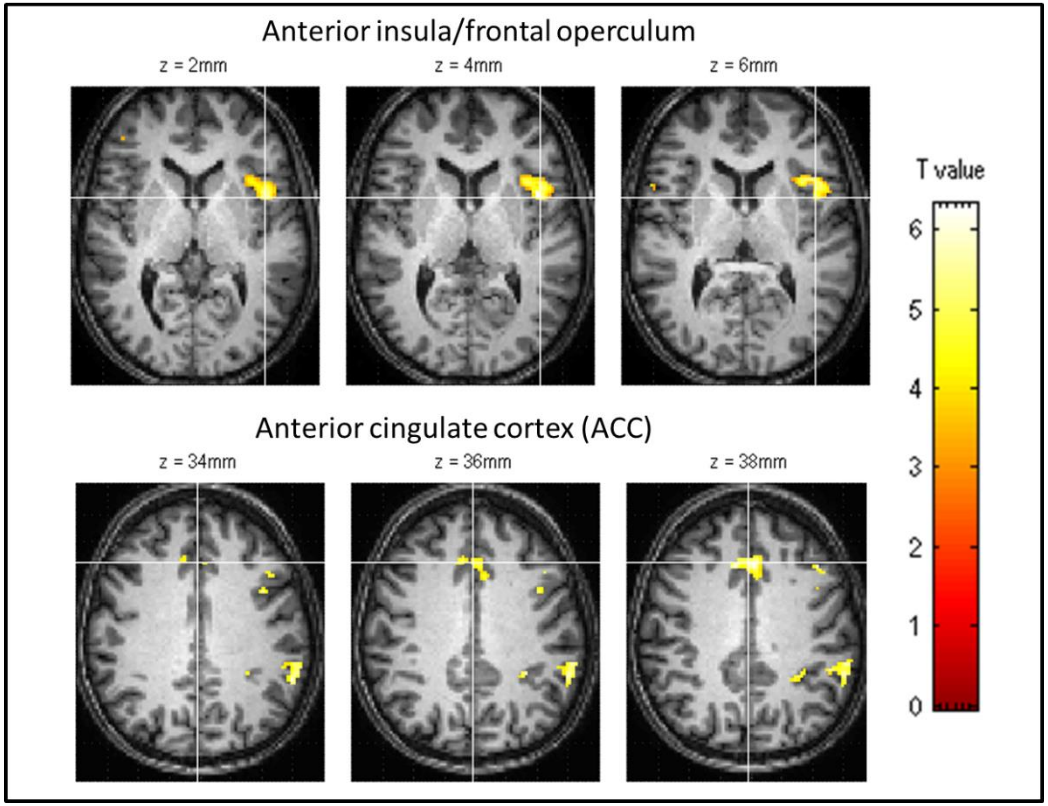
Do we s
associated
time

Phantom Taste Mapping: Phantom Tastes Perceived



fMRI: Subjects scanned during a paradigm in which the oral probe is heated and cooled.

Cortical response to phantom taste



Take home messages

- Ultimately it is important to bridge the gap between sensory science and brain imaging.

- Recent developments in MR technology, enabled investigation of the neural underpinnings in nutrition research.

- Taste phenotypes are important characteristics to consider when exploring taste perception, food preference which drive food choice.

Interested in research?

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Funded PhD positions

- www.findaphd.com
- www.jobs.ac.uk
- www.prospects.ac.uk
- Check individual University websites

Acknowledgements

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- Sue Francis
- Sally Eldeghaidy

SPMIC Sir Peter Mansfield Imaging Centre Nottingham

- Joanne Hort
- Martha Skinner
- Rebecca Ford

SSC Sensory Science Centre

BBSRC bioscience for the future

Unilever

www.nottingham.ac.uk/biosciences/research/research-themes/taste-map/taste-map.aspx