What Is Taste? How Brains Make Taste Sensations

Contents

Abstract

Brain transforms perceptual properties into patterns and motions of geometric-algebra vectors, making microscopic surface textures whose spatial and temporal properties are sensory experiences.

Keywords

6-n-propylthiouracil, basic taste, bitter receptor, chemoreceptor, cranial nerve, G-protein, insula, ion channel, L-glutamate, medulla, monosodium glutamate, orbitofrontal cortex, parabrachial nucleus, phenylthiocarbamide, phenylthiourea, potassium channel, primary taste, salt receptor, second messenger, solitary tract nucleus, sour receptor, sweet receptor, taste zero, thalamus, unami

1. Anatomy

Tongue chemical receptors send to thalamus, which sends to cortical regions.

1.1. Chemical receptors

Tongue receptors chemically bind to water-soluble molecules with molecular weights less than 200: hydrogen ions, hydroxide ions, salt ions, sugars, or amino acids. Receptor cells have 50 chemoreceptors, all of the same receptor type.

1.2. Neurons

Taste neurons receive from more than one taste-receptor type, but detect one main taste category: salt-best, sugar-best, acid-best, and bitter-best.

All bitter-receptor types synapse on same taste-neuron type (so people cannot discriminate among bitters).

1.3. Brain

Medulla solitary tract nucleus receives from tongue cranial nerves 7, 9, and 10, and sends to thalamus and to parabrachial nucleus (which also receives from GI tract).

Taste cortex is in insula, which sends to orbitofrontal cortex.

2. Physiology

Tongue receptors chemically bind to acid, base, salt, sugar, L-glutamate, and other amino acids.

2.1. Salty

Salt receptors detect positively charged salt ions, including sodium and potassium ions. Positive ions enter ion channels and directly cause depolarization.

Salty chemicals are small and ionic and have neutral acidity. Sodium-chloride sodium ions make pure salt taste. Potassium-chloride potassium ions make salt and bitter taste.

2.2. Sour

Sour receptors detect acids. Hydrogen ions enter ion channels, block potassium channels, or bind to and open other positive-ion channels.

Sour chemicals are small, ionic, and acidic. Hydrogen chloride makes pure sour taste.

2.3. Sweet

Sweet receptors detect non-ionic organic compounds, mostly sugars. Sweet receptors couple to G-proteins, and second messengers close potassium channels.

Sweet chemicals are large and polar and have neutral acidity. Glucose makes pure sweet taste. Fructose and galactose are sweet.

2.4. Bitter

Thirty different bitter receptors detect non-ionic organic compounds, such as alkaloids, including quinine and unripe-potato alkaloid {solanine}. Bitter receptors couple to G-proteins. Second messengers release calcium ions from endoplasmic reticulum.

Bitter chemicals are small or large, ionic, and basic. Hydroxide ions make pure bitter taste.

For one-half to two-thirds of people, with dominant allele, urea compounds {phenylthiourea} (PTU) taste bitter. PTU has no taste to other one-half to one-third of people, who cannot recognize NC=S chemical functional group [Kalmus and Hubbard, 1960].

6-n-propylthiouracil (PROP) tastes bitter. Supertasters have its chemoreceptors {6-n-propylthiouracil taste receptor}, have many fungiform papillae, and have high-intensity tastes. One-third of people cannot taste PROP, lack those receptors, have fewer fungiform papillae, and have low-intensity tastes.

Phenylthiocarbamide tastes bitter and is similar to propylthiouracil. One-third of people cannot taste it.

2.5. Umami

L-glutamate receptors {umami receptor} are metabotropic receptors similar to brain glutamate receptors and underlie savory taste [Ikeda, 1909]. Glutamate receptors couple to G-proteins, which have unknown second messengers. People with L-glutamate chemoreceptors can detect monosodium glutamate (MSG) and can distinguish umami savory taste from salt taste.

Savory chemicals are large, ionic-polar, and slightly acidic. L-glutamic acid sodium salt {monosodium glutamate} tastes distinctively salty and sweet.

Other amino-acid receptors are altered sweet receptors that bind amino acids. Other amino-acid receptors couple to G-proteins, which have unknown second messengers.

2.6. Taste zero

Salt, acid, base, or sugar at same concentration as saliva concentration is tasteless {taste zero}.

Saliva substance concentrations vary during the day. For example, saliva salt concentration is highest in morning, drops until afternoon, and then rises again to high morning value, so salt amount needed for salt taste varies over the day. Concentrations can be up to ten times lowest concentration.

2.7. Neurons

Taste neurons inhibit and excite each other to compare sugar, acid, base, salt, and L-glutamate receptor inputs to find differences and indicate taste types [Kadohisa et al., 2005] [Pritchard and Norgren, 2004] [Rolls and Scott, 2003].

Tastes are relative. For example, salt only tastes salty relative to other tastes [Brillat-Savarin, 1825].

2.8. Acidity

Molecule atoms, bonds, and electric charge determine acidity, which can be acidic, neutral, or basic.

Sour is acidic. Salty is neutral acidity. Savory is neutral. Sweet is neutral. Bitter is basic.

Salty, savory, and sweet have similar neutrality.

Sour and bitter have opposite acidity.

2.9. Ionicity

Molecule atoms and bonds and molecule-electron properties determine ionicity, which can be ionic or polar.

Sweet and some bitters are polar. Salty, savory, sour, and some bitters are ionic.

Sour and sweet, salty and sweet, and savory and sweet have opposite ionicity.

2.10. Size

Sour and some bitters have similar small size.

Salts have medium size.

Sweet, savory, and some bitters have similar large size.

2.11. Polarity or Ionicity; Acidity, Neutrality, or Basicity; and Size

Taste molecules have a combination of polarity or ionicity; acidity, neutrality, or basicity; and size.

Taste molecules can be:

- acidic: hydrogen ion (sour)
- neutral: monosodium glutamate (savory)
- neutral: sodium chloride and potassium chloride (salt)
- neutral: glucose and fructose (sweet)
- slightly basic: phenylthiourea, phenylthiocarbamide, and 6-n-propylthiouracil (bitter)
- basic: hydroxide ion (bitter)

Taste molecules can be:

- polar: glucose and fructose (sweet)
- polar: phenylthiourea, phenylthiocarbamide, and 6-n-propylthiouracil (bitter)
- ionic: hydroxide ion (bitter)
- ionic: hydrogen ion (sour)
- ionic: sodium chloride and potassium chloride (salt)
- ionic: monosodium glutamate (savory)

(They cannot be non-polar, because non-polar does not dissolve in water.)

Taste molecules can have molecular weight 1 to 200:

1: hydrogen ion (sour)

17: hydroxide ion (bitter)

58: sodium chloride (salt)

75: potassium chloride (salt)

152: phenylthiourea and phenylthiocarbamide (bitter)

169: monosodium glutamate (savory)

170: 6-n-propylthiouracil (bitter)

180: glucose and fructose (sweet)

Taste molecules are:

- Sour: acidic, ionic, and small.
- Salt: neutral, ionic, and medium.
- Savory: neutral, ionic, and large.
- Sweet: neutral, polar, and large.
- Bitter: slightly basic, polar, and large.
- Bitter: basic, ionic, and small.

Acidic and polar do not exist, because acids are ionic. Basic and polar do not exist, because bases are ionic.

Small and polar do not exist, because small molecules are ionic. Medium and polar do not exist, because medium molecules are ionic.

Small and neutral do not exist, because small molecules have hydrogen ions or hydroxide ions. Large and acidic do not exist, because acidic molecules have small hydrogen ions. Large and basic do not exist, because basic molecules have small hydroxide ions.

Taste molecules fall into six categories:

- Large polar: neutral (sweet) or slightly basic (bitter)
- Large ionic: neutral (savory)
- Medium ionic: neutral (salt)
- Small ionic: acidic (sour) or basic (bitter)

3. Perceptual properties

Henning [Henning, 1916] said tastes are salty, sweet, sour, and bitter {primary taste} {basic taste}. Tastes can also be meaty/savory.

People can distinguish five or more tastes and hundreds of flavors.

3.1. Intensity

Intensity relates to relative concentration. People can distinguish 10 intensity levels.

3.2. Temporal order

Taste has early, middle, and late sensations.

3.3. Similarities

Sour acid and salt are similar. Bitter and salt are similar. Sweet and salt are similar.

3.4. Opposites

Sour (acid) and bitter (base) are opposites. Sweet (neutral) and sour (acid) are opposites. Salt and sweet are opposites.

3.5. Mixing

Bitter, sweet, salt, sour, and savory can mix. Taste is a synthetic sense, with some analysis.

3.6. Effects

Sour makes people's lips pucker, sometimes downward.

Bitter makes people's eyes and nose change.

Salt is alerting.

Savory is less alerting.

Sweet is calming.

3.7. Source location

Taste can detect source location. Taste can detect several sources from one location. Taste can have interference from more than one source.

4. Relations to other senses

Taste and retronasal-area smell combine to make flavor. Odors affect taste receptors.

Tastes feel like touches on fluids. Touch locates tastes to tongue. Texture affects taste.

Taste is painful at high concentrations.

Taste sensations are the starting points of smell sensations, because cells evolved first in water and only later in air.

5. Taste sensations

Taste detects small-chemical concentration, acidity, ionicity, and size [Brillat-Savarin, 1825/2000] [Henning, 1916] [Ikeda, 1909] [Kadohisa, et al., 2005] [Kalmus and Hubbard, 1960] [Pritchard and Norgren, 2004] [Rolls and Scott, 2003].

Taste perceives molecules that are:

- Polar and neutral, with medium size (saltiness)
- Non-polar and neutral, with large size (sweetness)
- Polar and acid, with small size (sourness)
- Polar and basic, with small size (bitterness)
- Somewhat polar and somewhat acid, with large size (savoriness)

[Acids and bases cannot be non-polar.]

6. Taste descriptors

Sour makes people's lips pucker, sometimes downward. Sour feels sharp like one point, contracting, with no fluid.

Bitter makes people's eyes and nose change. Bitter feels sharp/pungent with several points, neither diffusive nor contracting, with no fluid. It may be unpleasant/disagreeable.

Sweet is calming. Sweet feels rounded with no points, diffusive, with spreading fluid.

Salt is alerting. Salt feels biting/puckery/sharp/piquant/zesty with several points, neither diffusive nor contracting, with inflowing fluid.

Savory is less alerting.

Tastes feel attractive or repulsive.

7. Spatiotemporal properties and patterns

Taste perceptual-property spatiotemporal patterns are three-dimensional patterns.

Three-dimensional patterns contract and have one point, for acidity.

Three-dimensional patterns expand (or have no movement) and have many points, for basicity.

Three-dimensional patterns diffuse/expand and have no points, for sweetness.

Three-dimensional patterns slide (or inflow) and have many points, for saltiness.

Three-dimensional patterns contract and slide, for savoriness.

8. Machines

Machines can simulate taste sensations using a microscopic-surface-texture array with motions and elements with asymmetric units. More elements represent higher intensities.

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Date: February 27, 2016