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Modelling Cacao and Chocolate Flavour Through Human Sensory Tasting

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Flavour: Past, Present, Future

Current Flavour Systems

Text Descriptions: Qualitative
Flavour Wheels: Infographic
Spider Diagrams: Ad-hoc

The Science of Flavour

The Chemistry of Chocolate Flavour
Flavour Relations and Networks
How Does the Brain Do It?

Modelling Chocolate Flavour

A Neural Model For Flavour Perception
A Map for Chocolate Flavour
Real-World Tasting Experiments

Future Work

Expanding the Map
Towards Field Cacao Profiling
But Does the Chocolate Taste Good?

Text Descriptions: Qualitative

Based on Listing of Attributes

Uses descriptors with an unquantified, but defined meaning

Resists Spurious Oversystematisation

Does not attempt to apply systems that may naïvely oversimplify the complexity of flavour

But: Usually Requires Expertise

Knowing what the attribute descriptors mean generally requires some years of tasting experience

Cannot Indicate Precise Character

Since attributes are unquantified, the balance of each - and hence the overall profile, cannot be described.

Perception	Sensory attribute	Volatile compound (IK)
Floral	Floral	1,426, 1,450, 1,578, 1,609, 1,688, 1,695, 1,696, 1,712, 1,750, 1,752, 1,773, 1,825, 1,832, 1,862, 1,894, 1,930, 2,254, 2,830
	Jasmine	1,696, 1,748
	Rose	1,743, 1,773, 1,832, 1,862, 2,382
	Lavender	1,743
	Honey	1,748, 1,773, 1,775, 1,862, 2,125, 2,254, 2,830
	Balsam	1,475, 1,895, 2,020, 2,125
	Refreshing	1,450
	Faint balsamic	2,310
	Essences	2,486
	Fragant	1,445, 1,773, 1,862
	Heavy floral	1,762
	Wax flowers	2,496
Vegetal	Herbaceous	1,195, 1,320, 1,688, 1,762
	Green	1,195, 1,304, 1,320, 1,695
	Mild green	1,100, 2,226
	Woody	1,445, 1,815, 2,031
	Spicy	1,578, 1,663
	Cereal	1,431
	Raw potato	1,373
Sweet chocolate	Cocoa	1,251, 1,297, 1,318, 1,377, 1,438, 1,475, 1,932, 1,968
	Chocolate	1,163, 1,251, 1,438, 2,594
	Vanilla	2,594
	Sweet	1,129, 1,420, 1,445, 1,460, 1,475, 1,540, 1,609, 1,727, 1,743, 1,748, 1,762, 1,775, 1,832, 1,894, 1,895, 2,022, 2,254, 2,382, 2,594
	Sweet candy	1,005

Partial List of Flavour Descriptors from Bonvehí, *Eur. Food Res. Technol.* **221**:19-29 [1]

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Flavour Wheels: Infographic

An Attempt to Group Flavours

Tries to put similar flavours close together on the wheel

Can Be Hierarchical

Inner wheel segments can represent supergroups

But: Implies a Cyclic Relationship

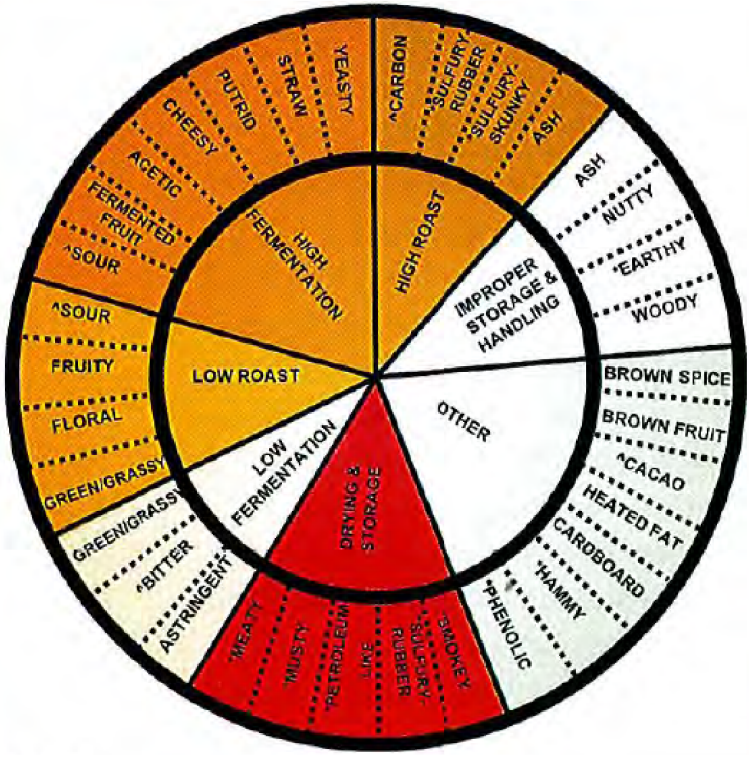
Does flavour link 'end-to-end'? There is always going to be a discontinuity somewhere.

Categories May Be Arbitrary

Without very careful research establishing what flavours are 'similar' can be very ambiguous

Only Says What You Might Get, Not What You Have

No way to represent relative strengths or similarities, or compare chocolates.



Flavour Wheel from Reed, *The Manufacturing Confectioner.* **90**(11):43-52 [2]

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Spider Plots: Ad-Hoc

Add A Quantitative Dimension

Spider plots can indicate relative strength of different factors.

Multivariate

Can depict several factors simultaneously.

But: Axes Are Defined Ad-Hoc

Arbitrary choice of variables, which may not be orthogonal. No standard exists.

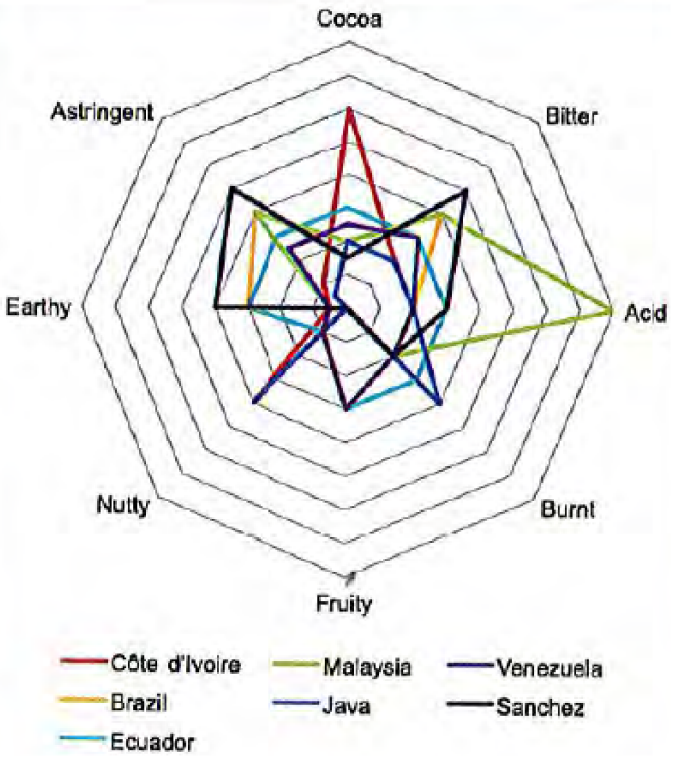
What is Being Quantified?

Since variables are qualitative, it is unclear exactly what feature they describe.

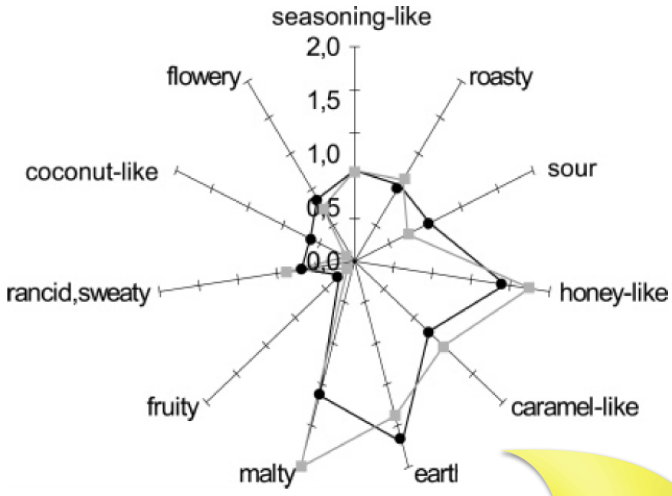
No Clear Link to Flavour

It is not easy to predict what a cacao will tastes like from a spider plot.

Spider Diagram from Reed [2]



Spider Diagram from Frauendorfer and Schieberle, *J. Agric. Food Chem.* **54**(15):5521-5529 [3]



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The Chemistry of Chocolate Flavour

General Method: GC-MS Analysis

Fractionates compounds and then identifies chemical signatures

Flavour 'Heroes'

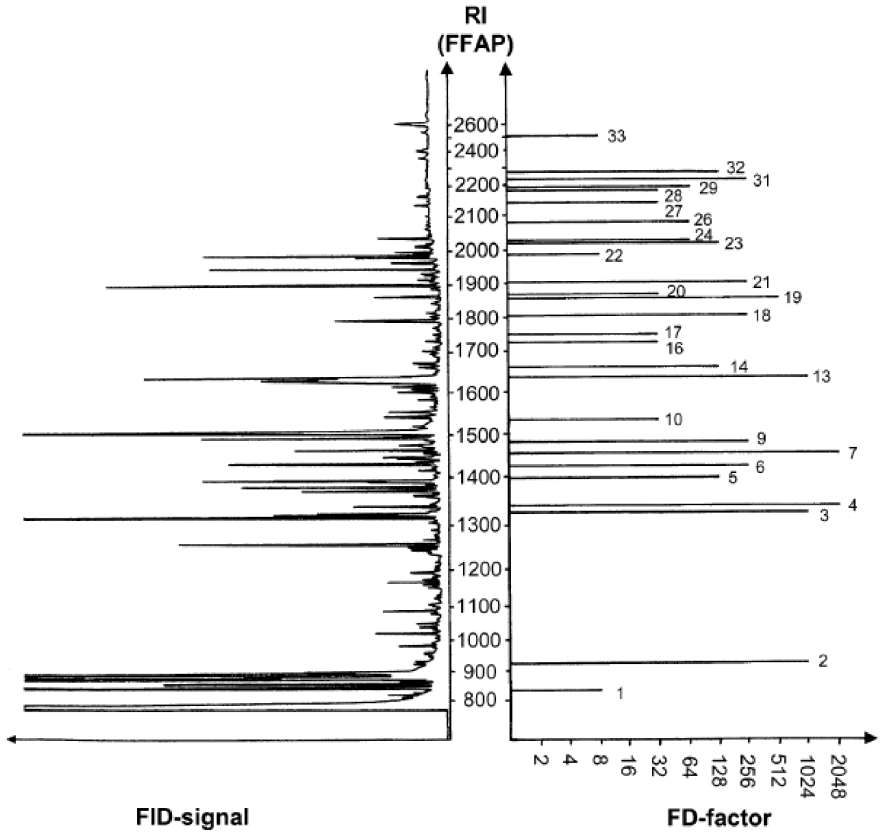
4-Hydroxy-2,5-dimethyl-3-furanone
Linaool Oxide
2-Phenyacetaldehyde

Flavour 'Villains'

3-Methybutanoic acid
Dimethyl di- and trisulphide

May Not Correspond to the Flavour Experience

Different chemicals taste different in different contexts, and the human sensory system does not taste chemicals separately.



GC-MS Plot from Frauendorfer and Schieberle, *J. Agric. Food Chem.* **54**(15):5521-5529 [3]

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Flavour Relations and Networks

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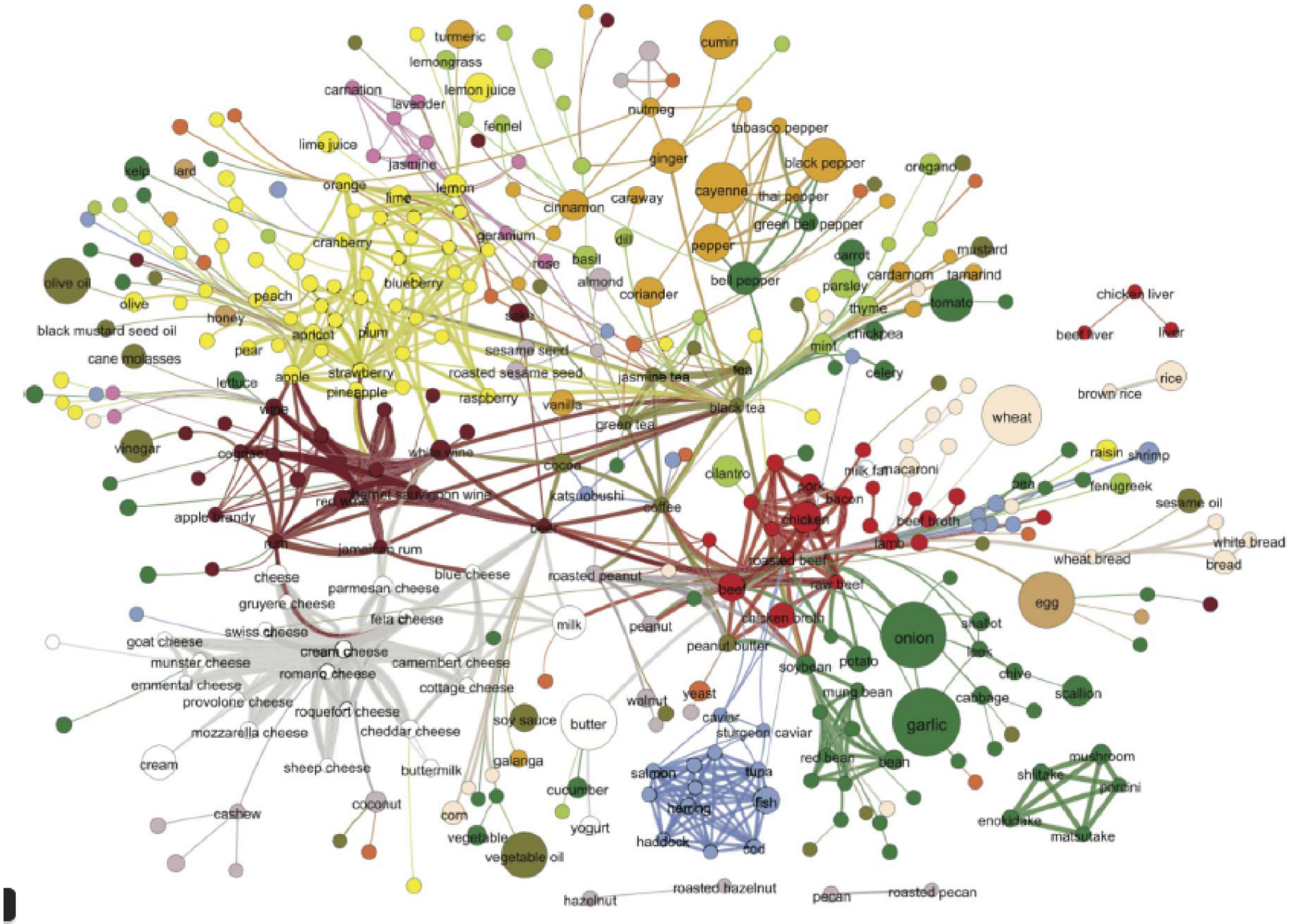

Categories

- fruits
- dairy
- spices
- alcoholic beverages
- nuts and seeds
- seafoods
- meats
- herbs
- plant derivatives
- vegetables
- flowers
- animal products
- plants
- cereal

Prevalence

50 %
30 %
10 %
1 %

Shared compounds

150
50
10

Flavour Network from Ahn, et al.
Scientific Reports. **1**:196 [4]

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How Does the Brain Do It?

Sensory Neurons: Input

Basic sensing of chemicals

Olfactory Bulb: Sorting

Chemicals are sorted into different pathways

Piriform Cortex: Patterning

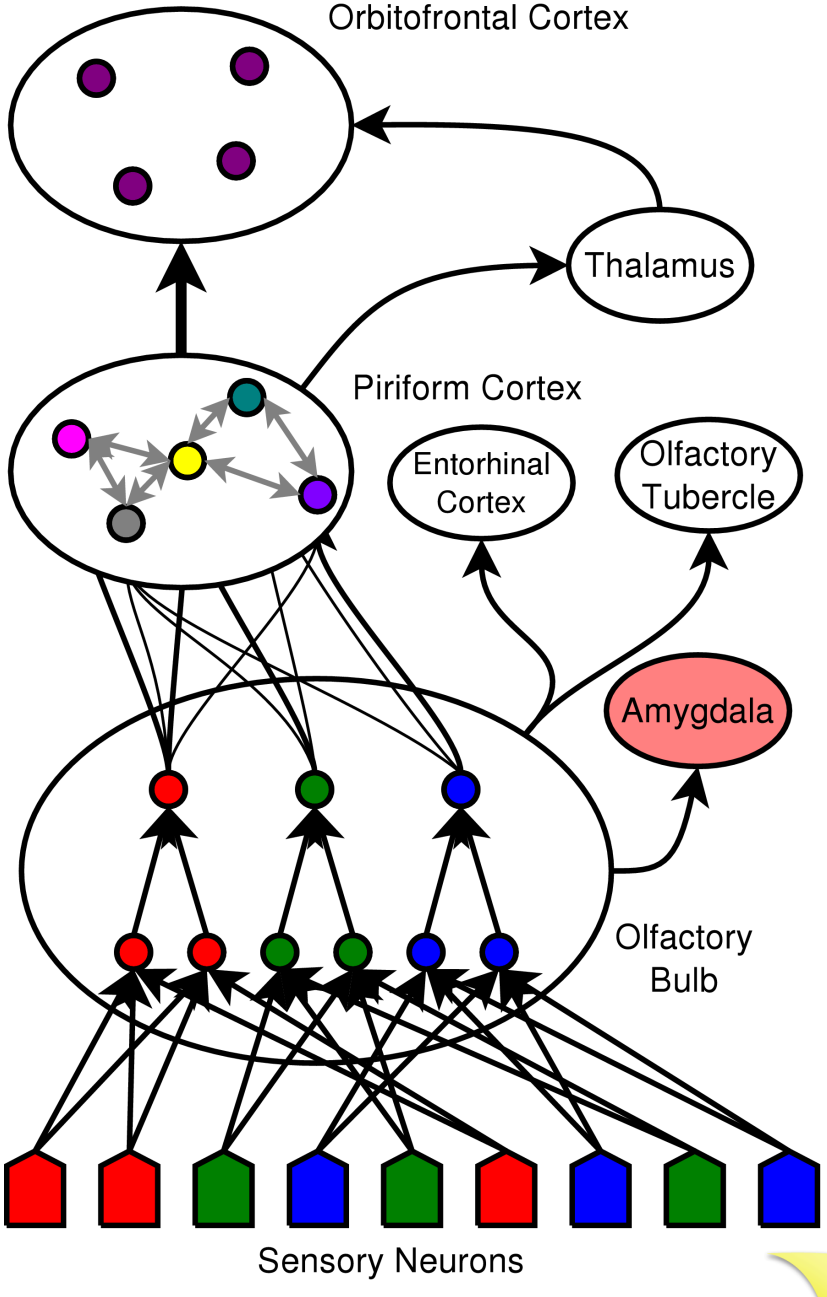
Chemical signatures are matched against stored archetypes

Orbitofrontal Cortex: Flavour

Archetypes are combined to represent an entire complex flavour

Amygdala: Emotion

Chemicals are classified according to degree of 'like' rather than type



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A Neural Model Of Flavour Perception

Neural Networks: Models of the Brain

A (hardware) computer-based simulation of a brain circuit (like the olfactory system)

3-Layer Model

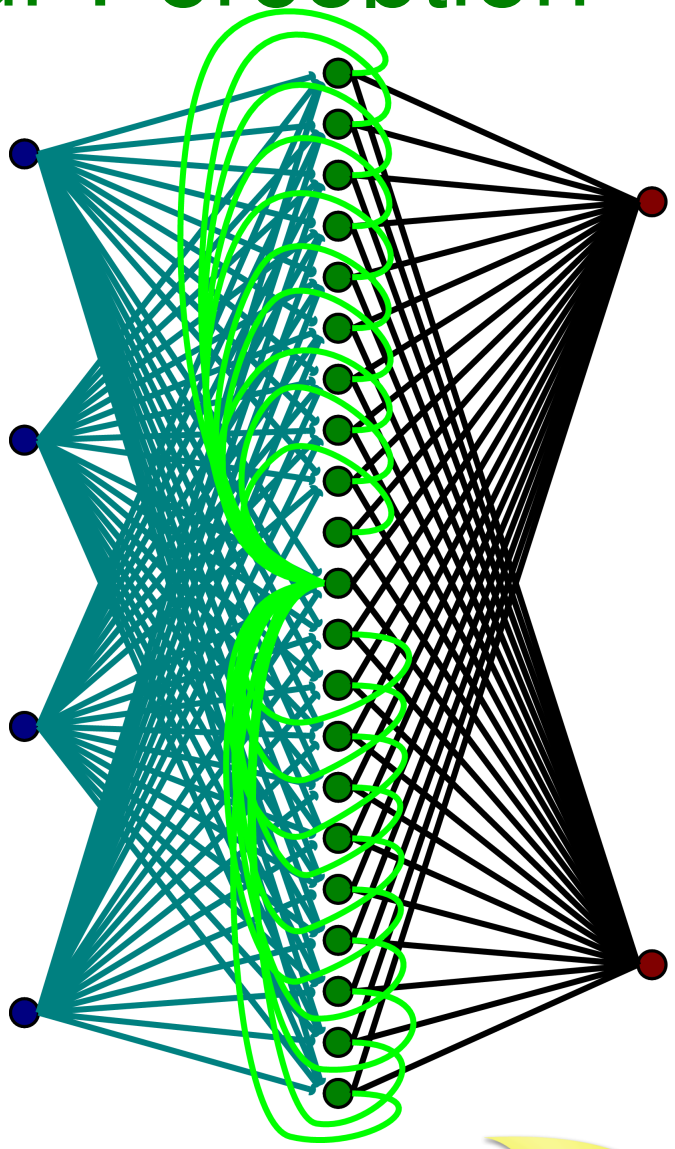
Models Olfactory Bulb, Piriform Cortex, and Orbitofrontal Cortex

Simplified Chemical Model

Uses data from Bonvehí, 'Investigation of Aromatic Compounds in Roasted Cocoa Powder'

Convolutional Network Model

Internal neurons match to a template and respond according to degree of match



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A Map of Chocolate Flavour

Uses an PCA of Composition to Flavour Profile

Principal Component Analysis: extracts the most important (in this case 2) variables affecting flavour.

Mapped Hidden-Layer Neurons

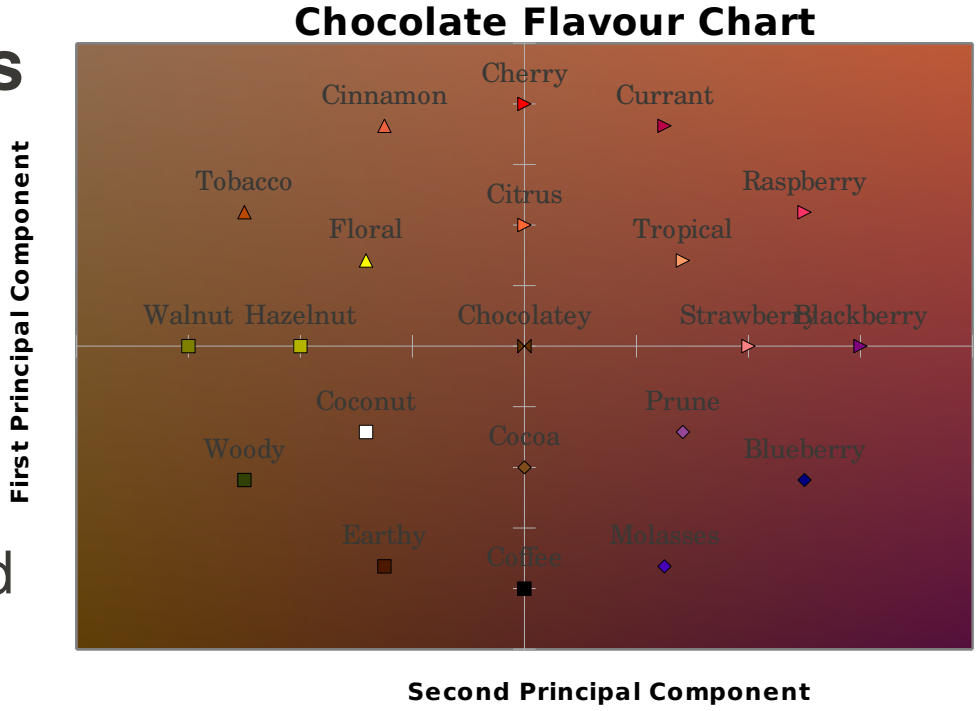
Each hidden layer neuron in the model represents one archetypal point in the space

Names Assigned Subjectively

Point names themselves are only for reference, can be changed and applied in different cultural contexts

Somewhat Synthetic

The model equally distributes archetypes in the space, in the real brain these might be nonuniform.



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Real-World Tasting Experiments

Real Tasters, Real Chocolates

44 different chocolates, up to 38 Tasters/Session

Tasters Used Profiling Map

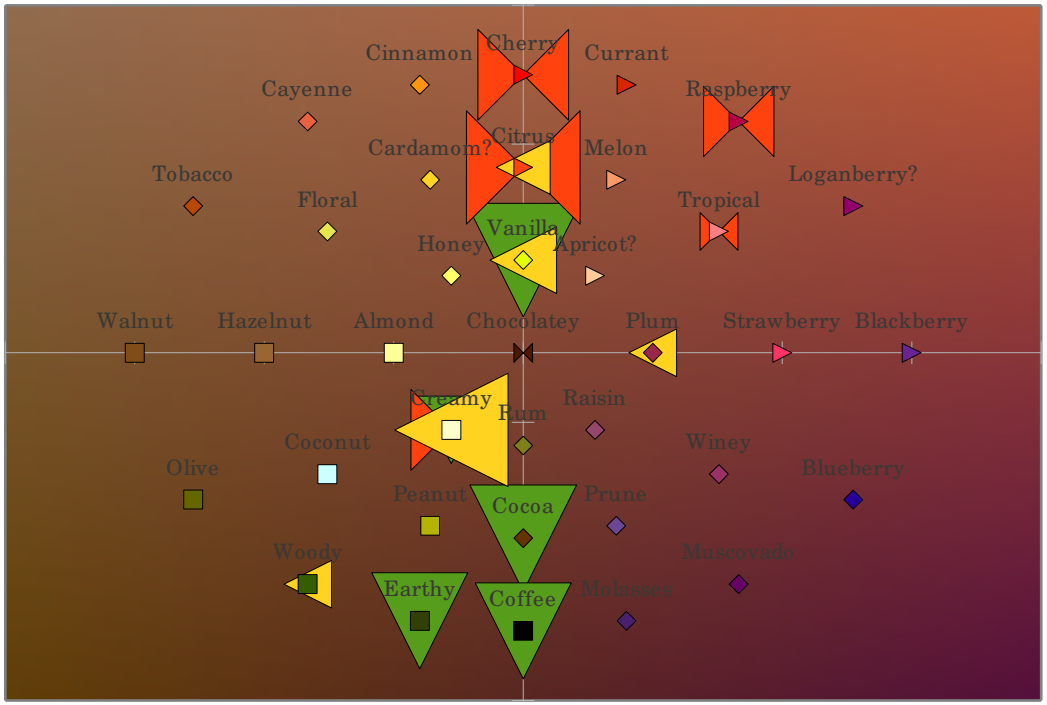
Expanded map as seen at right used for profiling, matched to neural data

Results Aggregated

Archetype score for each point added to give global total per point

Clear and Consistent Results

Live profiles closely match predictions



Orange Bowties: Akessons Madagascar 75%

Yellow Left-Arrows: Michel Cluizel Los Ancones

Green Triangles: Green & Black's 70%

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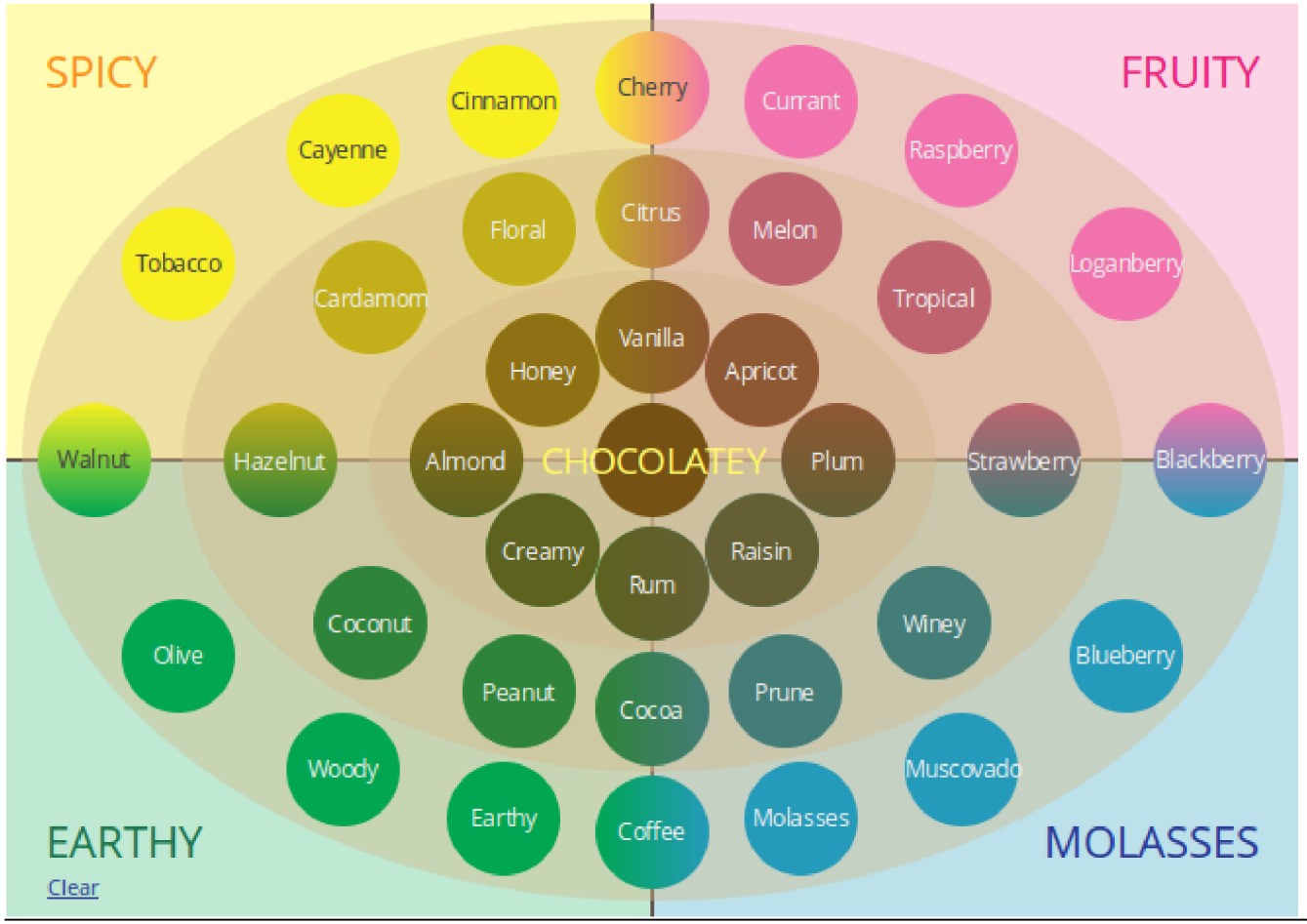
Expanding the Map



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Towards Field Cacao Profiling

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A Simple Field-Deployable Profiling System

Distributed on an electronic form that requires minimal prior expertise.

Hierarchical

Asks for easily-assessed characteristics first, with the ability to dig deeper but stop when unsure.

First Level: Basic Like/Dislike

The ultimate 'acid test': simple preference.

Second Level: Simple Attributes

Asks the profiler to describe why they like or dislike.

Third Level: Specific Qualities

Asks the profiler to detail positive and negative characteristics.

Evaluación calificada **¿Le gusta?**	**La muestra …**	**Su calificación (una solamente)**
Me gusta	**5.** tiene un gran sabor, sabor bien desarrollado, es cacao casi perfecto	
	4. sabor fantástico. Quiero comer más ahora.	
	3. tiene sabores interesantes, es placentero comer	
	2. tiene algunos sabores buenos, ningún defecto evidente	
Indiferente, bien	**1.** está bien, no es perfecta, pero tiene algunos puntos buenos	
	0. está bien para comer, pero no es interesante	
	-1. no es cacao malo, pero le falta sabor, no es complejo	
No me gusta	**-2.** no es agradable comerlo, puede tener defectos	
	-3. tiene defectos evidentes, yo no lo comería	
	-4. tiene defectos obvios y malos sabores obvios	
	-5. es repugnante, tengo que escupir	

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But Does It Taste Good?

Pleasure is What Matters in the End

The quality of a chocolate or cacao is ultimately decided by how much you like it.

Quantifying Flavour is Only a Tool

Models and systems of chocolate flavour can tell us what we have in a chocolate but do not decide whether it is good.

With Relevant Quantitative Systems We Can Reliably Establish Value

Uninformative systems will lead to unreliable quality assessment. Systems need to quantify the human experience of taste to give an accurate value to a given cacao.

With Relevant Ways to Describe Flavour We Will Gain Consumers

Clarifying the bewildering choice between equal-looking bars on a shelf removes the biggest barrier to consumer adoption.

70 seventy

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[2] Reed, S. 'Sensory Analysis of Chocolate Liquor', *The Manufacturing Confectioner* **90**(11), pp.43-52, November 2010

[3] Frauendorfer, F. and Schieberle, P. 'Identification of the Key Aroma Compounds in Cocoa Powder Based on Molecular Sensory Correlations', *Journal of Agricultural and Food Chemistry* **54**(15), pp. 5521-5529, 2006

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Questions?
Comments?

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