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Taste and function

Peter Svensson

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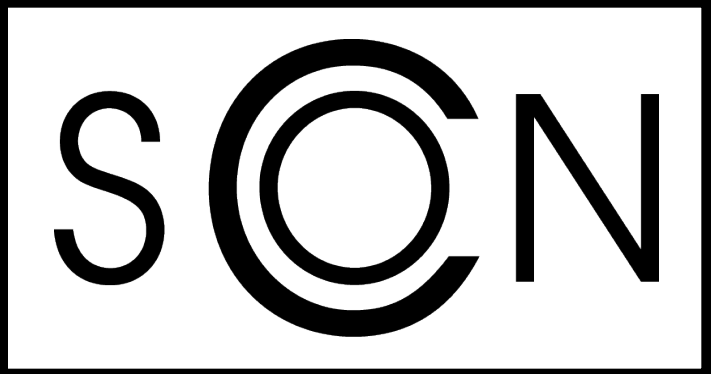
&
Scandinavian Center for Orofacial Neurosciences

Hokkaido University, October 18th, 2014

Scandinavian Center for Orofacial Neurosciences



Research triangle

Who are we?

- **Aarhus**
  - Peter Svensson
  - Lene Baad-Hansen
  - Eduardo Castrillon
  - Karina Bendixen
  - + 3-4 ph.d.-students
  - + 4 visiting ph.d.-students

- **Karolinska**
  - Mats Trulsson
  - Malin Ernberg
  - Krister Svensson
  - Nikos Christidis
  - Britt Hedenberg-Magnussson
  - Yanos Grigoriadis
  - + 3-4 ph.d.-students

- **Malmø**
  - Thomas List
  - Per Alstergreen
  - Maria Pig
  - Andreas Dawson
  - Ewa-Carin Ekberg
  - + 3-4 ph.d.-students

SCON 2014

Proposed SCON mission

- To bring together in a brickless center, leading Scandinavian groups in the field of orofacial neurosciences including oral physiology and orofacial pain, and to strengthen the research activities and impact on education and treatment in oral rehabilitation.

Reseach aim

- SCON aims to provide cutting-edge research results and to constitute an attractive alternative to other major international centers in the field by recruitment of the best young research talents and securing external funding.

Teaching aim

- SCON will provide a strong frame-work for research-based teaching of both under- and post-graduate scholars in the field.
- SCON will arrange and coordinate educational training of pre- and post-graduate students.

Clinical aims

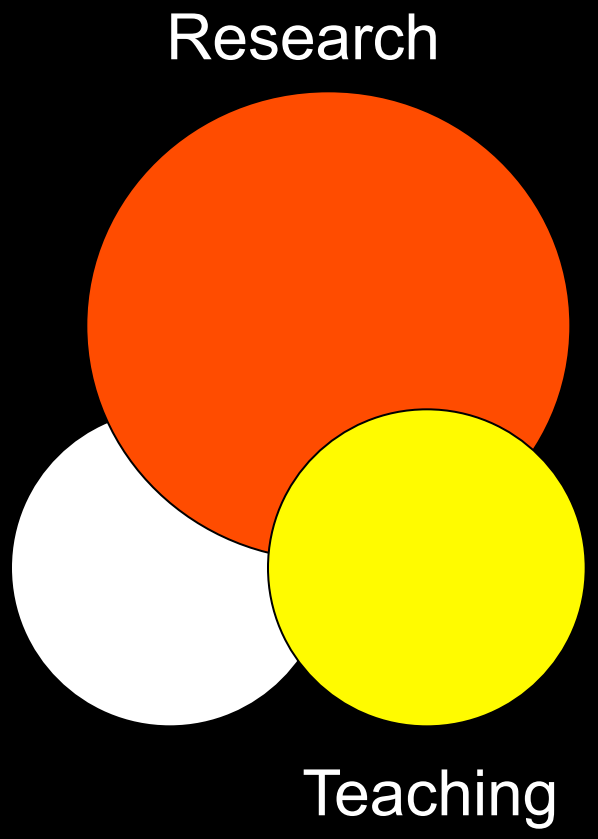
- SCON will help promote a paradigm shift in dentistry by emphasizing the importance of not only structure and esthetics, but also the functional aspects of oral rehabilitation.
- Oral neuroscience principles will help guide the optimal rehabilitation of sensory, motor and emotional function for the benefit of the compromised patients.

Section of Clinical Oral Physiology

People at COP 2014

- **Peter Svensson, professor**
- **Lene Baad-Hansen, a.professor**
- **Eduardo Castrillon, ½ a.professor, ½ clinical teacher**
- **Karina Bendixen, ½ a.professor, ½ clinical teacher**
- **Gunver Madsen, Clinical teacher**
- **Mohit Kothari, Post-doc**
- **Akiko Shimada, Ph.d.-stud.**
- **Lilja Dagsdottir, Ph.d.-stud.**
- **Simple Futurmal, Ph.d.-stud.**
- **Abhishek Kumar, Ph.d.-stud.**
- **Shun-Ichi Suzuki, Ph.d.-stud.**
- **Mika Honda, Ext. Ph.d.-stud.**
- **Hong Zhang, Ext. Ph.d.-stud.**
- **Yuri Costa, Ext. Phd.-stud**
- **Xuemei Yang, visiting researcher**
- **Tomoko Ikoma, Ext. Ph.d.-stud.**
- **Bente Haugsted, Research dental nurse**
- **Hanne Langgaard, secretary**

Wataru Yachida
Tomohiro Tanosoto
Tamy Takeuchi
Tomoko Ikoma



Research topics and themes at Clinical Oral Physiology

- Orofacial pain
  - Sensory function
  - Autonomic nervous system
- Brain function
  - Emotions and pain
- Jaw motor function
  - Mastication
  - Reflexes
  - Bruxism
  - Motor learning

Enjoyment of cooking !

Todays menu

- Enjoyment of food
- Masticatory function
- Taste physiology
  - Bad taste – pain ?
  - Good taste – enjoyment !

Semantics !

English is difficult

- Do women taste better than men ?
- Do women have better taste than men ?
- Are women better tasters than men ?

Enjoyment of food

Esthetics

Taste

Smell

Temperature

Texture

Masticatory function

Oral rehabilitation

Rehabilitation of people with [oral] disabilities is a process aimed at enabling them to reach and maintain their optimal physical, sensory, intellectual, psychological and social functional levels (WHO)

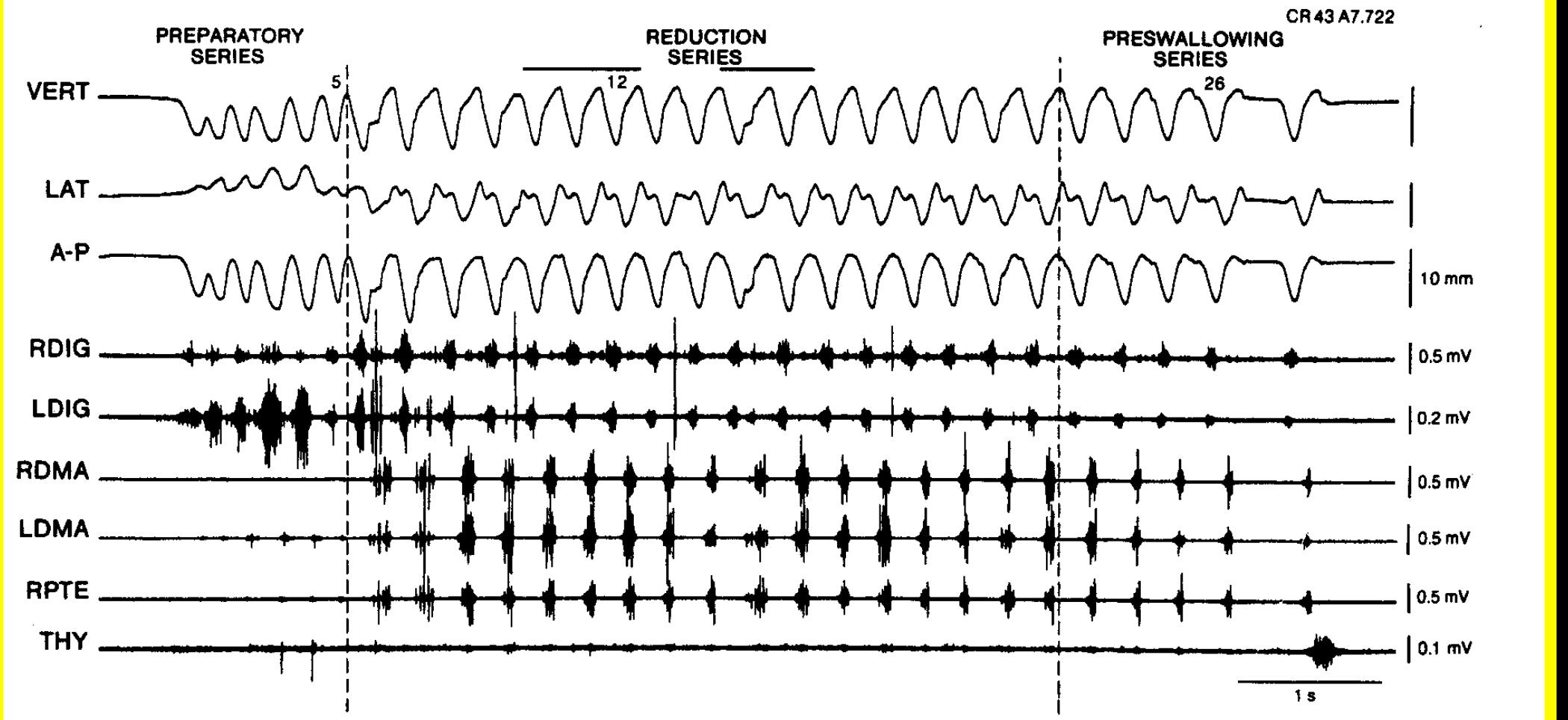
Optimal mastication is important part of oral rehabilitation

Masticatory function

- First stage in digestion
- Intermittant rhythmic act in which the tongue, facial and jaw muscles act in coordination to position the food between the teeth, cut it up, and prepare it for swallowing
  - I. Preparation - transport – ingestion and positioning of food
  - II. Reduction - processing – time trituration
  - III. Pre-swallowing - oropharyngeal accumulation time
  - IV. Swallowing - hypopharyngeal transit time

Mistry and Hamdy 2008

Rabbit mastication



From Schwartz et al. 1989

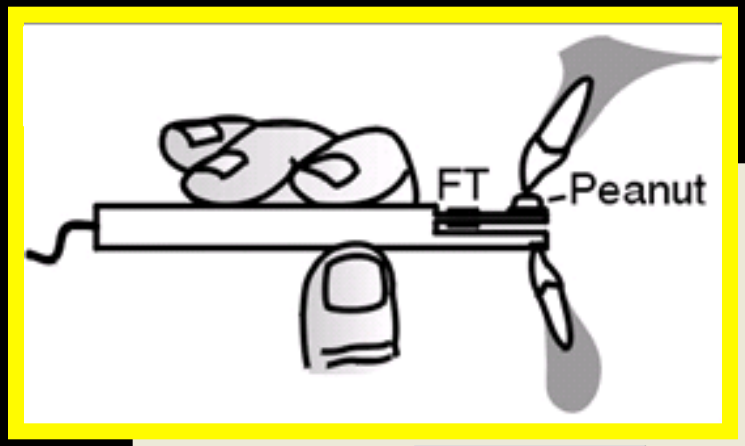
Human mastication

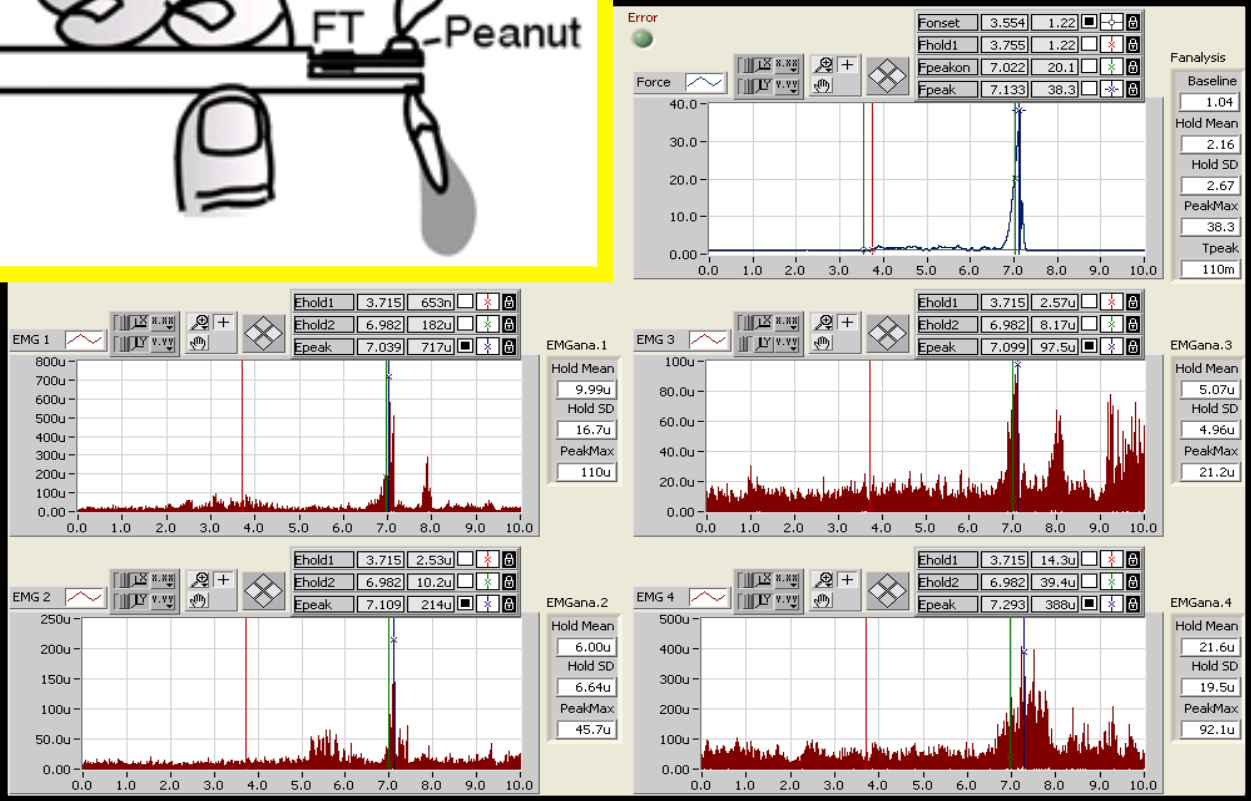
Woda et al. 2006

Assessment of isometric bite force

Maximum Bite Force

Incisor biting force – hold and split





Wang et al. JOR 1998
Trulsson and Gunne J Dent Res 1998
Kumar et al. Archs Oral Biol 2014

Assessment of dynamic bite force

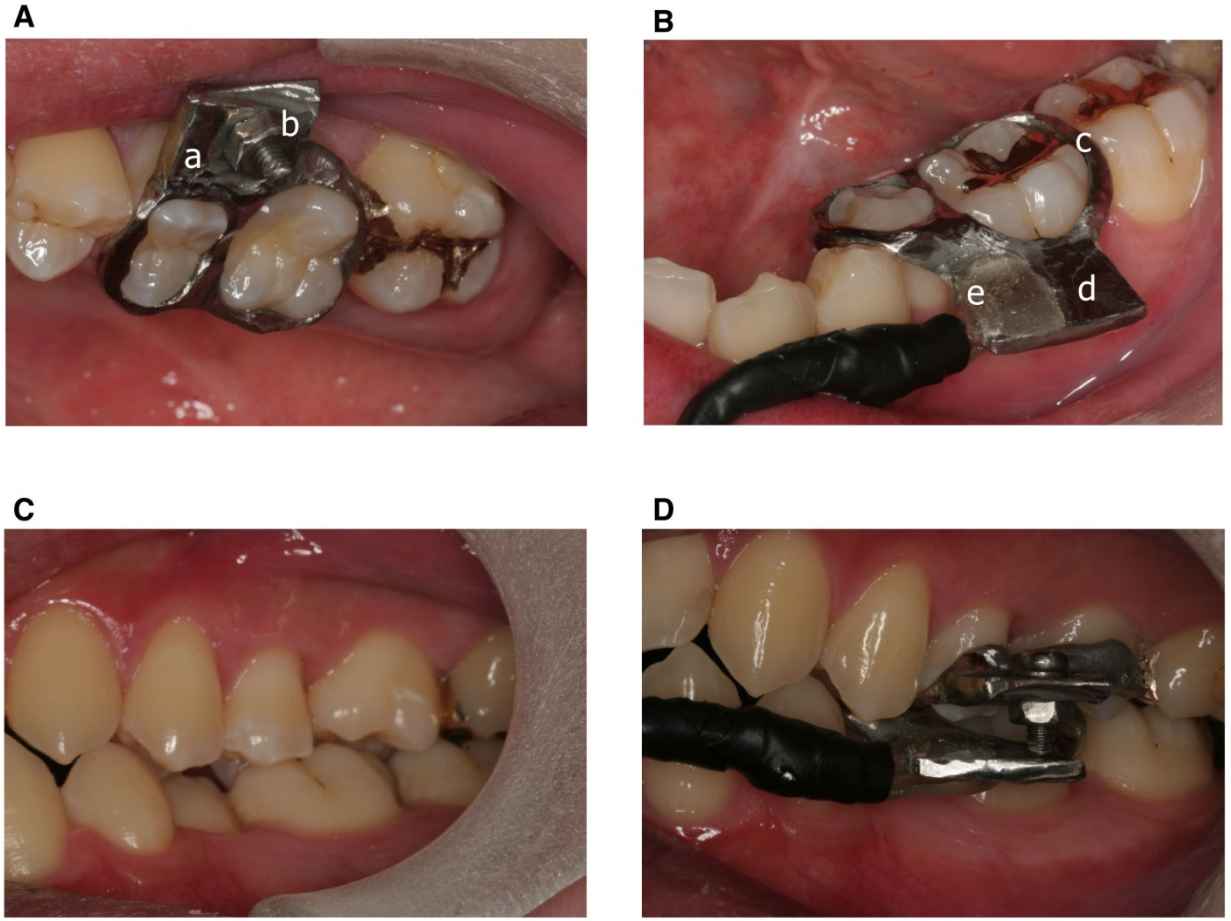


Fig. 1

Shimada et al. JOR 2012

Modulation of mastication

		Number of cycles	Sequence duration	EMG activity /sequence	EMG activity /cycle	Masticatory frequency	Vertical amplitude	Lateral amplitude	Closing velocity
Extrinsic factors	Hardness (from soft to hard)	↗ 10, 65, 66, 79, 81, 83	↗ 10, 25, 79, 83, 100	↗ 10, 65, 79, 83	↗ 10, 65, 78, 83	= 10, 79, 80, 83	→ 9, 10, 69, 79, 83, 84	→ 10, 81, 98	↘ 10, 32
	Physical properties (from elastic to plastic)	= 83	= 83	= 83	= 83	↘ 83	↗ 83	↗ 83	↗ 83
	Sample size	↗ 6, 84–86						→ 85, 89	↗ 6, 87, 89
Intrinsic factors	Age	↗ 39, 44, 49	↗ 39, 44, 49	↗ 39, 49	Depends on food 39, 49	= 39	= 39	= 39, 50	
	Gender (from female to male)	= 36–39	= 39	↗ 39	= 38, 39	→ 36, 38, 39, 94	↗ 36–39	↗ 36	↗ 36,37
	Tooth loss (edentate)	↗ 48, 101	↗ 48	↗ 48	Depends on food 48, 56, 99	↘* 48, 56, 101, 102			↘ 101

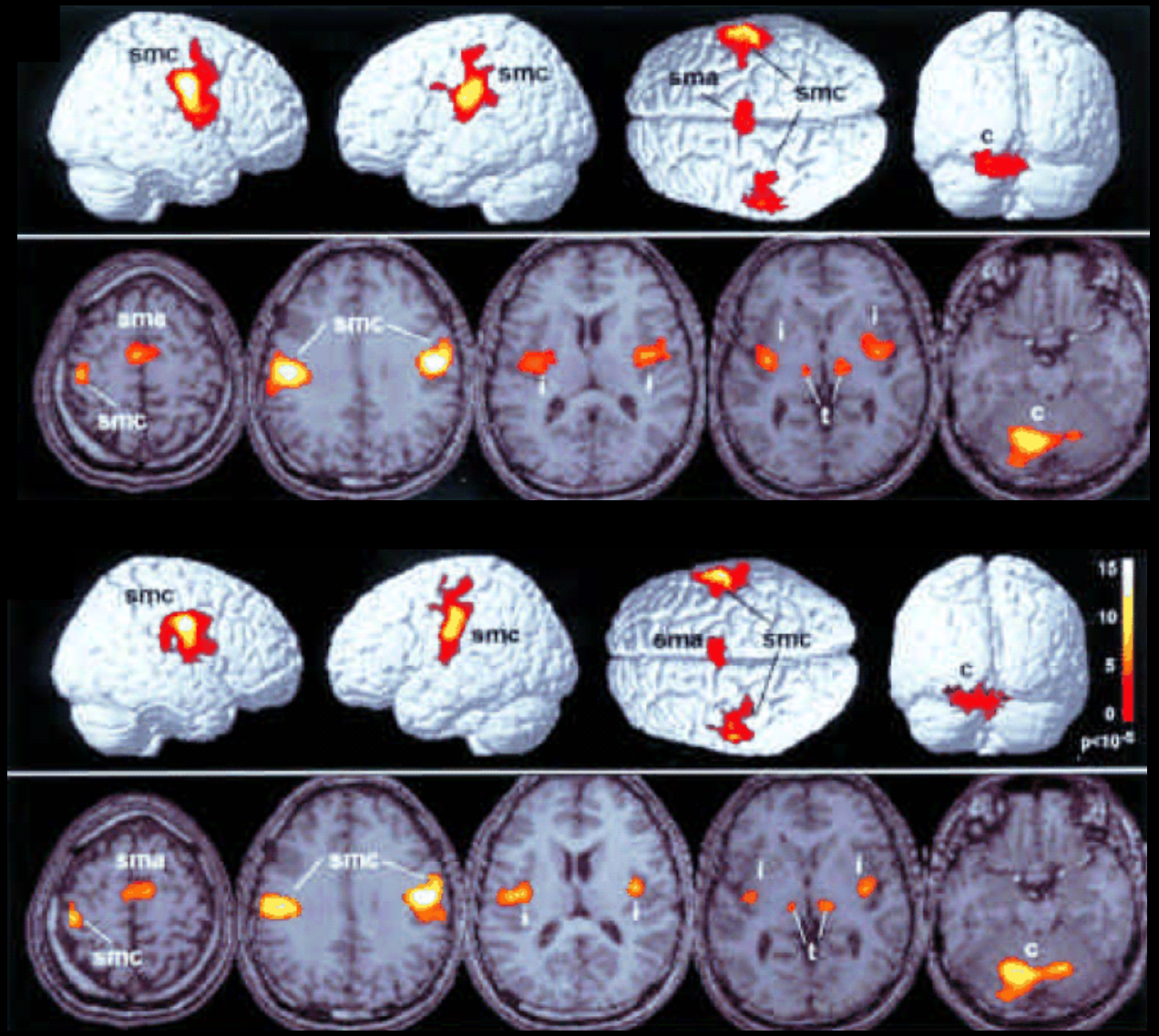
But what about taste ?

Woda et al. 2006

Mastication and brain activity

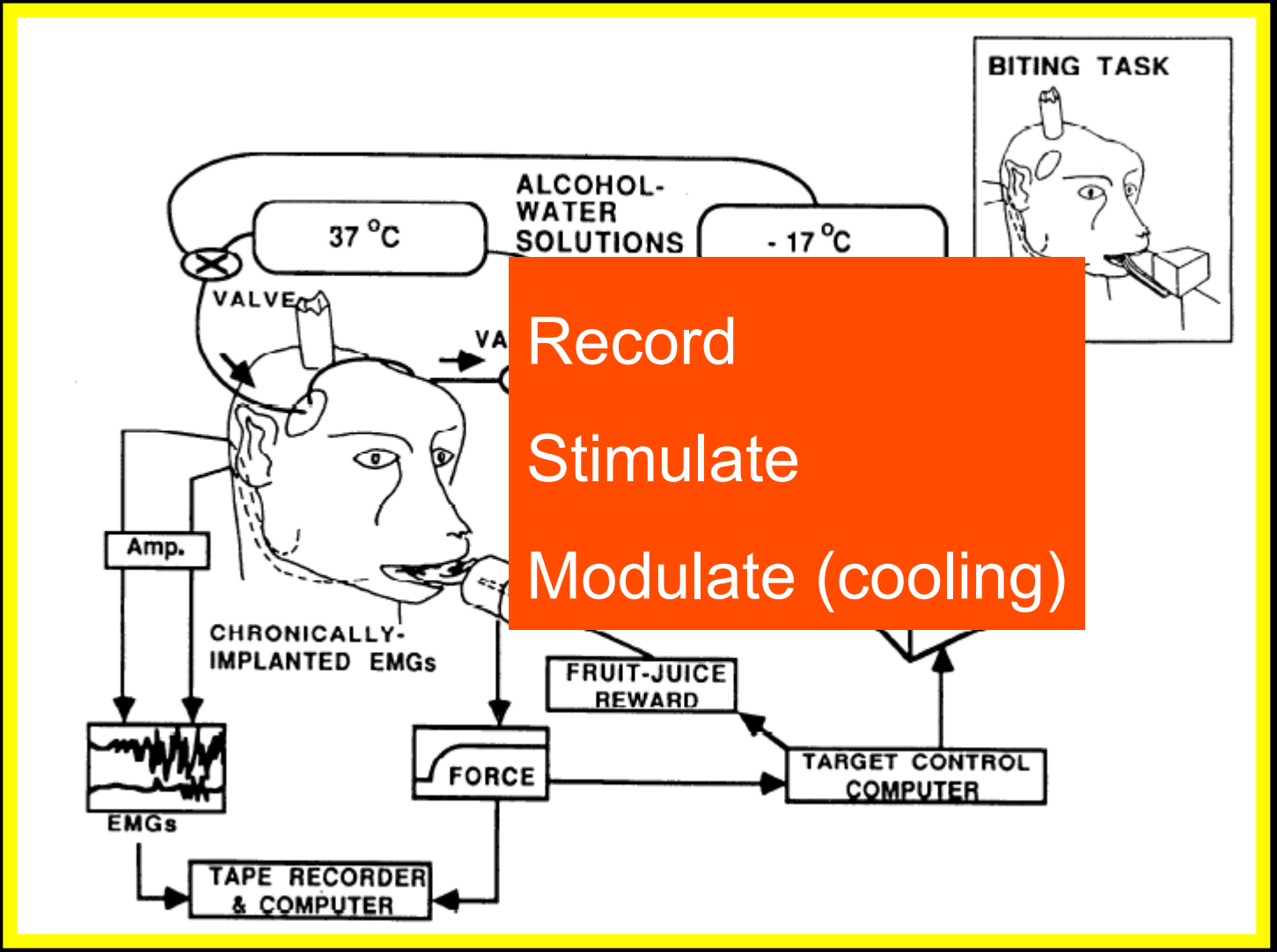
Moderate hard chewing gum

Hard chewing gum



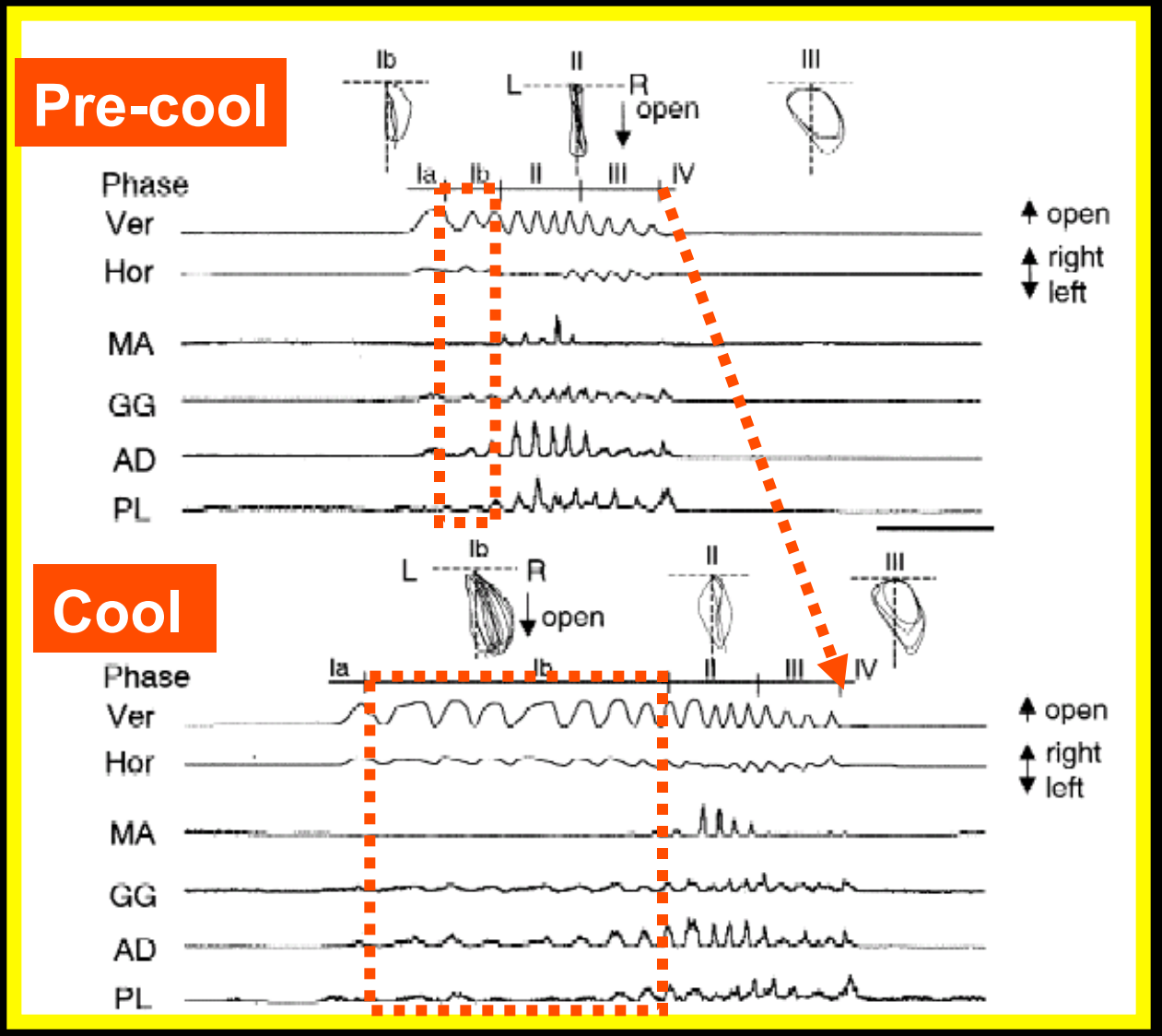
Onozuka et al. 2002

Importance of brain for mastication



From Sessle group

Effect of face MI cold block



Yamamura et al. 2002

Importance of brain for mastication

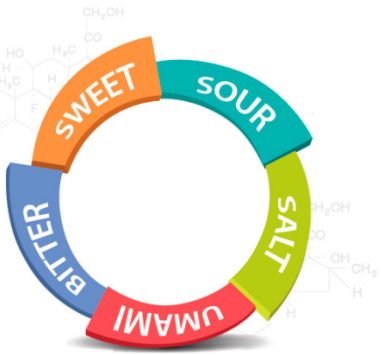
- Intracortical microstimulation, cold blocks, single neuron recordings have demonstrated the involvement of cortical masticatory area, MI, SI for semi-automatic movements, i.e., mastication in monkeys

Sessle 2011

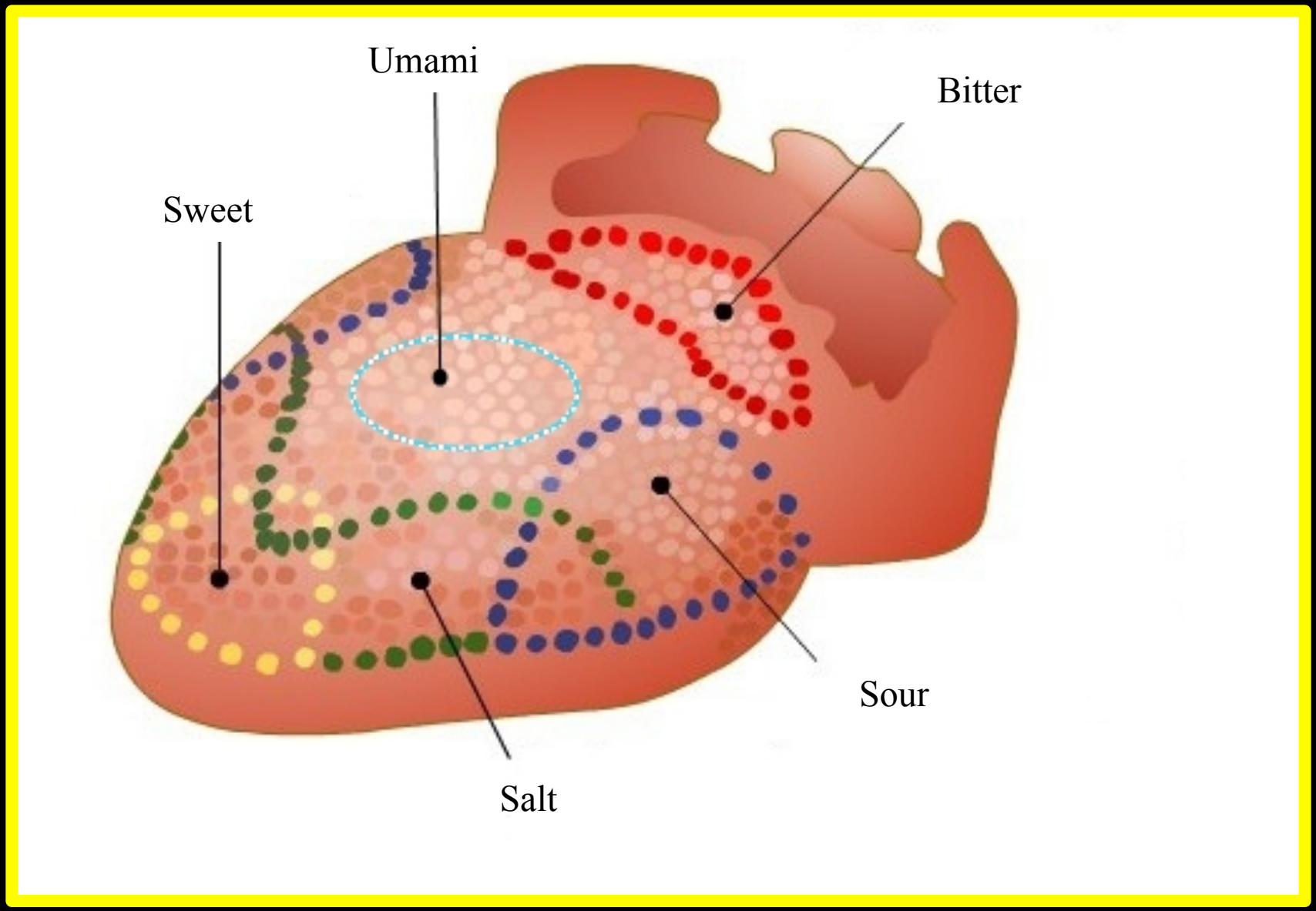
Summary

- Sensorimotor cortex and related brain areas important for initiation and fine regulation of mastication
- Sufficient masticatiory function important for nutrition and well-being
- But what about taste ?

Taste physiology



Taste modalities



Taste buds

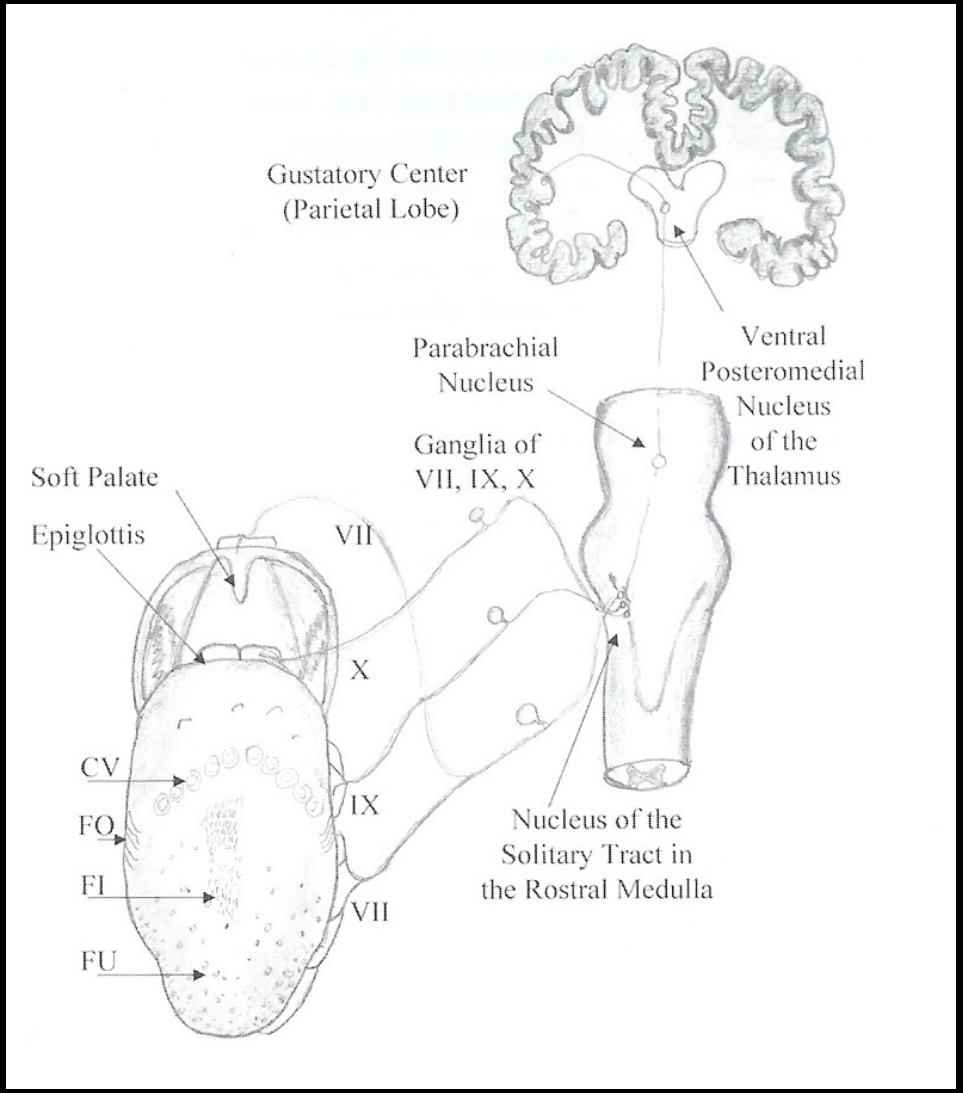
- 50-100 taste-receptors per taste bud
  - 1-10 p. fungiformis
  - 100-200 p. vallatae
  - 200-2000 p. foliatae
- Taste cells turnover: 10.5 days

Taste

- Needs 4 factors
  - A taste-receptor (taste bud)
  - A fluid environment (saliva)
  - A molecule to taste (food/drink)
  - A brain !

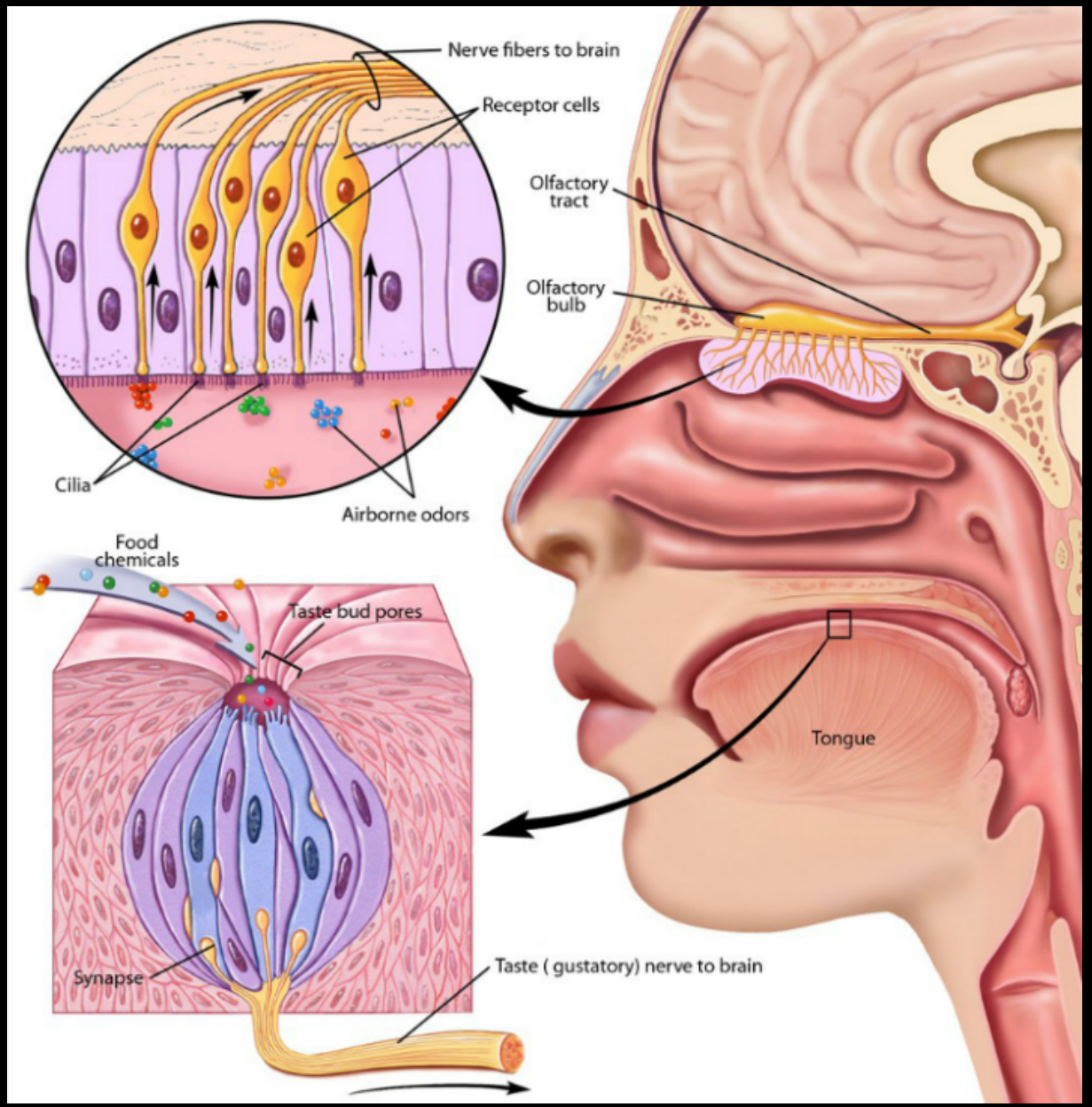
Gustatory system

Papillae vallatae
Papillae foliatae
Papillae filiformes (non-gustatory)
Papillae fungiformes



Smell

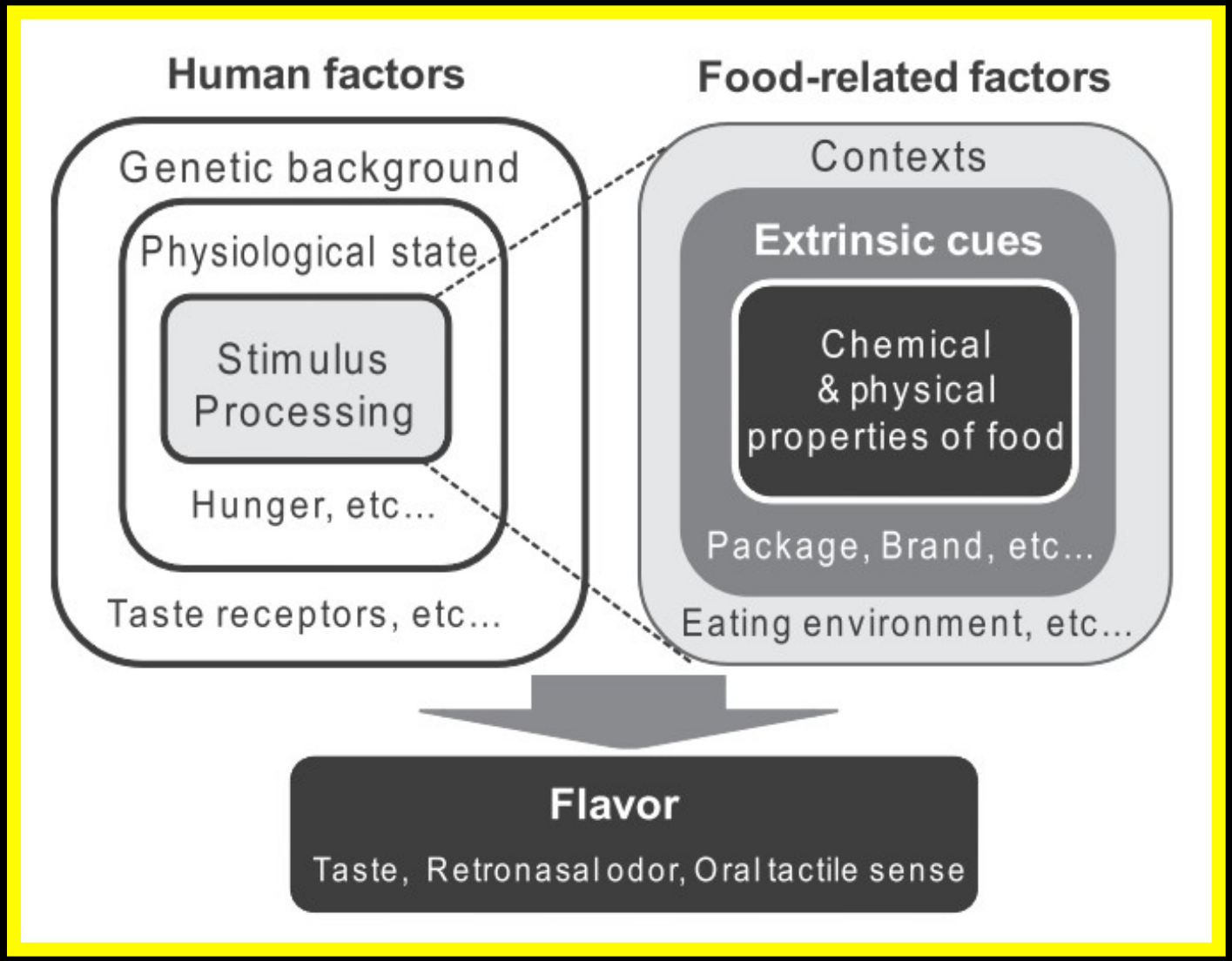
Taste


Nerve fibers to brain
Receptor cells
Olfactory tract
Olfactory bulb
Cilia
Airborne odors
Food chemicals
Taste bud pores
Tongue
Synapse
Taste (gustatory) nerve to brain

Flavors

Panna Cotta
Choc & Orange
Coconut
Caramelita
Swis Chocolate
Vanilla Dream
Raspberry
Maple Walnut
Strawberry
Rhubarb
Passion Fruit & Mango
Pistachio

Complexity of flavor



Problems with taste

- Hypogeusia
  - Diminished ability to detect gustatory stimulants
- Hypergeusia
  - Increased perception to gustatory stimulants
- Dysgeusia
  - Distorted perception to gustatory stimulants
- Taste agnosia
  - Inability to identify a gustatory stimulant although it is properly perceived
- Ageusia
  - Inability to detect gustatory stimulants

Taste disturbances

- Radiotherapy / chemotherapy in the neck or head
  - Collateral effects on both taste cells and saliva production
- Drugs / Medication / side-effects
- Dental treatment
  - Amalgam / removable dentures / chlorhexidin
- Infection/ inflammation
  - Candidiasis, gingivitis, periodontitis, BMS mm.
- Brain damage

Umami

Kikunae Ikeda

- Described in 1908 as 5° taste
- Glutamate (MSG mono-sodium-glu)
- “Savory / meaty / protein taste”
- Umami = “umai” (delicious) + “mi” (taste)

Umami

Umami

Enjoy
Enjoy Thank you

UMAMI SUPER-SEASONING
AJI-NO-MOTO
味の素
MONOSODIUM GLUTAMATE
GLUTAMATE MONODIQUE

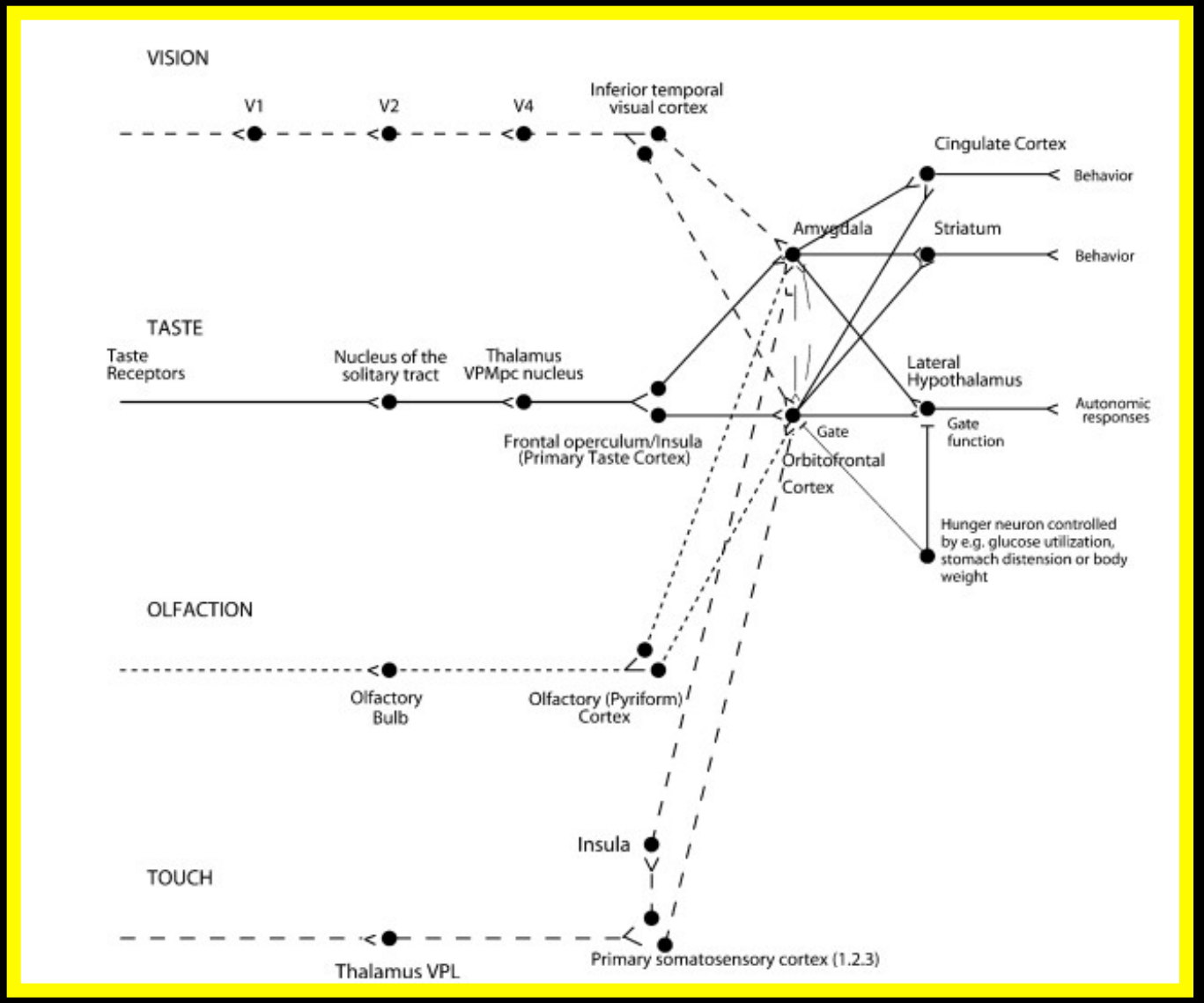
NOW EVEN CHEESIER!
NATURAL
Cheetos
WHITE CHEDDAR

Lipton
Soup Secrets
Chicken Noodle
with Diced White Chicken Meat
New Recipe...
SAME GREAT TASTE
NO Preservatives!
2 POUCHES

MSG
KFC
It's finger lickin' good!

Maruchan
Ramen
Noodle Soup
Chicken Flavor

Umami not just umami



Rolls 2014

Umami not just umami

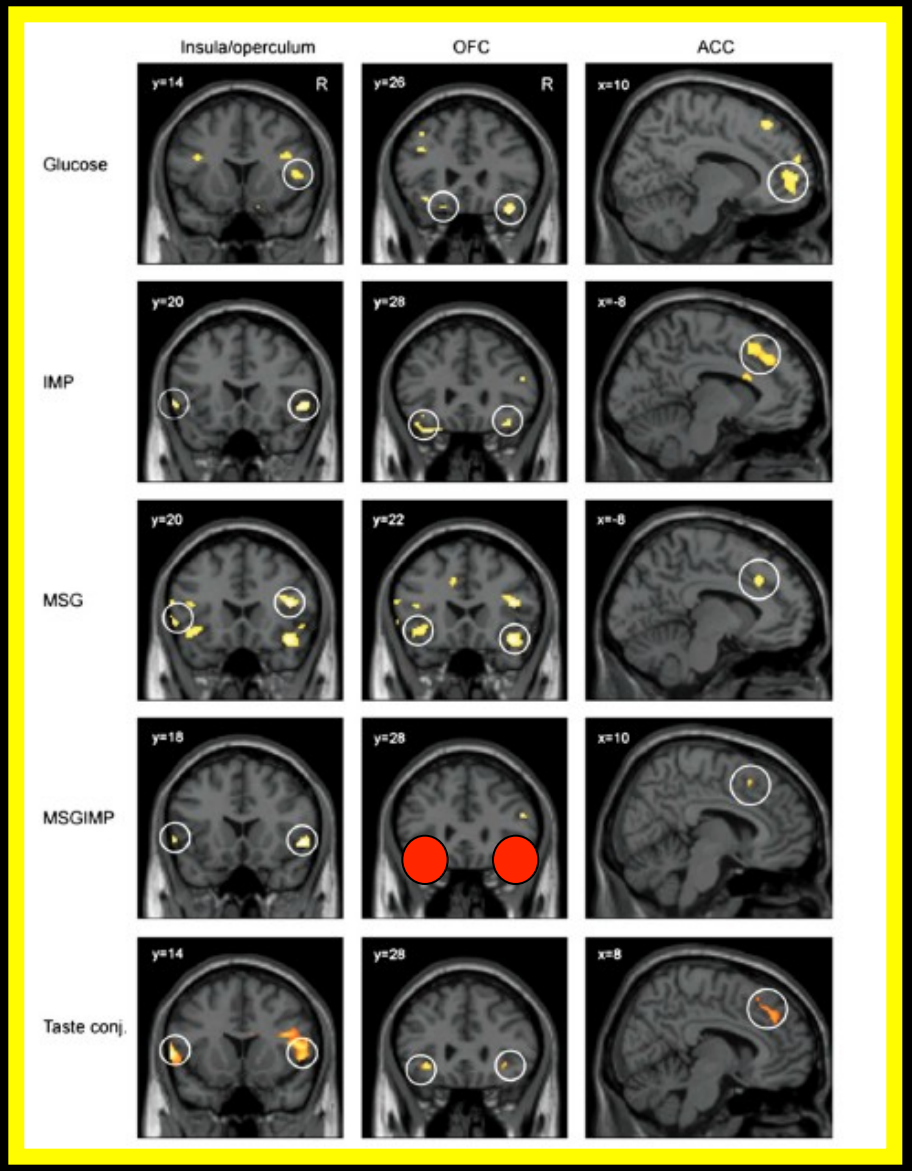
Sweet

Umami vegetable

Umami meet

Umami combined

Complex taste



Increased pleasantness

Rolls 2014

Can food cause pain ?

Excess MSG ?

- Headache
- Flushing
- Sweating
- Facial pressure or tightness
- Numbness, tingling or burning in the face, neck and other areas
- Rapid, fluttering heartbeats (heart palpitations)
- Chest pain
- Nausea
- Weakness

Shimada et al. The Journal of Headache and Pain 2013, 14:2
http://www.thejournalofheadacheandpain.com/content/14/1/2

The Journal of Headache and Pain
a SpringerOpen Journal

RESEARCH ARTICLE Open Access

Headache and mechanical sensitization of human pericranial muscles after repeated intake of monosodium glutamate (MSG)

Akiko Shimada[1*], Brian E Cairns[2], Nynne Vad[1], Kathrine Ulriksen[1], Anne Marie Lynge Pedersen[3], Peter Svensson[1,4] and Lene Baad-Hansen[1]

Original Article

Cephalalgia
International Headache Society

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SAGE

Effect of systemic monosodium glutamate (MSG) on headache and pericranial muscle sensitivity

L Baad-Hansen[1], BE Cairns[2], M Ernberg[3] and P Svensson[1,4]

Abstract

We conducted a double-blinded, placebo-controlled, crossover study to investigate the occurrence of adverse effects such as headache as well as pain and mechanical sensitivity in pericranial muscles after oral administration of monosodium glutamate (MSG). In three sessions, 14 healthy men drank sugar-free soda that contained either MSG (75 or 150 mg/kg) or NaCl (24 mg/kg, placebo). Plasma glutamate level, pain, pressure pain thresholds and tolerance levels, blood pressure (BP), heart rate and reported adverse effects were assessed for 2 h. No muscle pain or robust changes in mechanical sensitivity were detected, but there was a significant increase in reports of headache and subjectively reported pericranial muscle tenderness after MSG. Systolic BP was elevated in the high MSG session compared with low MSG and placebo. These findings add new information to the concept of MSG headache and craniofacial pain sensitivity.

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DOI: 10.1089/jmf.2012.0029

A Dietary Restriction Influences the Progression But Not the Initiation of MSG-Induced Nonalcoholic Steatohepatitis

Makoto Fujimoto,[1,2,*] Koichi Tsuneyama,[1,*] Yuko Nakanishi,[1] Thucydides L. Salunga,[1] Kazuhiro Nomoto,[1] Yoshiyuki Sasaki,[3] Seiichi Iizuka,[4] Mitsunobu Nagata,[4] Wataru Suzuki,[4] Tsutomu Shimada,[4] Masaki Aburada,[4] Yutaka Shimada,[2] M. Eric Gershwin,[5] and Carlo Selmi[5,6]

Departments of [1]Diagnostic Pathology and [2]Japanese Oriental Medicine, University of Toyama, Toyama, Japan.
[3]Institute for Animal Reproduction, Ibaraki, Japan.
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[5]Division of Rheumatology, Allergy, and Clinical Immunology, University of California, Davis, California, USA.
[6]Division of Rheumatology and Clinical Immunology, Humanitas Research Hospital, Rozzano, Milan, Italy.

IASP

Pain 132 (2007) 33–41

PAIN

www.elsevier.com/locate/pain

Systemic administration of monosodium glutamate elevates intramuscular glutamate levels and sensitizes rat masseter muscle afferent fibers

Brian E. Cairns [a,*], Xudong Dong [a], Mandeep K. Mann [a], Peter Svensson [b], Barry J. Sessle [c], Lars Arendt-Nielsen [d], Keith M. McErlane [a]

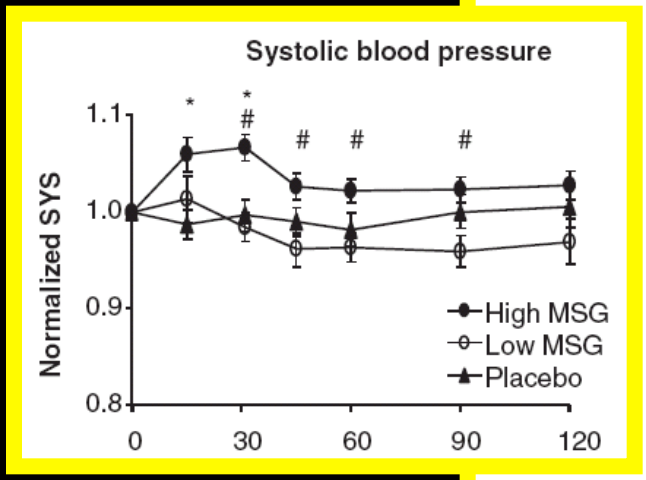
[a] Faculty of Pharmaceutical Sciences, The University of British Columbia, 2146 East Mall, Vancouver, BC, Canada V6T 1Z3
[b] Department of Clinical Oral Physiology, Dental School, Århus University, DK-8000 Århus C, Denmark
[c] Faculty of Dentistry, The University of Toronto, Toronto, Ont., Canada M5G 1G6
[d] Laboratory for Experimental Pain Research, Center for Sensory-Motor Interaction, Aalborg University, DK-9220 Aalborg, Denmark

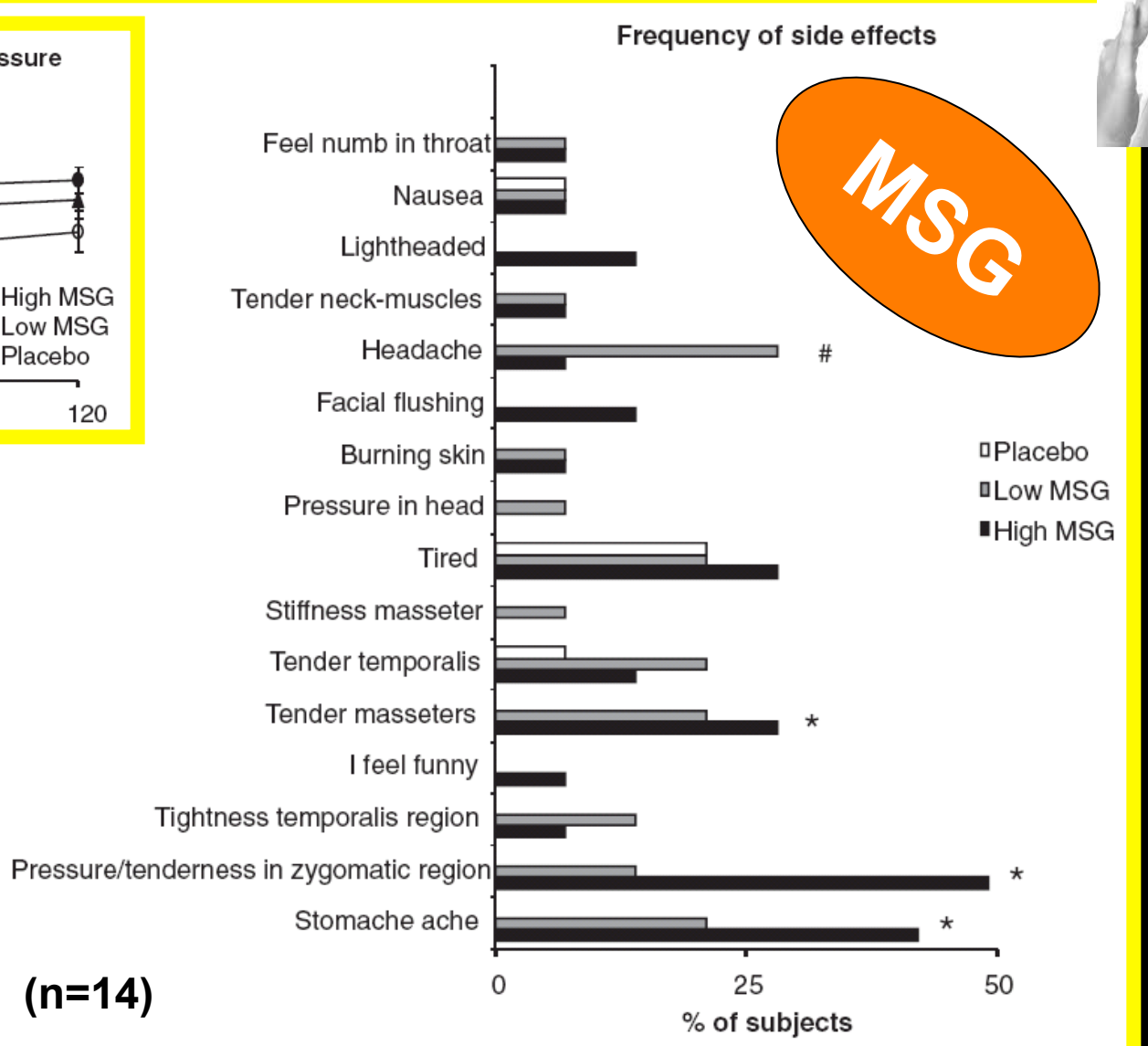
Received 4 October 2006; received in revised form 9 January 2007; accepted 25 January 2007

Consumption of monosodium glutamate in relation to incidence of overweight in Chinese adults: China Health and Nutrition Survey (CHNS)[1–3]

Ka He, Shufa Du, Pengcheng Xun, Sangita Sharma, Huijun Wang, Fengying Zhai, and Barry Popkin

Effects of systemic glutamate





Baad-Hansen et al. 2009

Taste aversion

Like it – or not ?

SURS

Fazer
SALMIAK
pastiller

Like it – or not ?

Grape Juice

Table 1
Mean ratings per group (likers/dislikers) of taste stimuli during MRI scanning.

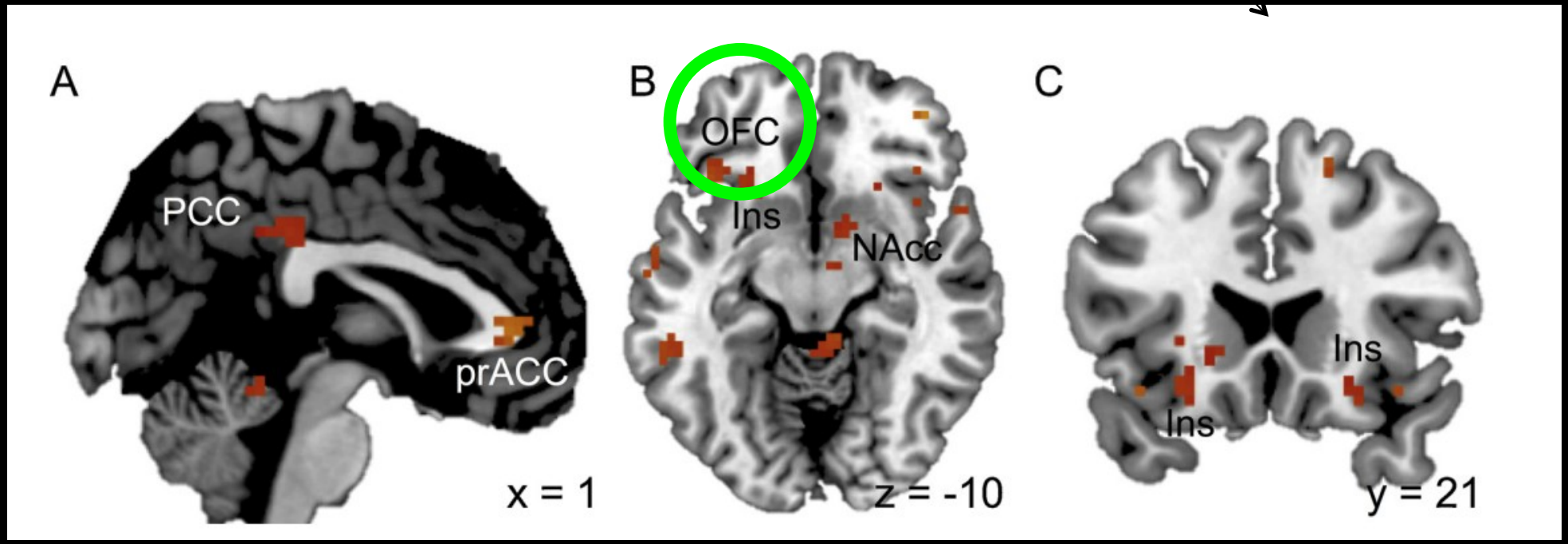
	Mean ± SD		GLM repeated measures one-way ANOVA[c]	
	Likers	Dislikers	*F* value	*p* Value
GJ liking[a]	2.5 ± 0.8	−2.6 ± 0.8	395.33	<.001
GJ intensity[b]	7.6 ± 0.7	7.9 ± 0.7	1.78	.19
GJ familiarity[b]	8.2 ± 0.8	7.3 ± 1.0	7.89	<.01
Sucr liking[a]	2.6 ± 0.8	2.9 ± 0.8	1.69	.20
Sucr intensity[b]	6.1 ± 1.4	6.0 ± 1.4	0.02	.89
Sucr familiarity[b]	6.8 ± 2.4	7.8 ± 0.9	3.33	.08
Quin liking[a]	−3.4 ± 0.6	−3.5 ± 0.6	0.06	.81
Quin intensity[b]	7.5 ± 1.1	7.4 ± 1.1	0.05	.83
Quin familiarity[b]	4.6 ± 2.9	5.2 ± 2.4	0.45	.51
W liking[a]	−0.1 ± 0.7	−0.1 ± 0.7	0.03	.96
W intensity[b]	2.5 ± 1.4	2.1 ± 1.4	0.49	.49
W familiarity[b]	5.1 ± 2.6	5.3 ± 3.0	0.03	.87

[a] Liking ratings were measured on a 9-point scale ranging from −4 “dislike extremely” to 4 “like extremely”.
[b] Intensity and familiarity ratings were measured on a 9-point scale ranging from 1 “not at all” to 9 “extremely”.
[c] Repeated measures GLM was used to analyze differences in liking and intensity ratings between likers and dislikers. Differences in familiarity ratings between groups were analyzed using a one-way ANOVA.

Van den Bosch et al. 2014

Like it – or not ?

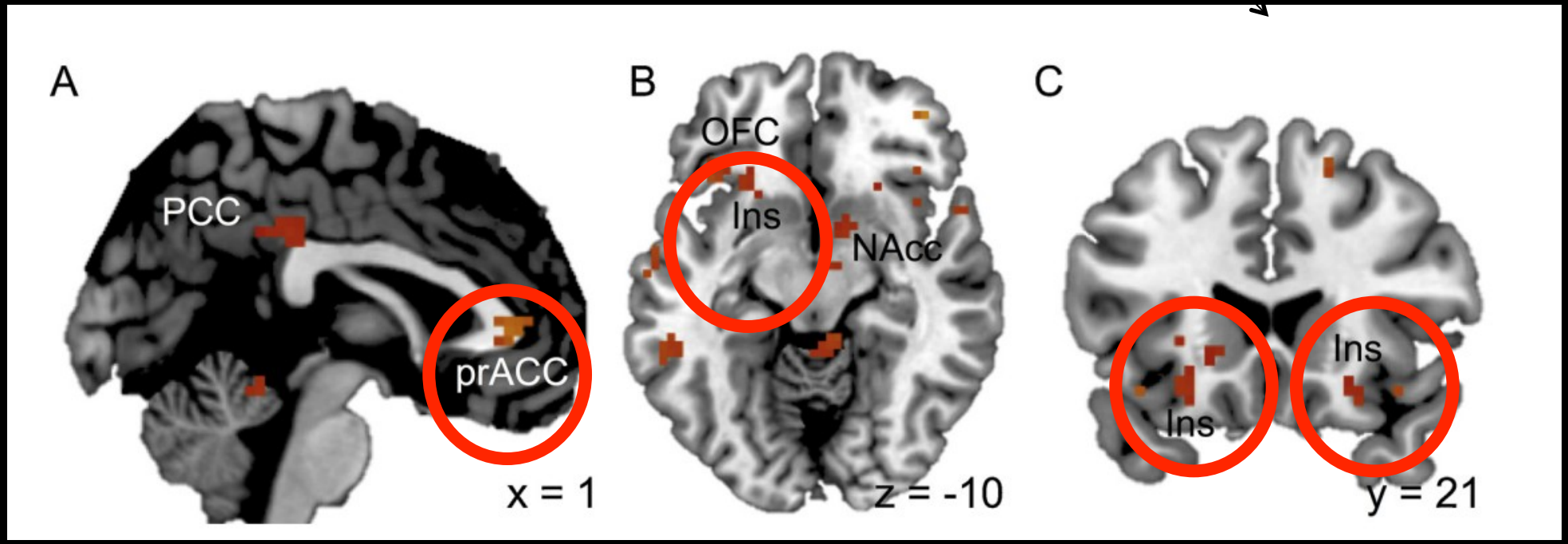
Likers ↑



Van den Bosch et al. 2014

Like it – or not ?

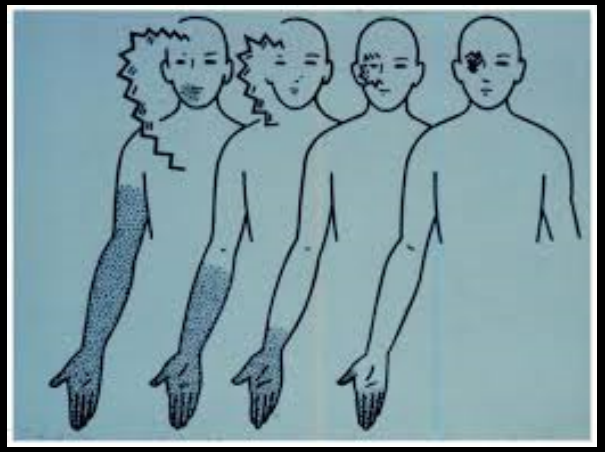
Dislikers ↑



Van den Bosch et al. 2014

Can food cause pain ?

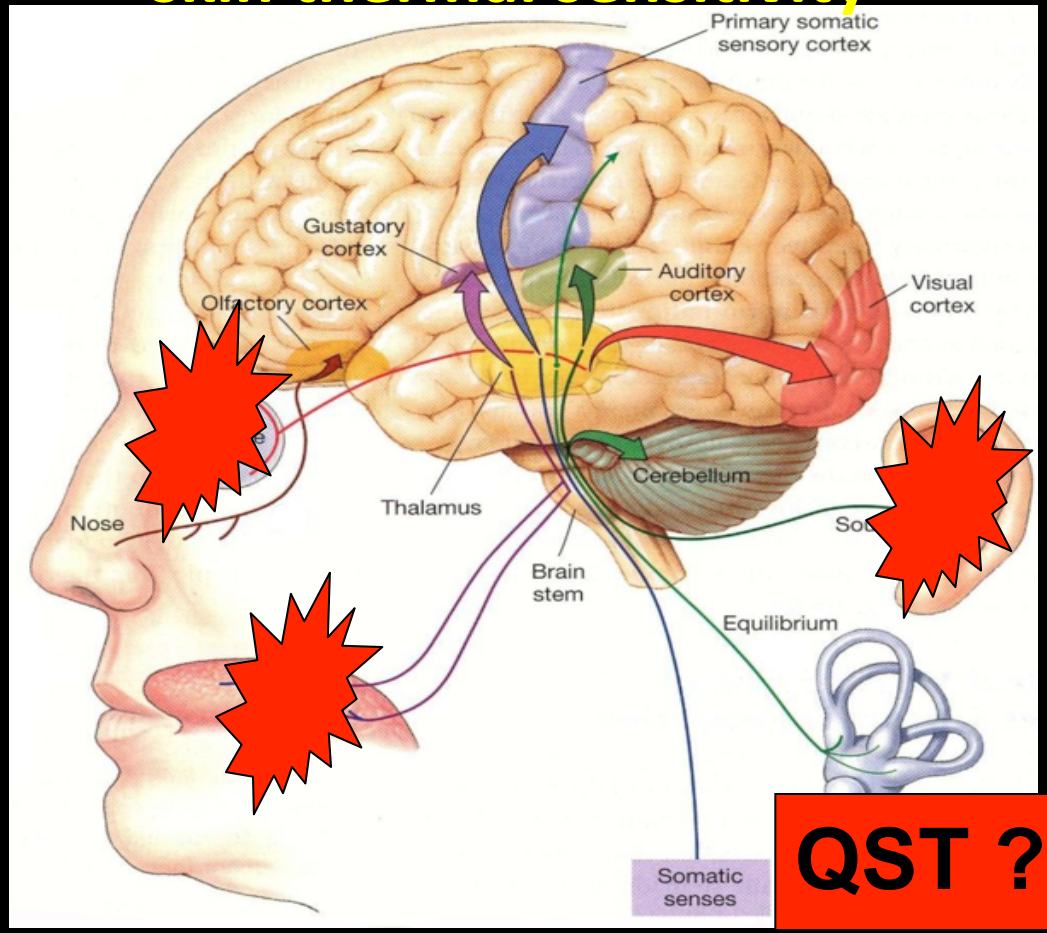
Migraine



Migraine triggers

Multisensory integration

Effect of negative emotions evoked by unpleasant light, noise and taste on skin thermal sensitivity



QST ?

Yang et al.
J Headache Pain 2014

Methods

- QST: thermal sensitivity
  - CDT, WDT, CPT, HPT
- Physiological measures
  - Heart Rate, Skin Temperature
- Rating of conditioning stimuli
- Affective state evaluation

Yang et al. J Headache Pain 2014

Methods

Light session

Base line
1000 lux light

Base line
3000 lux light

Base line
9000 lux light

Randomized order

Noise session

Base line
60 dB noise

Base line
75 dB noise

Base line
90 dB noise

Randomized order

Taste session

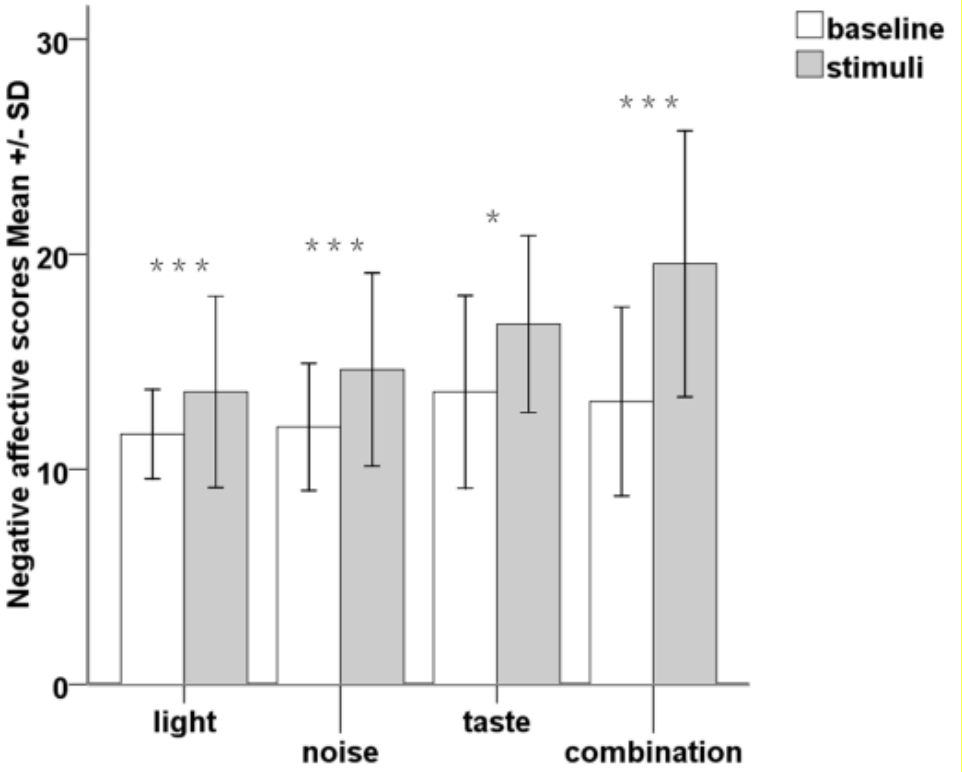
Base line
0.1% quinine gelatin

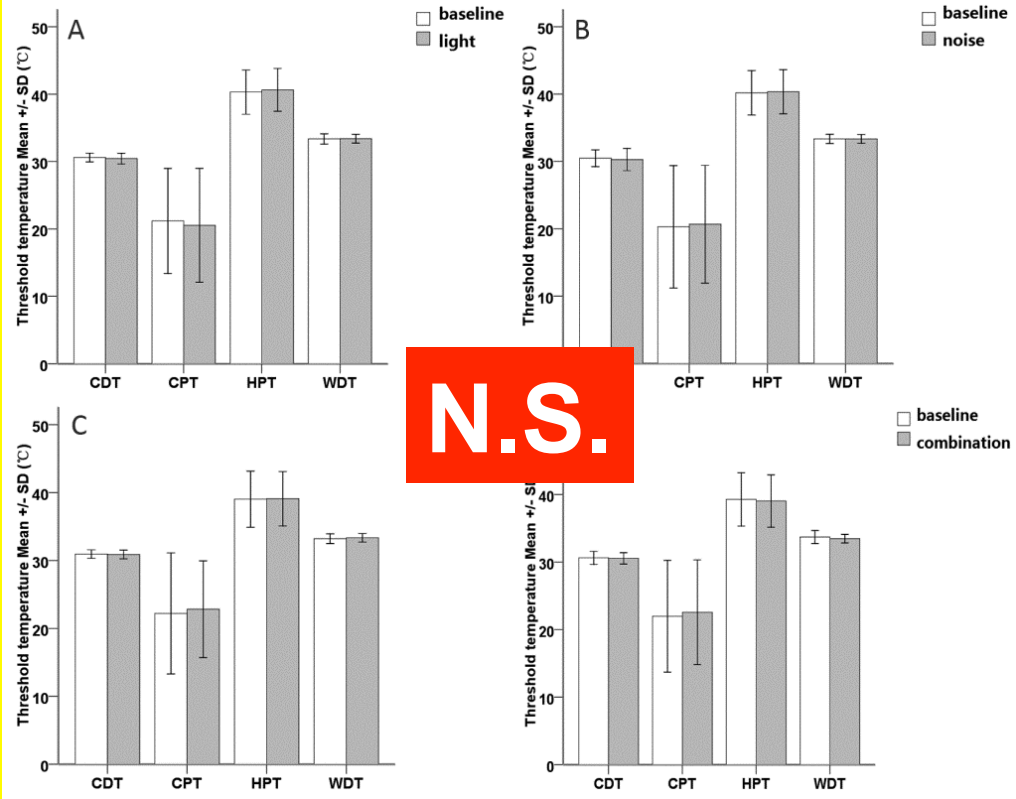
Combination session

Base line
Light noise taste

Yang et al. J Headache Pain 2014

Outcome





Yang et al. J Headache Pain 2014

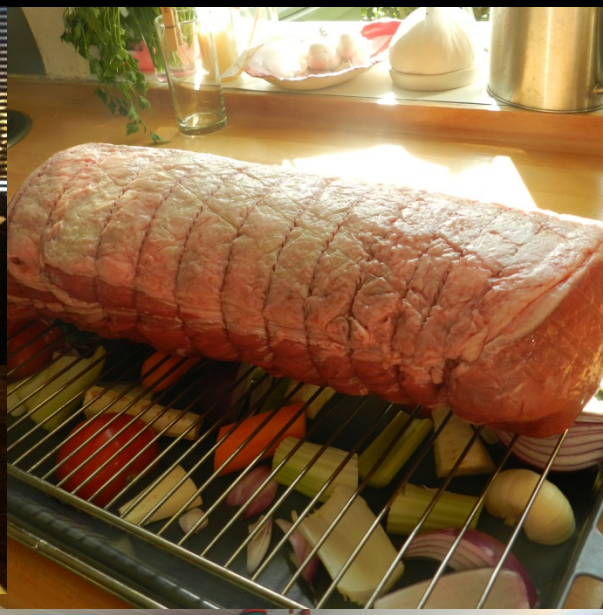
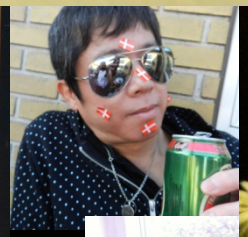
N = 20

Summary

- Although unpleasant, innocuous sensory stimuli alone seem insufficient to trigger sensitization of the normal trigeminal somatosensory system

Enjoyment

Enjoyment of food – and wine

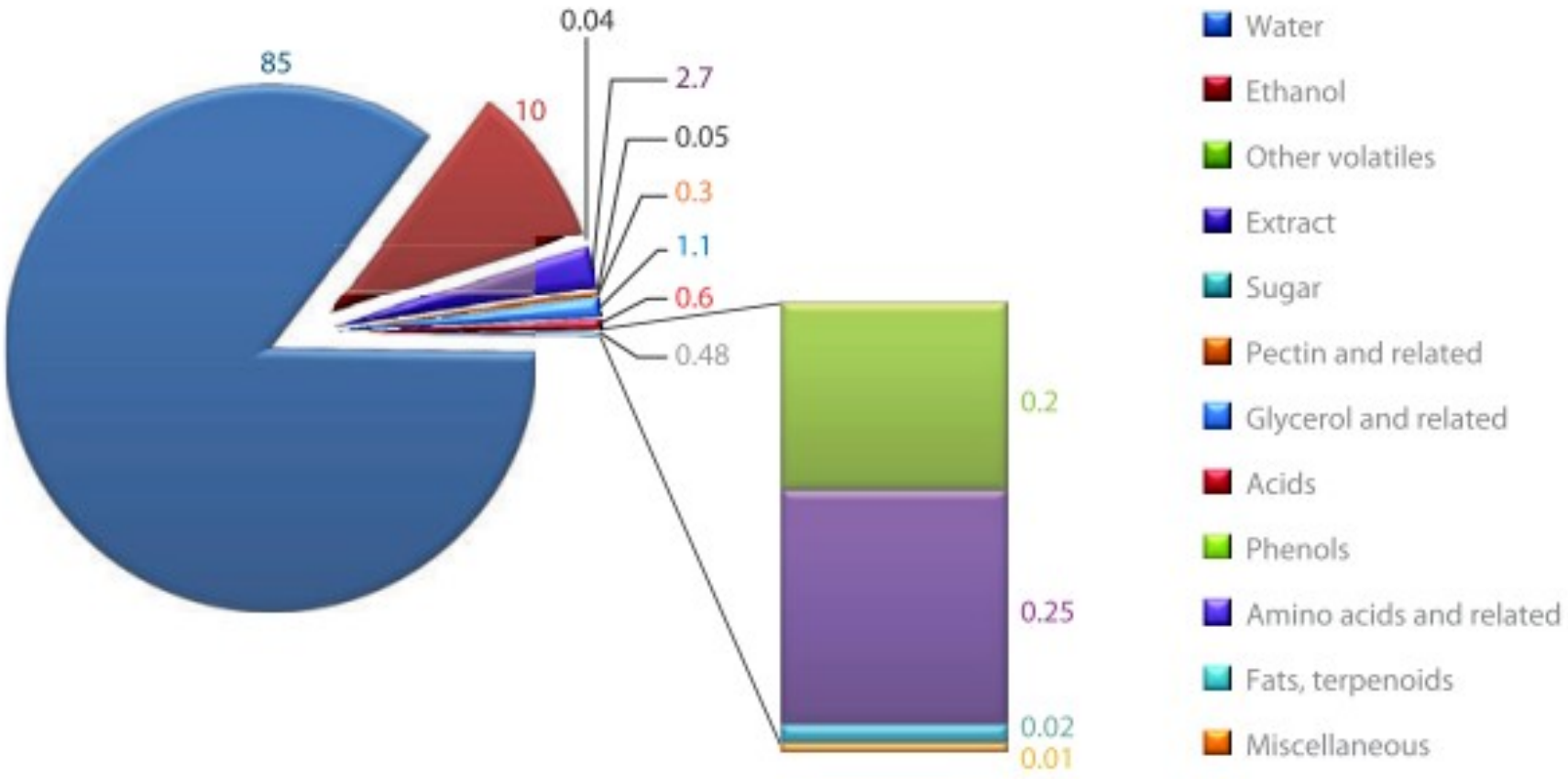



Wine matrix

- Non-volatile fraction
  - Etanol
  - Polyphenolic compounds
  - Proteins
  - Carbohydrates
- Volatile fraction
  - Flavor and aroma compounds

Villamore and Ross 2013

Complexity of wine



Villamore and Ross 2013

Wine aroma

- Primary aromas
  - Grape-derived
  - Exocarp (skin)
  - Molecule specific

Villamore and Ross 2013

Complexity of wine

Compound	Molecular weight (g mol^{-1})	Boiling point (°C)	Log *P* value[d]	Concentration (μg L^{-1})	Threshold (μg L^{-1})	Aroma descriptor[k]
Carbonyls						
β-damascenone[a,b,c]	190	265	4.21	2,[a] 29,[b] 3.5[c]	0.05[e,h]	apple, honey
β-ionone[c]	192	263	3.84	0.23[c]	0.09[g]	seaweed, violet
3-octanone[b]	128	168	2.22	17[b]	21-50[j]	herb, butter
esters						
ethyl 2-methylbutyrate[c]	130	135	2.26	32[c]	18[g], 1[e]	apple
ethyl 3-methylbutyrate[c]	130	135	2.26	20[c]	3[g]	fruit
ethyl butyrate[a,c]	116	122	1.85	680,[a] 69[c]	20[g,h]	apple
ethyl hexanoate[a,b,c]	144	167	2.83	650,[a] 140,[b] 29[c]	14,[g,h] 5[e]	apple peel, fruit
ethyl cinnamate[c]	176	271	2.99	1.22[c]	1.1[g]	honey, cinnamon
isoamyl acetate[a,b,c]	130	142	2.25	60,[a] 142,[b] 120[c]	30[e,g,h]	banana
Alcohols						
isoamyl alcohol[a,b,c]	88	131	1.16	150,000,[a] 1,412,[b] 112,800[c]	30,000[e,h]	whiskey, malt, burnt
1-hexanol[a,b,c]	102	158	2.03	8,000,[a] 617,[b] 780[c]	8,000[e,g,h]	resin, green
2-phenylethanol[a,b,c]	122	218	1.36	34,000,[a] 6,089,[b] 60,300[c]	14,000,[g,h] 10,000[e]	honey, rose
methionol[c]	106	178	0.44	3,750[c]	1,000[g]	sweet, potato
1-heptanol[b]	116	177	2.62	15[b]	3[j]	chemical, green
Phenols						
guaiacol[c]	124	205	1.32	47.3[c]	9.5,[g] 10[e]	smoke, medicine
eugenol[c]	164	253	2.27	60[c]	6,[e] 5[e]	clove, honey
4-vinylguaiacol[c]	150	247	2.24	30[c]	40,[e] 10[j]	clove, curry
Terpenes						
β-citronellol[b,c]	156	224	3.91	21,[b] 1.2[c]	100[f]	rose
linalool oxide[b]	170	233	2.08	3.0[b]	4–10[k]	flower, wood
geraniol[b,c]	154	230	3.56	19,[b] 3.2[c]	20,[e] 30[c]	rose, geranium
lactone						
cis-whiskey lactone[c]	156	261	2.00	151[c]	67[j]	coconut
Acids						
3-methylbutyric acid[c]	102	176	1.16	1,670[c]	33[g]	sweat, acid
hexanoic acid[a,b,c]	116	205	1.92	5,300,[a] 120[b], 2,730[c]	420[g,h]	sweat
octanoic acid[a,b,c]	144	239	3.05	26,000,[a] 555,[b] 1,910[c]	500[g,h]	sweat, cheese

Complexity of wine

Variety[a]	Characteristic odorants	Odor quality	Sensory threshold	Ref.
Muscat	Linalool,	Floral	170 ng L^{-1} (in water)	7,8
	Terpenols, *e.g.* geraniol, nerol	Citrus, floral		
Riesling	TDN (1,1,6-trimethyl-1,2-dihydronaphthalene)	Kerosene, bottle age	20 µg L^{-1}	9,10
Cabernet Sauvignon, Sauvignon blanc, Cabernet franc, Merlot, Carmenere	3-Isobutyl-2-methoxypyrazines (IBMP)	Bell pepper	2 ng L^{-1} (in water)	11–14
Gewürztraminer	*cis*-Rose oxide	Geranium oil, carrot leaves	200 ng L^{-1}	15–20
	Wine lactone	Coconut, woody, sweet	0.02 pg L^{-1} (in air)	
Vitis labrusca, *Vitis rotundifolia*	*o*-Aminoacetophenone	Foxy, sweet	400 ng L^{-1}	21,22
Sauvignon blanc, Scheurebe	4-Methyl-4-mercaptopentan-2-one	Blackcurrant	0.6 ng L^{-1} in water–ethanol (90 : 10, w/w)	16,18
Grenache rosé, Sauvignon blanc, Semillon	3-Mercapto-1-hexanol	Grapefruit/citrus peel (*R* isomer)	50 ng L^{-1}	23
		Passion fruit (*S* isomer)	60 ng L^{-1}	24
Shiraz	Rotundone	Black pepper	16 ng L^{-1} (in wine)	25,26

[a] All varieties are *Vitis vinifera* except where indicated.

Villamore and Ross 2013

Wine aroma

- Secondary aromas
  - By-products by fermantation
  - Fusel oils (pungent odor)
  - Acetate esters (fruity aromas)
  - Aldehydes / ketones / yeasts (dried fruit / buttery)
  - Phenoles (animal / horse sweat / stable)

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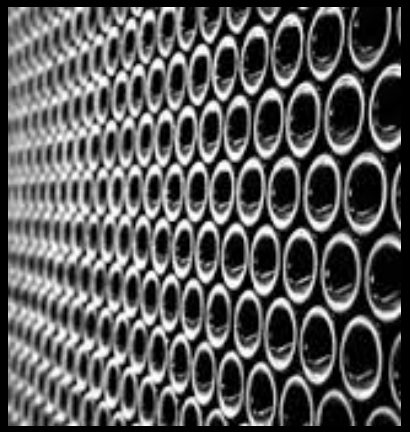
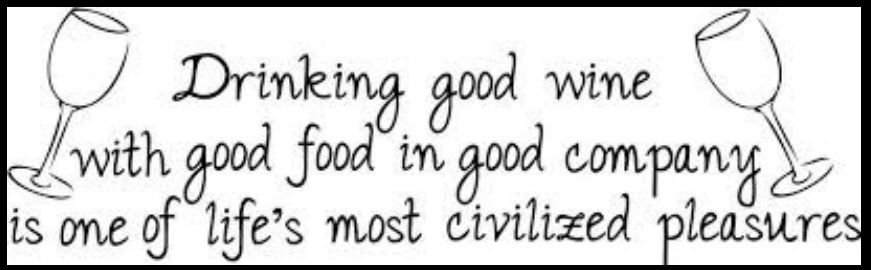
Wine aroma

- Tertiary aromas
  - Aging !
  - Wood / barrel / steel
  - Storage (temperature / light)



Villamore and Ross 2013

Enjoyment of wine



Taste and mastication

- Mastication is essential for living
- Taste is essential for enjoyment

Thank you for your attention

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