Sensory analysis: Objectives and Principles of Good Practice

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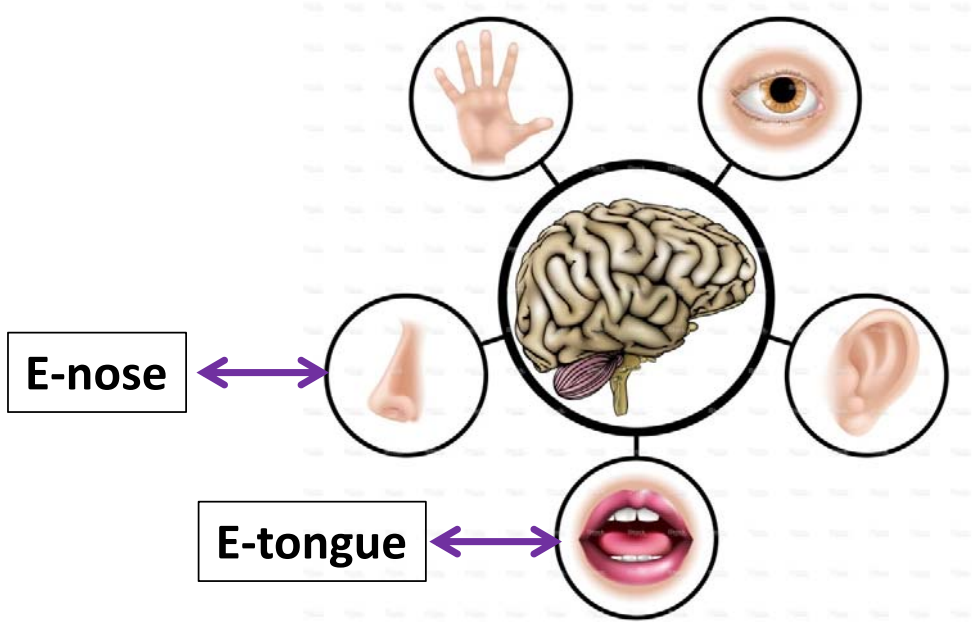
Sensory analysis: what is it?

- Scientific method used to to evoke, measure, analyze, and interpret human responses

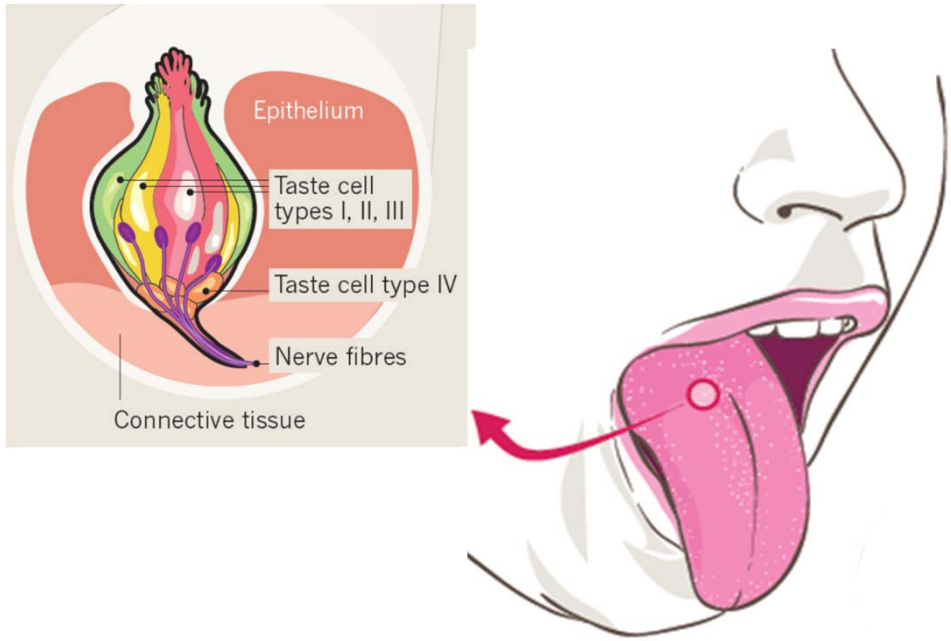
  to physico-chemical characteristics of products

  as perceived through the senses of sight, smell, touch, taste, and hearing



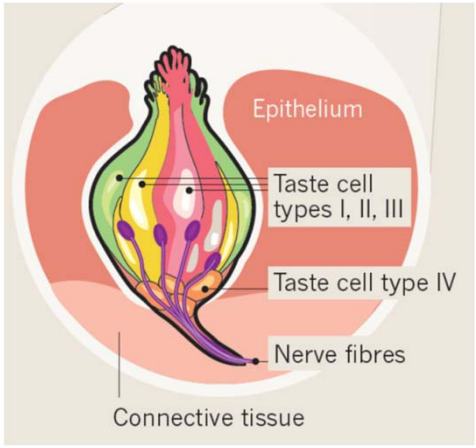
Sense of taste

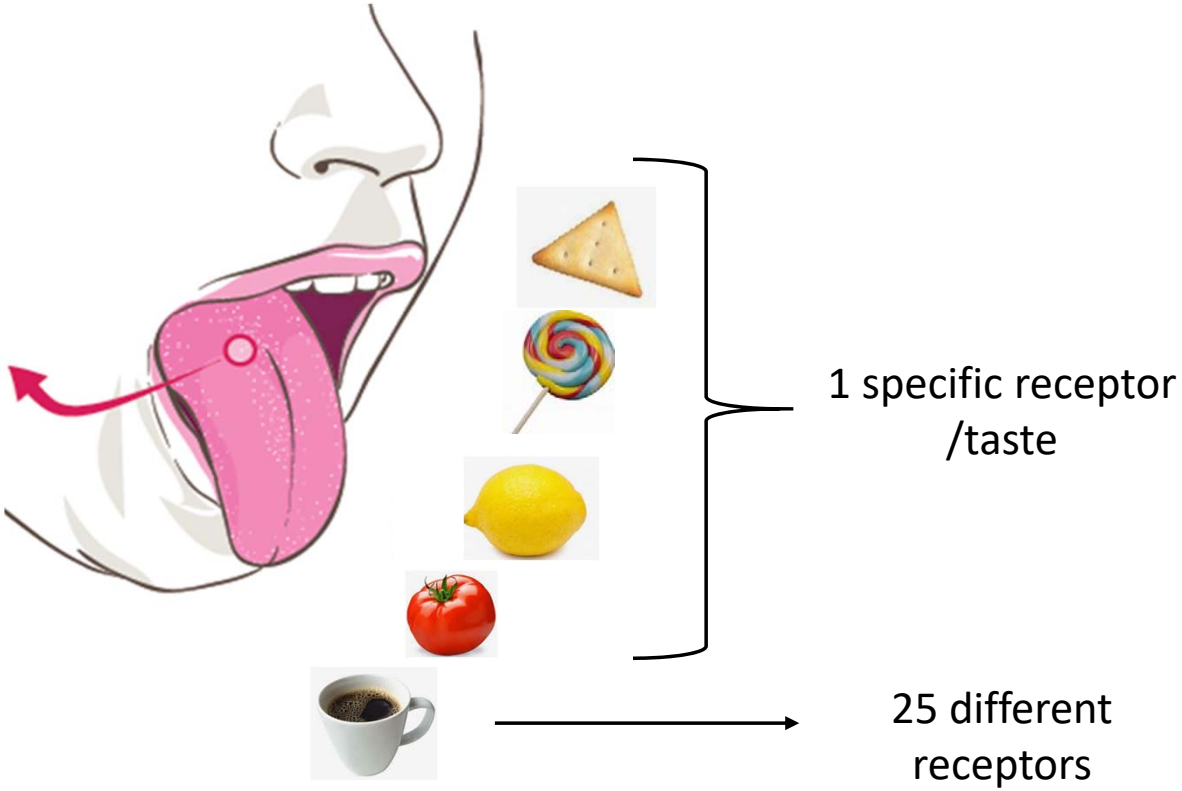
- A tongue, papilla, taste buds, receptors



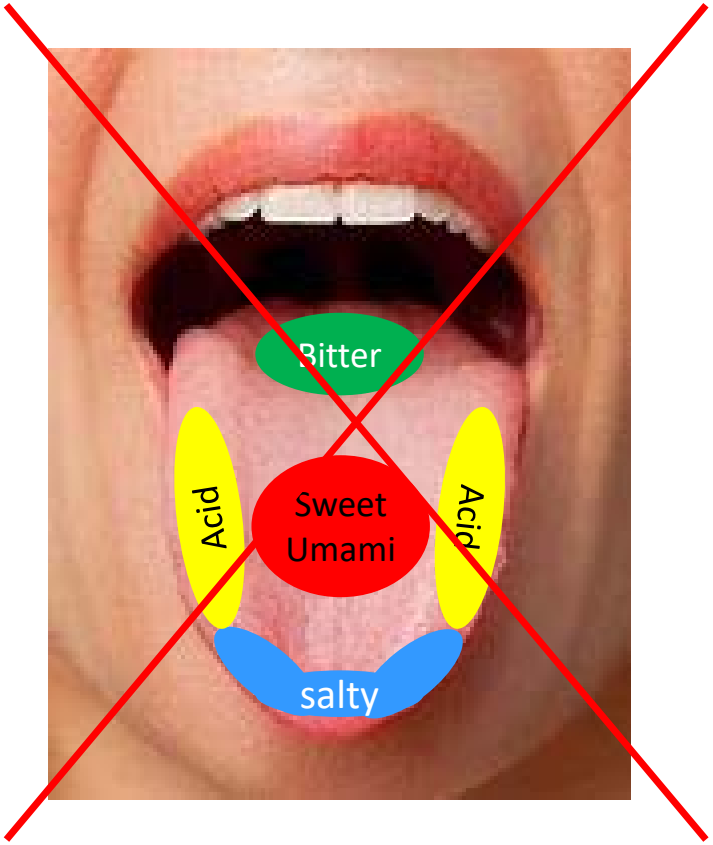
Sense of taste

- A tongue, papilla, taste buds, receptors
- Allowing us to distinguish different tastes





Sense of taste



False!

Sweet compounds

- Carbohydrates (C-H_2O)n

Sucrose = ref
Sweetening power*=1


Fructose
Sweetening power*=1.2

Lactose
Sweetening power*=0.25


Glucose
Sweetening power*=0.6

Sweetening power*:
10% in water at 20°C

Sweet compounds

- Low-calorie sweeteners

Molecule	Sweetening power	Origin	Comment
Saccharin	300	artificial	Delay in sweetness onset, bitter aftertaste
Aspartam	200	artificial	Slight delay in sweetness onset
Sucralose	750	artificial	Slower rate of decay
Cyclamate	40	artificial	Bitter taste
Rebaudioside A	250	natural (Stevia, south America)	Bitter taste
Stevioside	210	natural (Stevia, south America)	Bitter after-taste, liquorice aroma
Glycyrrhizin	93-170	natural (root of liquorice)	Slow sweetness onset, liquorice after-taste
Brazzein	2000	natural (African fruit)	More sucrose-like sweet taste/ other proteins
Monellin	3000	natural (African fruit)	Slow sweetness onset, persistant
Thaumatin	1600	natural ("miracle fruit", Africa)	Slow sweetness onset, liquorice after-taste





Sweetening power*:
Same concentration than sucrose
Generally: 10% in water at 20°C

Salt compounds

- Na^+Cl^-

- K^+Cl^- : possible substitute

Main problem: K^+ stimulates some receptors to bitterness

Bitter compounds

- Origin
  - Many from plants
  - Generated during the processing, aging, or spoilage of food
- No reliable inventory of bitter molecules, estimates: tens of thousands
- A large range of chemical classes

Molecule	Source	Bitter receptors (amongst the 25 receptors) stimulated with some natural bitter compounds											
		1	4	7	10	14	16	38	39	40	43	44	46	47
Absinthin	Absinthe				+	+							+	+
Allyl Isothiocyanate	Mustard seeds							+						
Caffein	Coffee bean			+	+	+					+		+	
Coumarin	Tonka bean				+	+							+	+
Humulone	Hops	+				+				+				
Limonin	Citrus							+						
Quinine	Cinchona		+	+	+	+			+	+	+	+	+	
Sinigrin	Cauliflower, Brussels sprouts						+	+						

Meyerhof et al., Chemical Senses, 2010

Sour compounds

- Organic acids

Molecule	Source
Acetic acid	Vinegar
Ascorbic acid	Berries (blackcurrant), citrus Broccoli, bell peppers
Citric acid	Citrus
Lactic acid	Yogurt, sauerkraut
Malic acid	Apple, pear, grape
Tartric acid	Wine

- Perceived sourness = f (concentration, pH, anion species)

Sowalsky & Noble, Chemical Senses, 2010

Umami compounds

- Monosodium glutamate (MSG)
- L-glutamate
- L-aspartate
- Lactoyl-glutamate & succinoyl-glutamate
- 5’-inosine monophosphate (IMP)
- 5’-guanidine monophosphate (GMP)
- 5’-adénosine monophosphate (AMP)
- 5’-xanthosine monophosphate (XMP)










Synergy with MSG

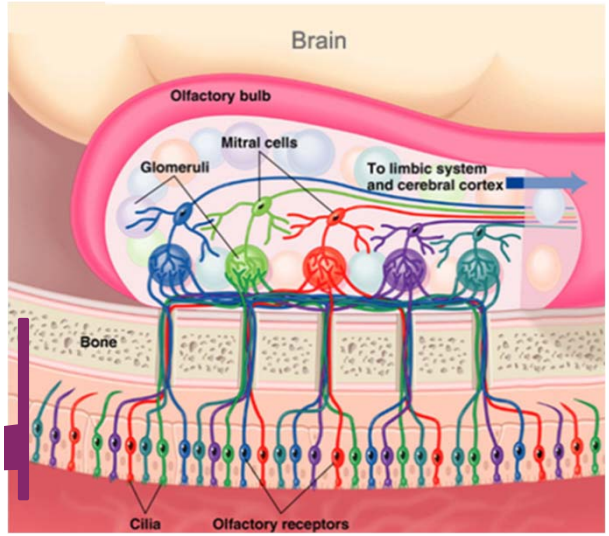
- Rubemanine (FEMA 4310)
- Rubescenamine (FEMA 4773)

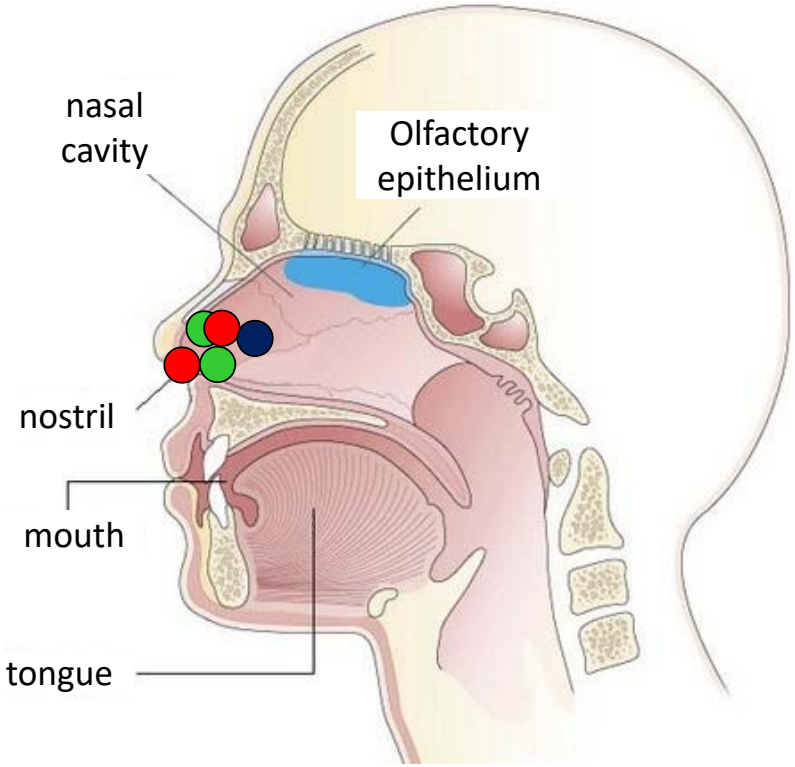
zanthoxylum rubescens
(Africa)

- ….

Sense of smell

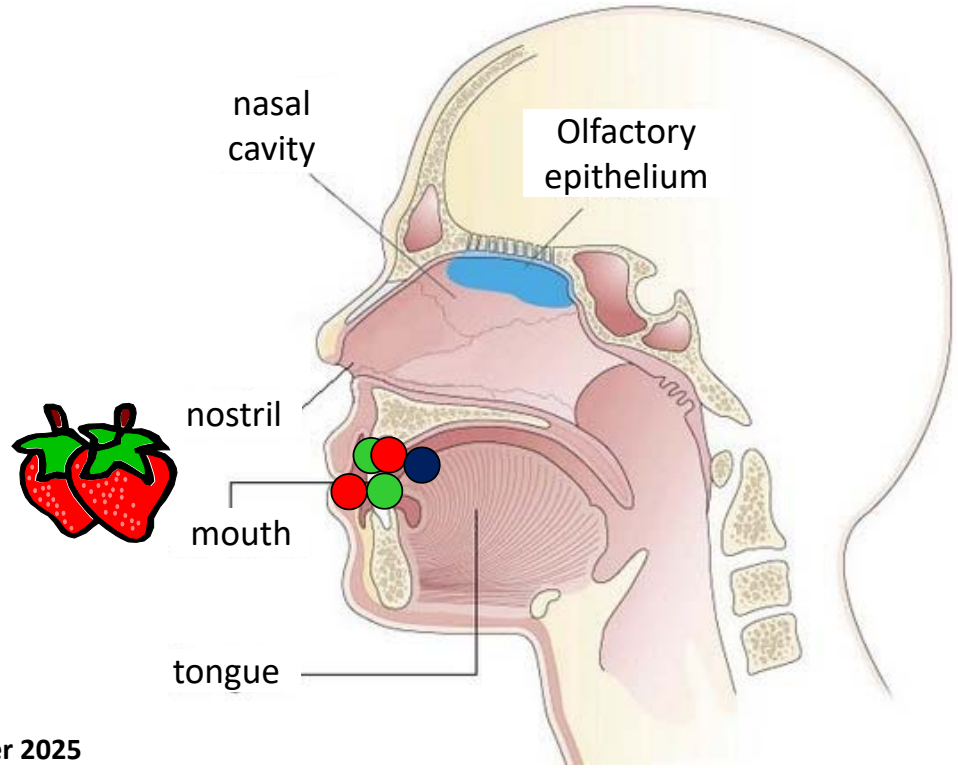
- Orthonasal or sniffing route: odours





Sense of smell

- Retronasal route: « aromas »



Odorant compounds

- To be odorant a molecule must be
  - volatile enough to enter the air phase : 30 < molar mass < 400 g/mol
  - be nonvolatile and hydrophilic enough to sorb into the mucous layer coating the olfactory epithelium
  - be hydrophobic enough to enter an olfactory receptor binding pocket
  - activate at least one olfactory receptor

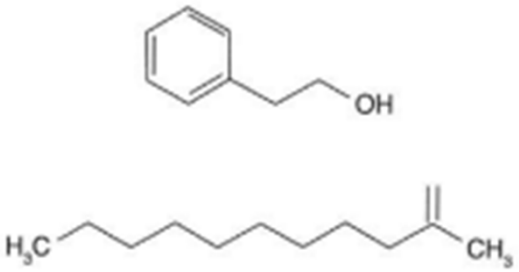
Mayhew et al., PNAS, 2022

Odorant compounds

- A large range of chemical classes
  - Hydrocarbons
  - Alcohols
  - Acids
  - Esters
  - Aldehydes
  - Ketones
  - Phenolic compounds
  - Sulphur compounds
  - ….
- ≈ 400 olfactory receptors
  - Each receptor can be activated by many different compounds
  - Each volatile compound can activate different receptors
- Several thousands of different odours

Odorant compounds

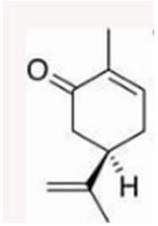
- The relationship between molecular structure and odour is still a challenge



2-phenyl ethanol

2-undecanone

Carvone



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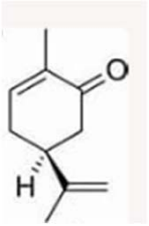
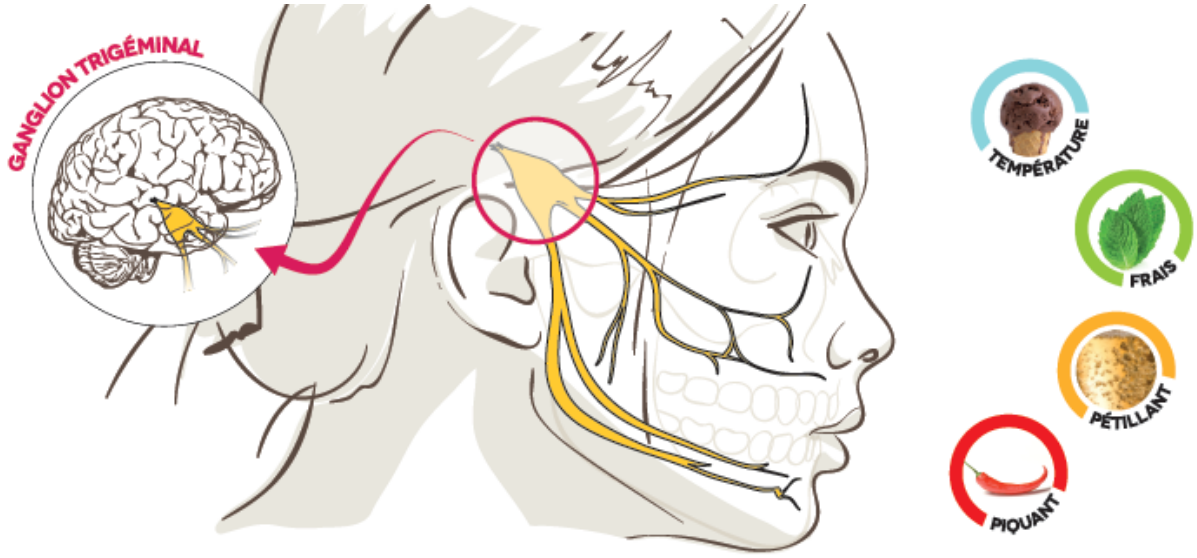


(S)-(+)

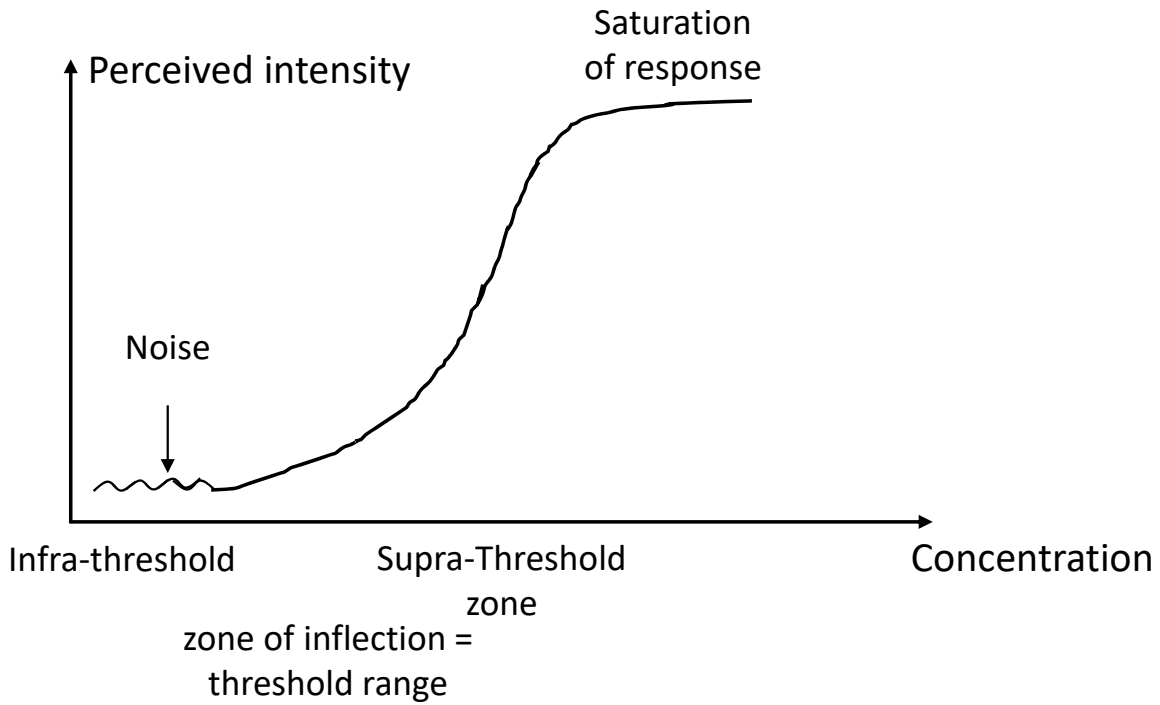
Trigeminal perception

- The trigeminal nerve innervates the oral and nasal cavity
- Perceptions
  - Temperature
  - Texture
    - Fizzy
    - Astringency
  - Chemoperception
    - Burning
    - Fresh



Perception

- 3 dimensions
  - Quality
  - Intensity



  - Hedonism

Sensory analysis: what is it?

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  as perceived through the senses of sight, smell, touch, taste, and hearing

= Panellists should based their judgements only on their own sensory experience related to the products

⇒ Guidelines for the preparation and serving of samples under controlled conditions

Sensory analysis: what is it?

⇒ Guidelines for the preparation and serving of samples under controlled conditions

- ⇒ Individual test booths
  - o to avoid the influence of other panel members (suggestion error)
  - o To reduce distraction
- ⇒ Sensory room: free of visual, auditory, odorous disturbances
- ⇒ Control temperature, relative humidity, lighting

Sensory analysis: what is it?

⇒ Guidelines for the preparation and serving of samples under controlled conditions

- ⇒ Reduce all biasing factors when serving samples (expectation error)
  - Neutral containers (colour, no odour)
  - Same volume, same size for all samples
  - Same temperature
  - Samples labelled with random numbers

Sensory analysis: what is it?

- Scientific method used to evoke, measure, analyze, and interpret **human responses**

⇒ Panel recruitment
  - Where ?

	Internal	External
Cost	Indirect	Direct
Choice	Often limited	Large option in cities
Bias	Product, process knowledge	
Availability	Often limited	Ok if defined in advance
Consequences	Positives for quality insurance	

Sensory analysis: what is it?

- **Scientific method** used to evoke, **measure**, analyze, and interpret human responses

  $\Rightarrow$ Sensory evaluation is concerned with
  - Precision or reliability
  - Accuracy
  - Sensitivity

Sensory analysis: what is it?

- **Scientific method** used to evoke, **measure**, analyze, and interpret human responses

  $\Rightarrow$ Sensory evaluation is concerned with

  - Precision or reliability
  - Accuracy
  - Sensitivity = ability
    - To perceive a stimulus
    - To detect differences

Physiological factors affecting sensitivity

- Individual differences in sensitivities
  - Genetics: differences in thresholds
    - Taste: large differences for bitterness perception

→ Bimodal distribution of thresholds for

- phenylthiourea (PTC)
- 6-n-propylthiouracil (PROP)
- other compounds with the functional group N-C=S, group present in biter compound found in crucifers

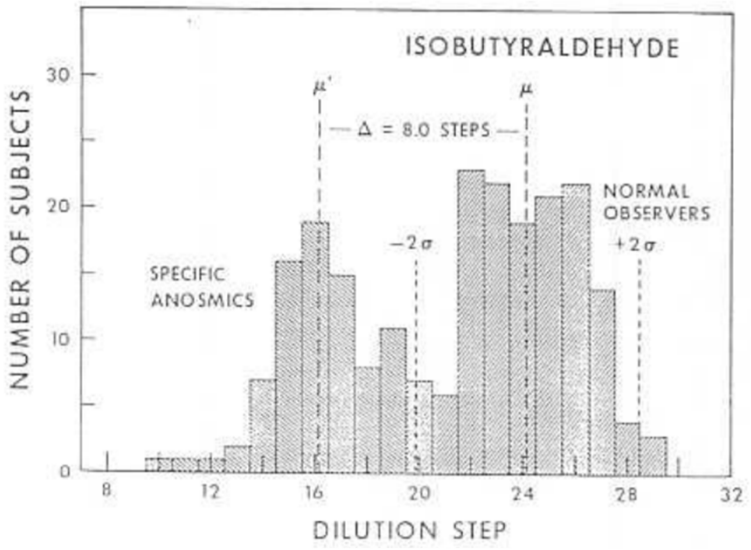
→ Due to a modification in one receptor TAS2R38

Physiological factors affecting sensitivity

- Individual differences in sensitivities
  - Genetics: differences in thresholds
    - Olfaction: specific anosmia

→ Bimodal distribution of thresholds

Compound	Odour
Isobutyraldehyde	Malty odour
5α-Androst-16-en-3-one	Boar taint
ω-Pentadecalactone	Musky odour
Trimethylamine	Fish spoilage taint
(S)-(+)Carvone	Spearmint
1,8-Cineole	Camphor odour
Isovaleric acid	Sweaty odour
4-ethyl-octanoic-acid	Goat cheese
…	



Amoore, In Smell and taste in health and disease, 1991

Boelens et al., Perfumer & Flavorist, 1983

Physiological factors affecting sensitivity

- Individual differences in sensitivities
  - Gender and hormonal influence
    - Olfaction

Women generally outperform men in odour tests, in particular in odour identification

But changes in odour perception during pregnancy :

Pregnant women give higher intensity ratings to some odorants, demonstrate an improved ability to identify some odorants, but also do worse for other odorants

- Taste

No consensus

Effect of pregnancy seems to differ according to tastes and studies

Physiological factors affecting sensitivity

- Individual differences in sensitivities
  - Diseases and medical treatments
  - Ageing: Decline in chemosensory abilities
    - Physiological mechanisms (ageing process per se)
    - Previous chronic exposure to toxic compounds
    - Diseases & medications

Sensory analysis

To answer to which questions?

Are the products perceived differently?

What are the differences between the products?

Sensory analysis

To answer to which questions?

Are the products perceived differently?

Difference testing

Generally screened for sensory acuity
Sometimes trained

What are the differences between the products?

Descriptive analyses

Screened for sensory acuity
Trained or highly trained

Screening : a battery of tests that are appropriate

- to the products to be evaluated
- to the tasks required of the panellists

Difference testing

- Most common methods

Test name	Task	Probability	Question/situation	Training
Triangle test	What is the different sample?	1/3	e.g.: New ingredient; new process Objective: no perceptible change	Yes Taste acuity and/or olfactory acuity
Duo-trio	Which sample is the same than the reference	1/2	e.g.: New ingredient Objective: no perceptible change	Yes Taste acuity and/or olfactory acuity
3-AFC	What is the sample different from the other two?	1/3	Threshold determination	Yes or not
Pair test	Choose sample with most of specified attribute		e.g.: Formulation change targetted to a specific attribute	Yes Taste acuity and/or olfactory acuity

Difference testing

- Triangle test

"Choose the sample that is (most) different"

A B A

Six possible serving orders: AAB, ABA, BAA, BBA, BAB, ABB

Counterbalanced across all panellists

Difference testing

- Duo-trio test

  “Choose the sample that is the same (or most similar) to the reference”

A B A

Two possible orders: AB, BA

Counterbalanced across all panellists

Difference testing

- 3-AFC

"What is the sample different from the other two?"

For threshold measurements:

- 2 'neutral' samples and 1 sample with the test compound
- Panellists are informed about the quality of the test compound

If the aim is to evaluate the effect of individual characteristics on threshold:

- Same order for all panelists

If the aim is to evaluate the threshold of a given compound:

- Three possible serving orders: AAB, ABA, BAA
- Counterbalanced across all panellists

Difference testing

- How many panellists?

In many cases, the purpose is to declare that 2 products are non-distinguishable

$\Rightarrow$ Control the risk of wrongly drawing such a conclusion

	The 2 products are	
Truth / Decision	non-distinguishable	distinguishable
H_0 true A = B	OK	2^{nd} type risk β
H_1 true A $\neq$ B	1^{st} type risk α	OK Power: 1- β

→ I declare A=B when actually A≠B

↓ I declare A ≠ B when actually A=B

Decrease $\beta \Rightarrow$ Increase the panel size

Schlich, Food Quality and Preference, 1993

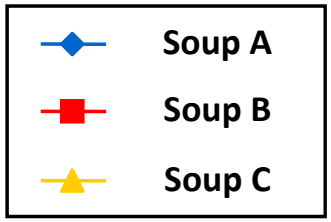
Descriptive analysis: aims

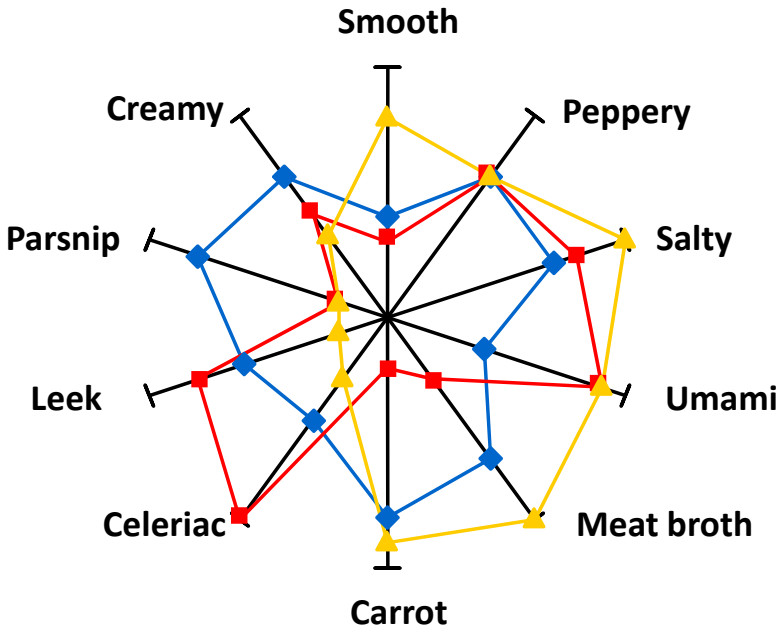
- Comparing different varieties or different cultural practices in the vegetal production domain
- Comparing different species or different rearing practices in the animal production domain
- Quality insurance
  - checking the quality of ingredients and raw materials
  - checking the quality of the final product
- Studying the impact of a change in the origin of raw materials or ingredients, or in the product formulation
- Studying the impact of different parameters of the process
- Obtaining useful information for determining the ‘best before date’ and to compare different packaging in shelf-life testing
- Assessing competitive products

Descriptive analysis: definition

- Sensory method providing a sensory description of products
  - qualitative
  - quantitative

⇒ Panellists have to rate the perceived intensity of a list of sensory attributes (descriptors)





Descriptive analysis: which method?

- Analyse Descriptive Quantitative ou QDA® (Stone et al., 1974)
- **Sensory profile (ISO 13299, 2016)**
- Texture profile (Brandt et al., 1963 ; Szczesniak, 1963)
- Spectrum Method™ (Munõz et Civille, 1992)

"Conventional methods"

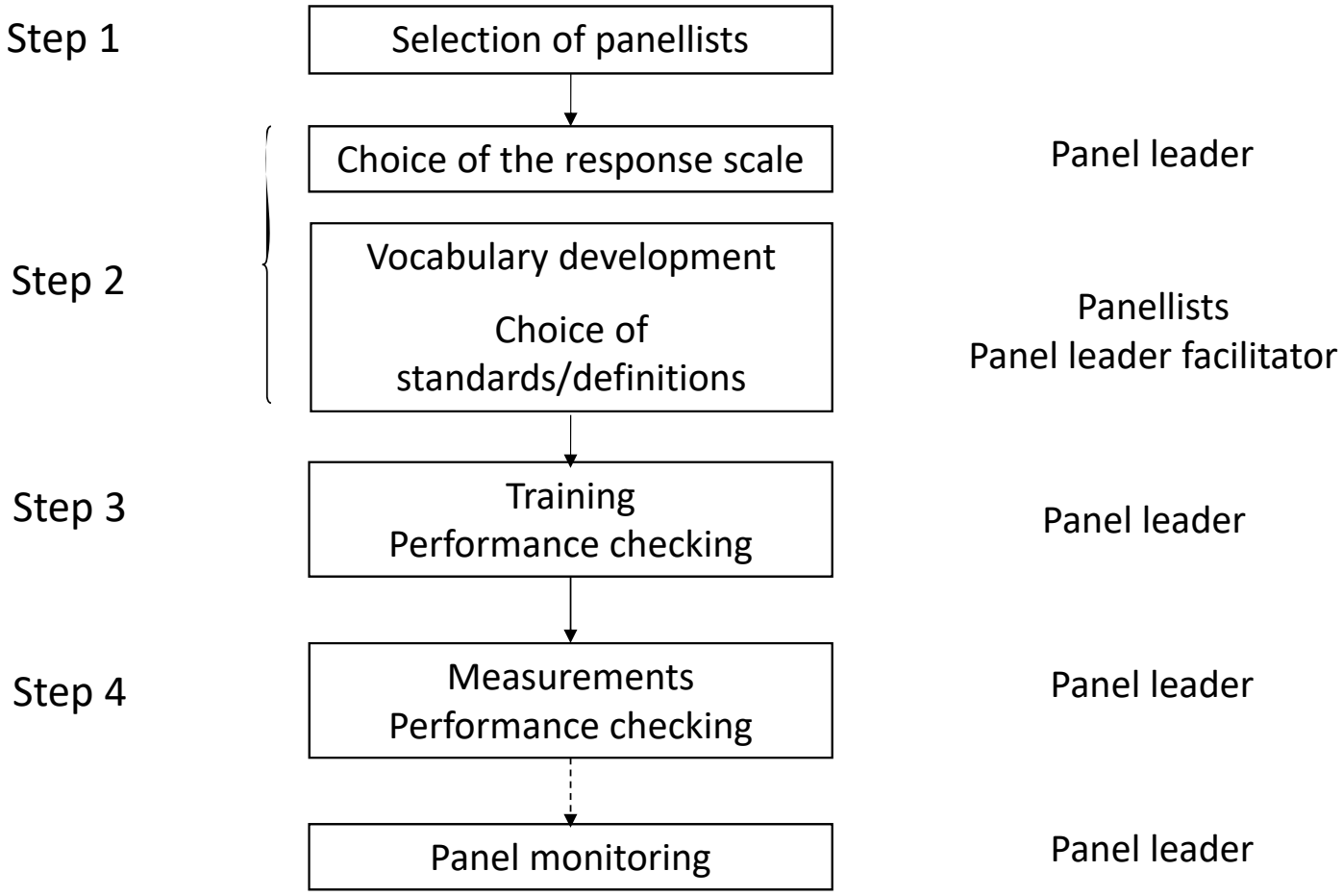
- Free choice profile (Williams et Langron, 1984)
- Flash profile (Sieffermann, 2000)

Rapid methods

Descriptive analysis: different methods

Situation	Method	Comments
Key product(s) for a company	Conventional profile	Long and expensive
Large range of products	Spectrum Method™	Long and expensive
Quick results	Free choice profile	No consensus on vocabulary Only multivariate analysis
		No consensus on vocabulary Only multivariate analysis Comparative approach ⇒ limited number of products no comparison over time

Sensory profile: different steps



Sensory profile: panellists' selection

- Sensory acuity: Normal taste and odour perceptions using actual products from the category
- Ability to discriminate stimuli
- Ability to express oneself verbally about sensory perception
- Ability to memorize odours
- Ability to concentrate on a task
- Long-term availability

Sensory profile: vocabulary development

- Assessors are presented with the largest possible range of samples similar to what they are supposed to encounter later, at a rate of a few samples per session
- Each assessor works independently
  is asked to write down the largest possible number of descriptors characterizing each sample on the sensory dimensions defined by the panel leader
- Terms are gathered, discussed and compared
- The panel decides the sequence for evaluating each attribute

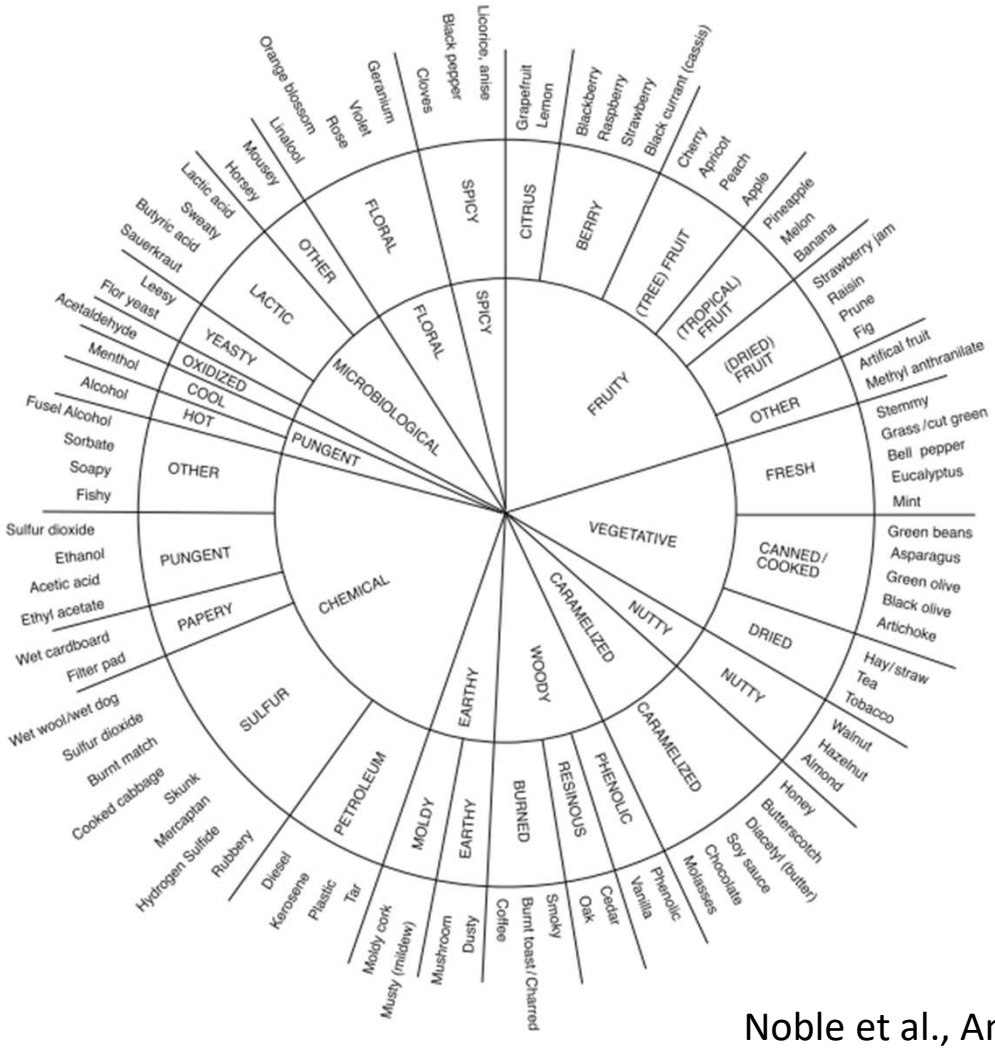
Sensory profile: vocabulary development

- The panel leader should
  - ask to eliminate hedonic terms
  - encourage to eliminate obvious synonyms
  - help to be as precise as possible
    - o “creamy”: texture and/or aroma ?
    - o “acid aroma”: pungency?, vinegar aroma?
  - help to choose reference products to illustrate descriptors/ give a definition
  - help to define a protocol to evaluate some characteristics, in particular those referring to texture

Sensory profile: the case of a previously established list of descriptors

- Important not to impose this pre-established list on the panel
- The panel must have the opportunity to modify the list to better fit the range of products to be studied
- Examples of pre-established lists
  - Beer flavour wheel (Meilgaard et al., 1982)
  - Wine aroma wheel (Noble et al., 1987)
  - Cheese sensory (all sensory dimensions) wheel (Pagliarini et al., 1991)

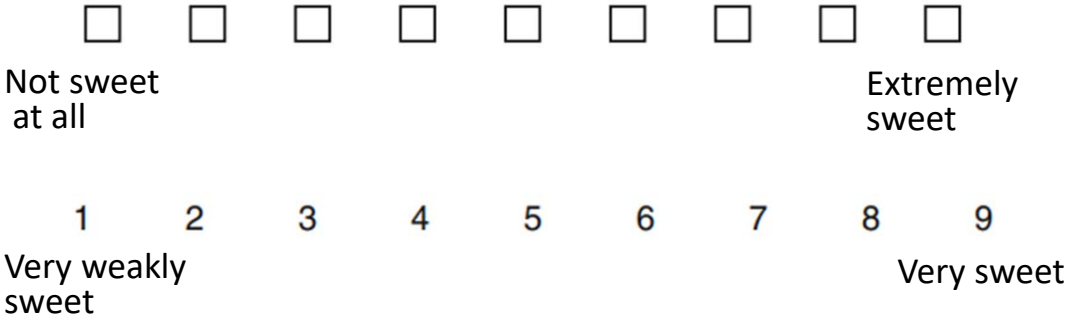
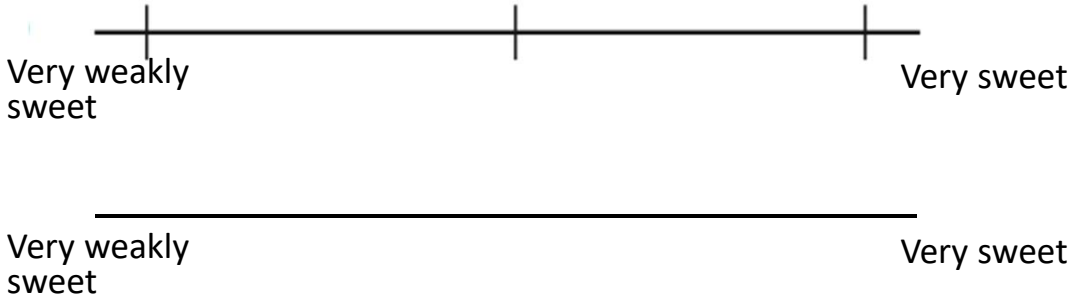
Wine aroma wheel



Reference materials for the outer terms

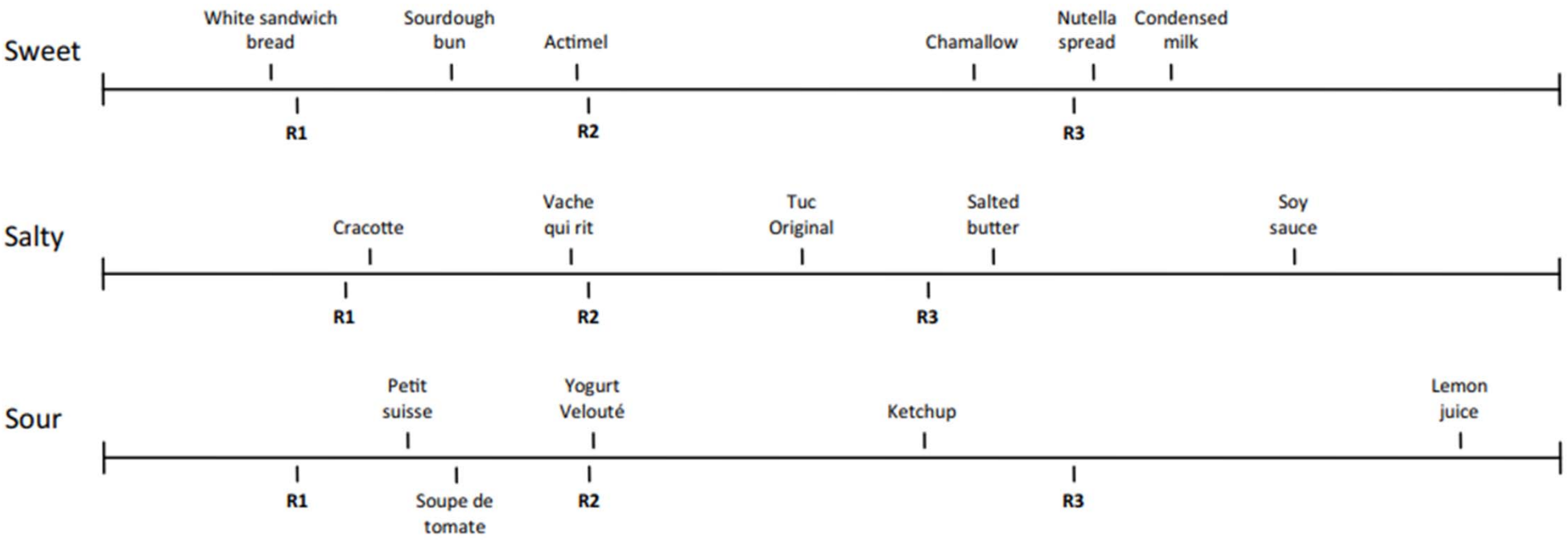
Noble et al., American Journal of Enology and Viticulture, 1987

Different types of response scales

Response scale		Data properties
Discrete category scale		Ordinal Interval?
Line scale		Interval

Universal scales

- Develop and employs in the Spectrum method™ (Muñoz & Civille, 1992)
- Adapted in a work to create a taste database for French foods (Martin et al. 2014)



Physiological factors affecting results

- Adaptation
  - Continued exposure to a stimulus
    - ↘ sensitivity to that stimulus
    - ↘ sensitivity to stimuli activating the same receptors
    - The higher the concentration, the higher the adaptation
- Carry-over effect
- May be minimized by
  - Using a design of presentation balanced for order effect and carry-over effect
  - Providing palate cleansers (water, bread, apple, …)

Psychological factors affecting results

- Fatigue/boredom
  - Attention and concentration ↘ along the session
- May be minimized by
  - Using a design of presentation balanced for order effect & carry-over effect
  - Limit the number of samples per session

Psychological factors affecting results

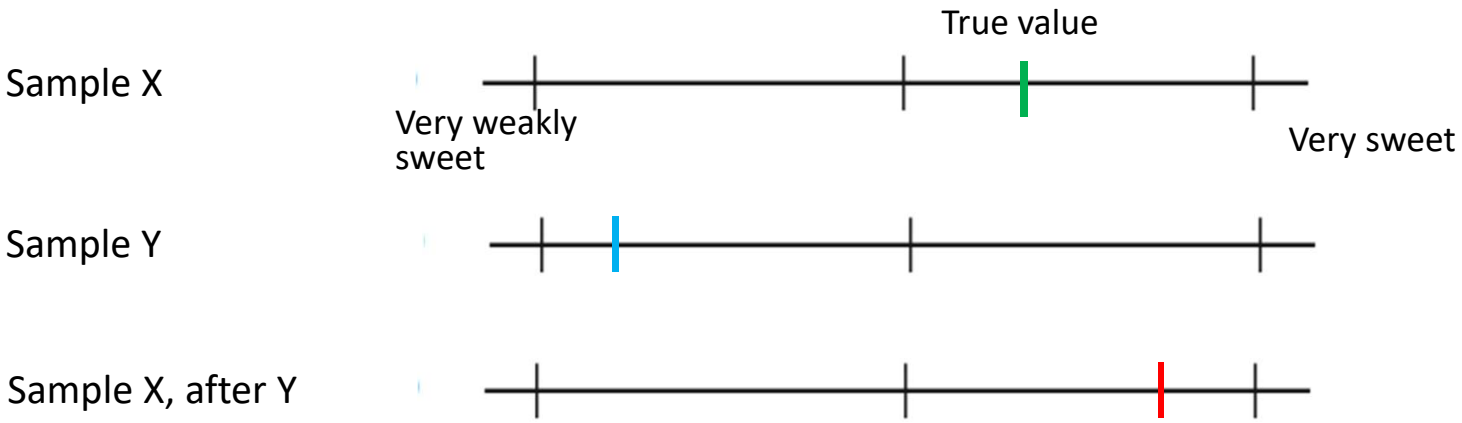
- Errors related to the presentation order of the samples
  - Positional bias
    - 1st position effect: especially quite strong in hedonic measurements
    - Also observed in descriptive analysis
    - Also found that
      - o the occurrence of the order effect depends on the descriptor
      - o the direction also depends on the descriptor:

      ratings for acid, astringent and floral flavour are lower when a coffee sample is evaluated in the 1st position

      ratings for bitter and burnt flavour are higher when a coffee sample a coffee sample is evaluated in 1st first position.

Psychological factors affecting results

- Errors related to the presentation order of the samples
  - Positional bias
  - Sequence of presentation
    - Contrast



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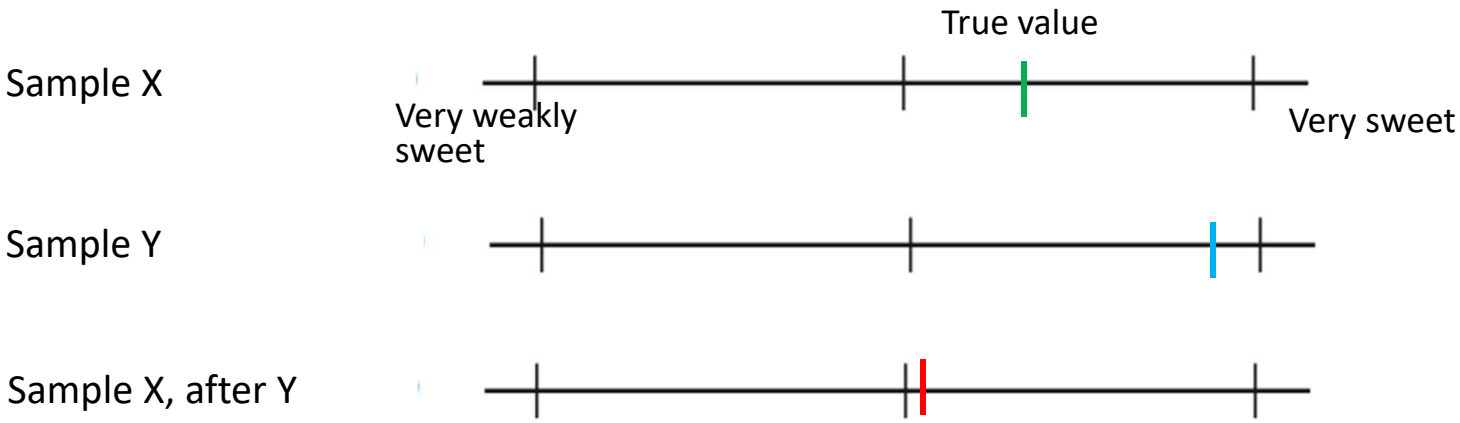
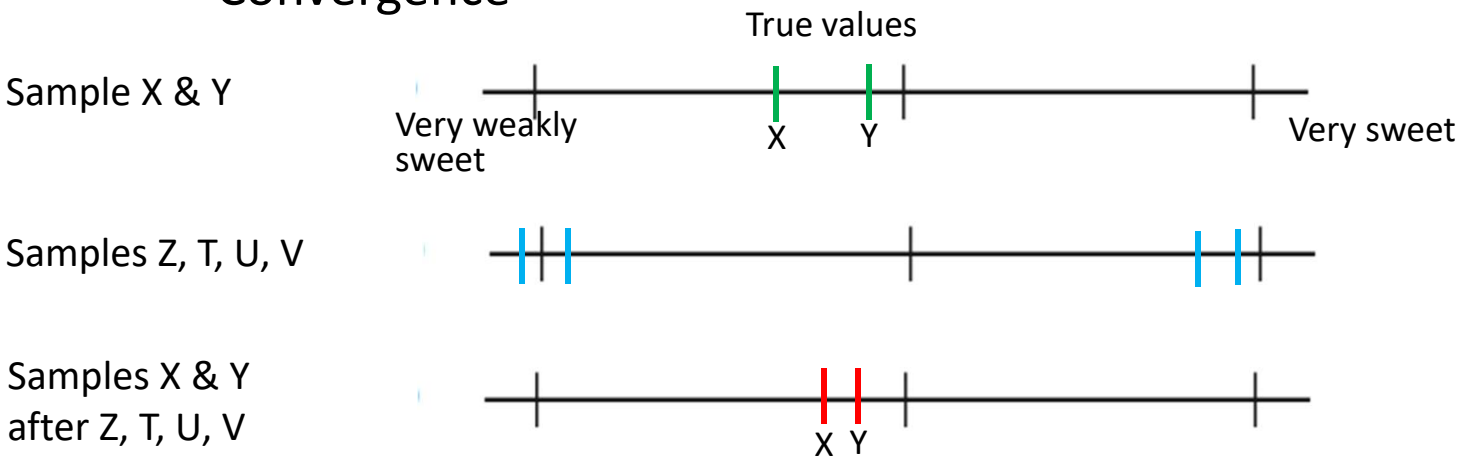


Psychological factors affecting results

- Errors related to the presentation order of the samples
  - Positional bias
  - Sequence of presentation
    - Convergence



Psychological factors affecting results

- Errors related to the presentation order of the samples
  - Positional bias
  - Sequence of presentation
    - Contrast
    - Convergence
- May be minimized by
  - Using a design of presentation balanced for order effect & carry-over effect
  - Same range of variation between samples at each session

Psychological factors affecting results

Designs of presentation balanced

Latin square

For order effect

Sample order

Panellists	1	2	3	4
1	A	B	C	D
2	B	C	D	A
3	C	D	A	B
4	D	A	B	C

Williams Latin square

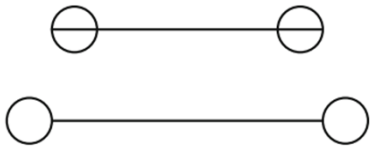
For order effect and carry-over effect

Sample order

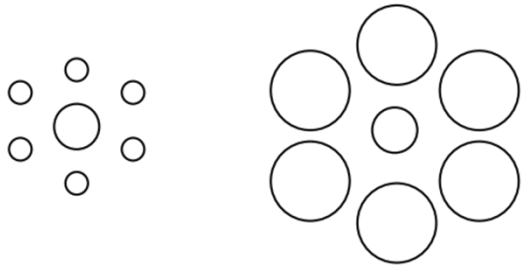
	1	2	3	4
1	A	B	C	D
2	B	D	A	C
3	C	A	D	B
4	D	C	B	A

Psychological factors affecting results

- Context effects



The dumbell version of
the Muller–Lyer illusion

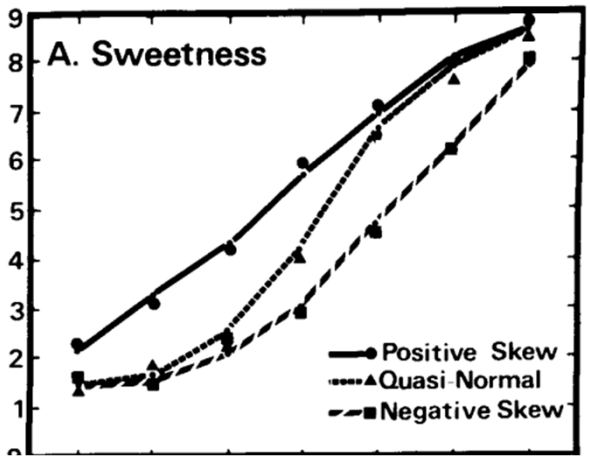


The Ebbinghaus illusion

Lawless & Heymann, Sensory evaluation of food. Principles and practices, 2010

Psychological factors affecting results

- Context effect or range frequency effect



Frequency of presentation (over 21 Trials) of each of 7 sucrose concentrations in the 3 Contexts

	Sucrose Molarity						
Context	.06	.11	.19	.34	.59	1.0	1.8
Positive Skew	7	4	3	3	2	1	1
Quasi-Normal	1	2	4	7	4	2	1
Negative Skew	1	1	2	3	3	4	7

- May be minimized by
  - Training
  - Spectrum scales

Psychological factors affecting results

- Central error

Tendency to use the middle of the scales and avoid the extremes

- May be minimized by
  - Training
  - Spectrum scales

Dumping effect

- Occurs when a relevant attribute is missing in the ballot

$\Rightarrow$ Panellists report their perception on one or several of the available attributes

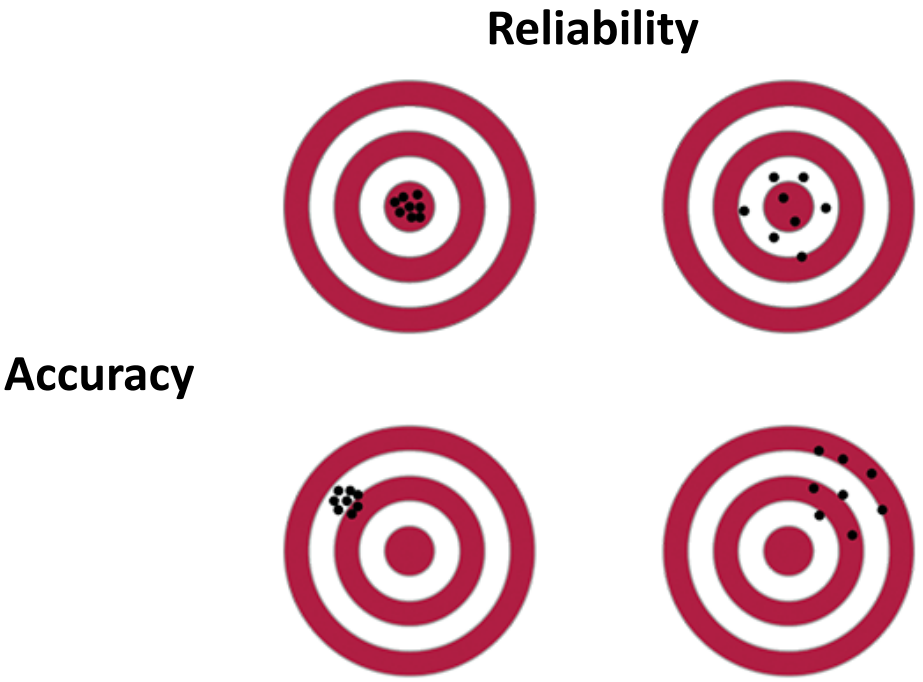
- May be minimized
  - If all relevant descriptors are included in the ballot

  and/or
  - By adding a scale labeled “other” to prevent this effect

Panel performances

- **Scientific method** used to evoke, **measure**, analyze, and interpret human responses

  ⇒ Sensory evaluation is concerned with
  - Precision or reliability
  - Accuracy
  - Sensitivity



Panel performances

- Reliability

⇒ Include replicates within a session or at different sessions

- Accuracy: cannot be checked as with physical measurement

→ Consistency = degree of agreement between panelists

or even between two panels

- Discrimination

⇒ When possible include samples with known concentration of an ingredient known to induce a specific sensory perception

- These performances must be checked at two levels
  - Individual
  - Group

Ethics in sensory analysis

- Panel = Human subjects

$\Rightarrow$ Need to follow the guidelines that constrain the use of human subjects

- Main principles related to participation of human subjects
  - Participants must be informed
  - Participants must give their consent
  - Participants have the right to stop their participation at any time and without any negative consequence
  - Participants' personal data must be protected
  - Constraints and risks should be minimized
    - Safety risk
    - Psychological risk
- Ethical questioning related to the aims of the project
  - The study should yield fruitful results for the good of society

Lawless & Heymann, Sensory evaluation of food. Principles and practices, 2010

WMA Declaration of Helsinki - Ethical principles for medical research involving human participants (2024). https://www.wma.net/policies-post/wma-declaration-of-helsinki/

Conclusion

Sensory analysis

- Useful tool to answer many questions
- Requires knowledge and skills in different disciplines
  - Food science
  - Physiology
  - Psychology
  - Statistics
  - Ethics

Thanks for your attention !

Questions ???