Lecture 08: Multi-Sensory Interactions

Part 01

Relevance

Giordano, B.L., Visell, Y., Yao, H.Y., Hayward, V., Cooperstock, J.R. and McAdams, S., 2012. Identification of walked-upon materials in auditory, kinesthetic, haptic, and audio-haptic conditions. *The Journal of the Acoustical Society of America*, *131*(5), pp.4002-4012.

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Learning Objectives

To provide an introduction to the concepts associated with research in the multisensory processing of information.

To provide an introduction to the main sense receptors

To provide an overview of the relevance of multisensory research for developments in interface design and evaluation.

Learning Outcomes

To develop an understanding of the key concepts associated with research in the multisensory processing of information.

To be able to describe the main sense receptors

To be able to provide examples of the relevance of multisensory research in interface design and evaluation.

Real World

Multisensory processing.

Relationship between neuronal activity and perceptual and cognitive correlates.

How are we affected: Detection and localization behaviours, speeded reaction times, enhanced/ degraded speech perception, and cross-modal illusions.

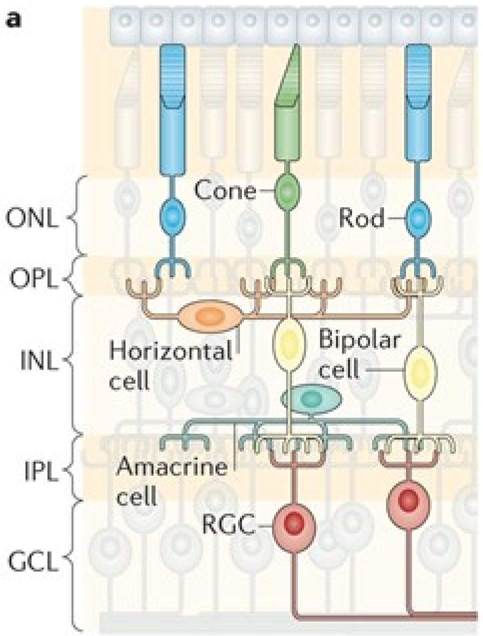
Multisensory convergence: Merging of inputs from different sensory sources - the effects of neural activity in one sensory modality can influence those of another.

Multisensory convergence (a physical and connectional property) must occur for multisensory processing (a functional effect) to take place.

B.E. Stein (2012). The New Handbook of Multisensory Processing

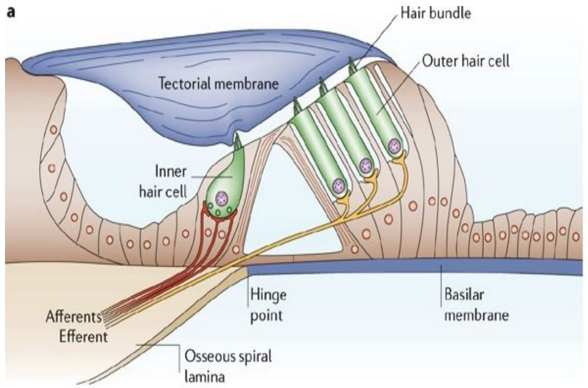
Senses Receptors

Vision

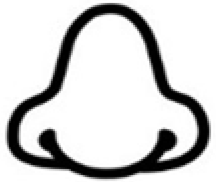


From: Cepko, C., 2014. Nat. Rev. Neurosci., 15, 615-627.

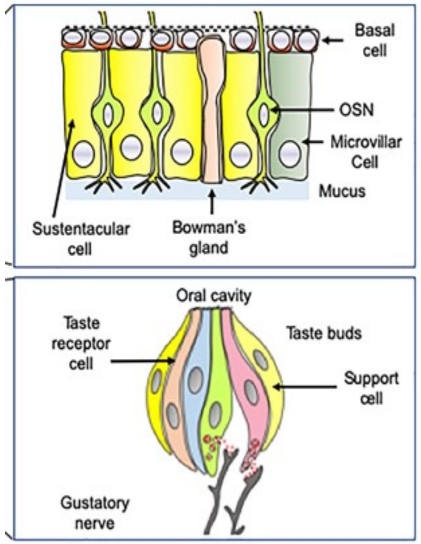
Hearing



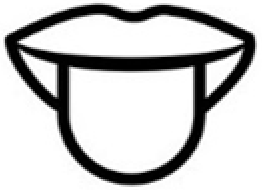
From: Fettiplace, R. & Hackney, C.M., 2006. Nat. Rev Neurosci., 7, 19-29.



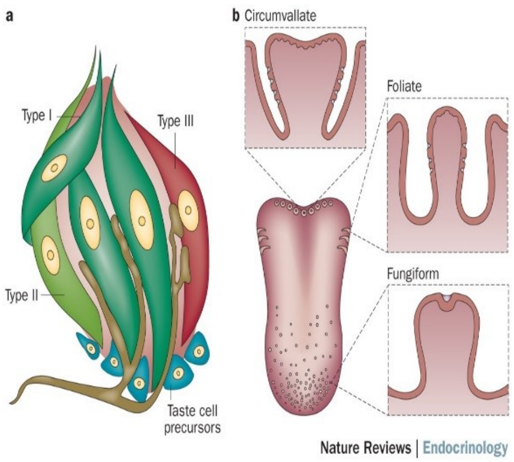
Olfaction



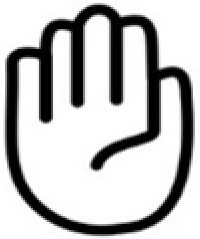
From: Meunier, N., et al. 2021. Frontiers in Physiol., 1882.



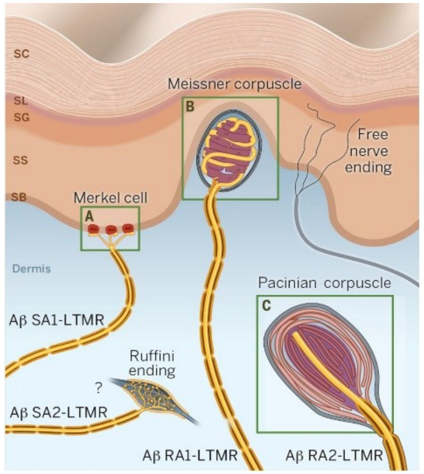
Taste



From: Calvo, S.S.C. & Egan, J.M., 2015. Nat. Rev. Endocrinol., 11, 213-227.

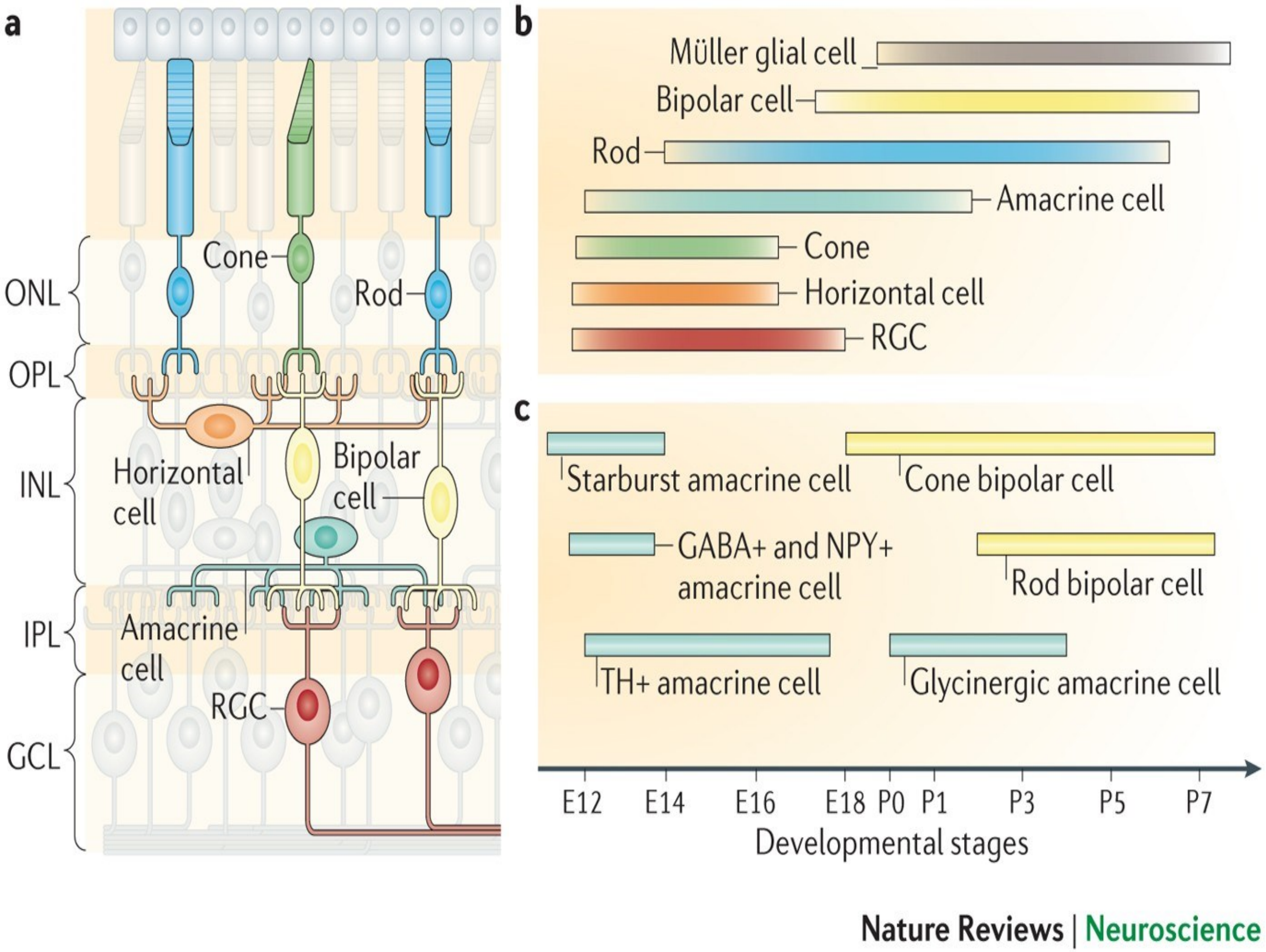


Touch



From: Zimmerman, A., et al. 2014. Science, 346, 950-954.

Vision: Receptors



Visual receptors: rods and cones (contain visual pigments).

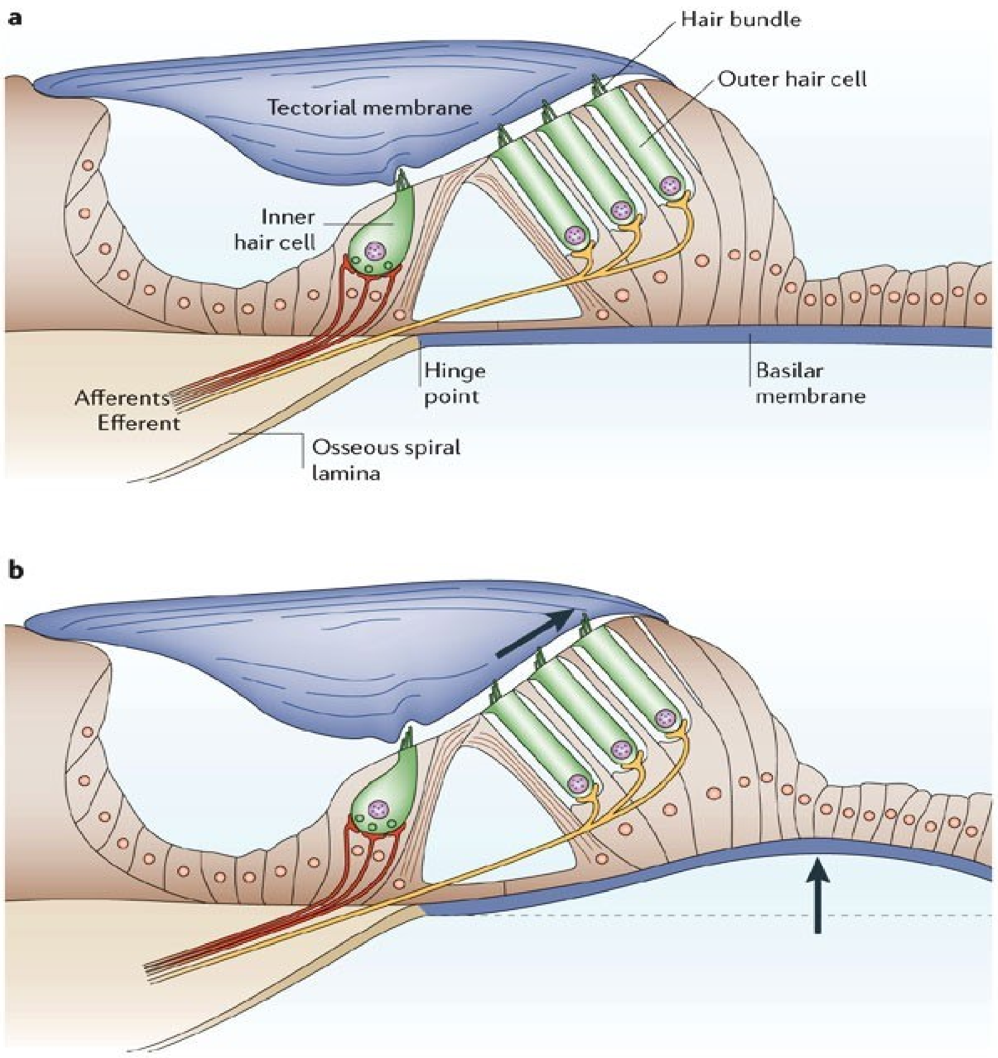
Pigments react to light -> electrical signals (action potential).

Rods: Outer segment contain stacks of discs.
Each disc contains visual pigment molecules – opsin.
Light-sensitive molecule retinal molecule attached to the opsin.

Retinal absorbs 1 photon of light -> changes shape (isomerization) -> electrical activity.

From: Cepko, C., 2014. Intrinsically different retinal progenitor cells produce specific types of progeny. *Nature Reviews Neuroscience*, *15*(9), pp.615-627.

Audition: Receptors



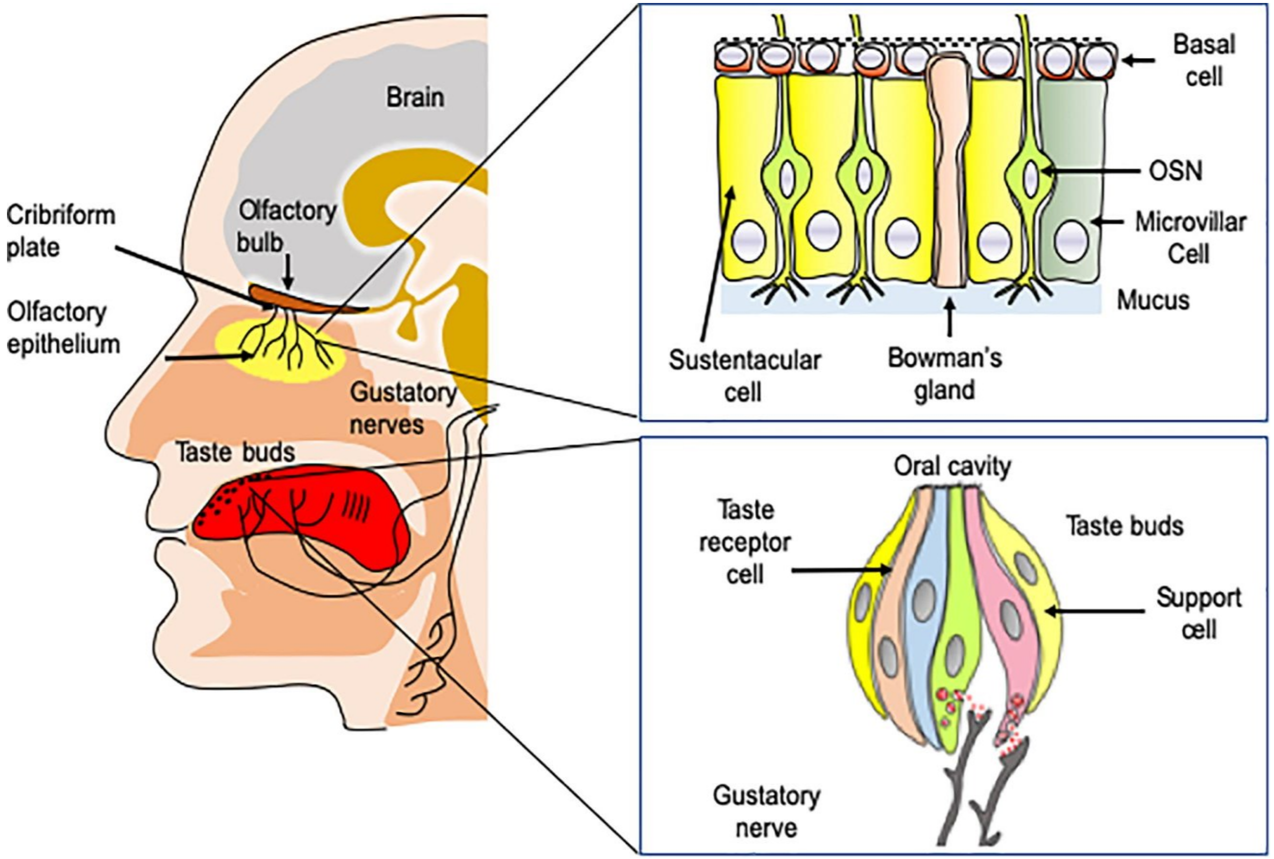
Inner hair cells (IHCs): Basilar membrane vibrations -> stereocilia (small hairs on top of the cell) of IHCs to bend.

Stereocilia bending -> membrane depolarisation -> neurotransmitter release -> electrical activity (action potentials) in the auditory nerve fibres.

Outer hair cells (OHC): Information **from the higher auditory brain areas -> OHCs** & **amplify** the response of the basilar membrane.
[OHCs are **motile**, i.e., they can stiffen and move in response to the vibration & so amplify and sharpen basilar membrane vibrational response].

From: Cepko, C., 2014. Intrinsically different retinal progenitor cells produce specific types of progeny. *Nature Reviews Neuroscience*, *15*(9), pp.615-627.

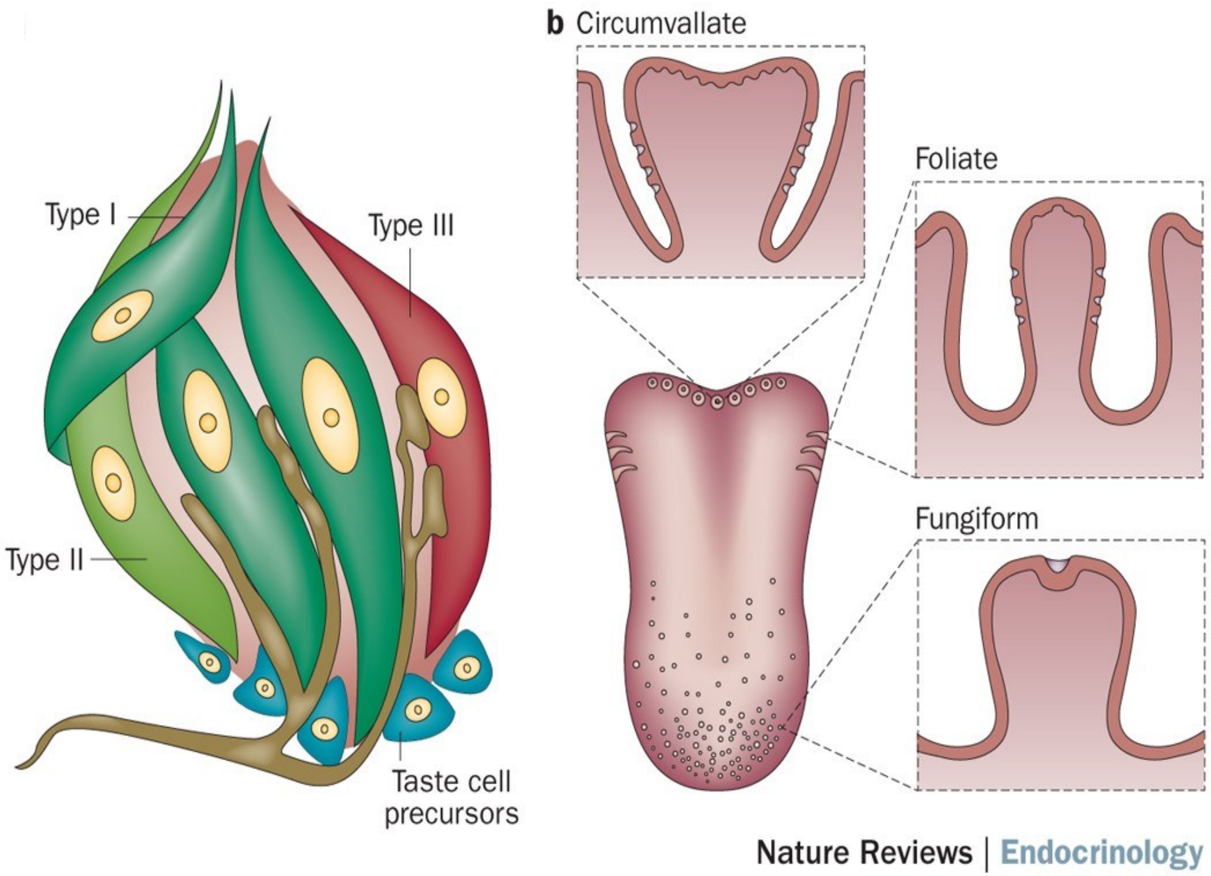
Olfaction: Receptors



Odorants enter nose
Odoronts flow over mucosa
Olfactory receptors stimulated (~350 different types of olfactory receptors)
Olfactory receptor neurons activated (action potentials generated)
Signals sent to glomera in olfactory bulb
Signals sent to higher cortical areas of brain

From: Meunier, N., et al. 2021. Frontiers in Physiol., 1882.

Taste: Receptors



Each taste bud contains ~50-100 taste cells.
When chemicals contact receptor sites on tips of taste cells -> transduction -> electrical activity (action potentials).

Electrical signals generated in taste cells transmitted from tongue in number of different nerves depending on where on tongue taste cells activated: Front and side of tongue, back, mouth & throat, soft palette.

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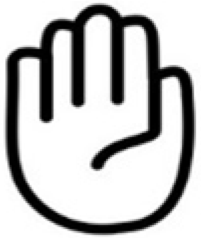
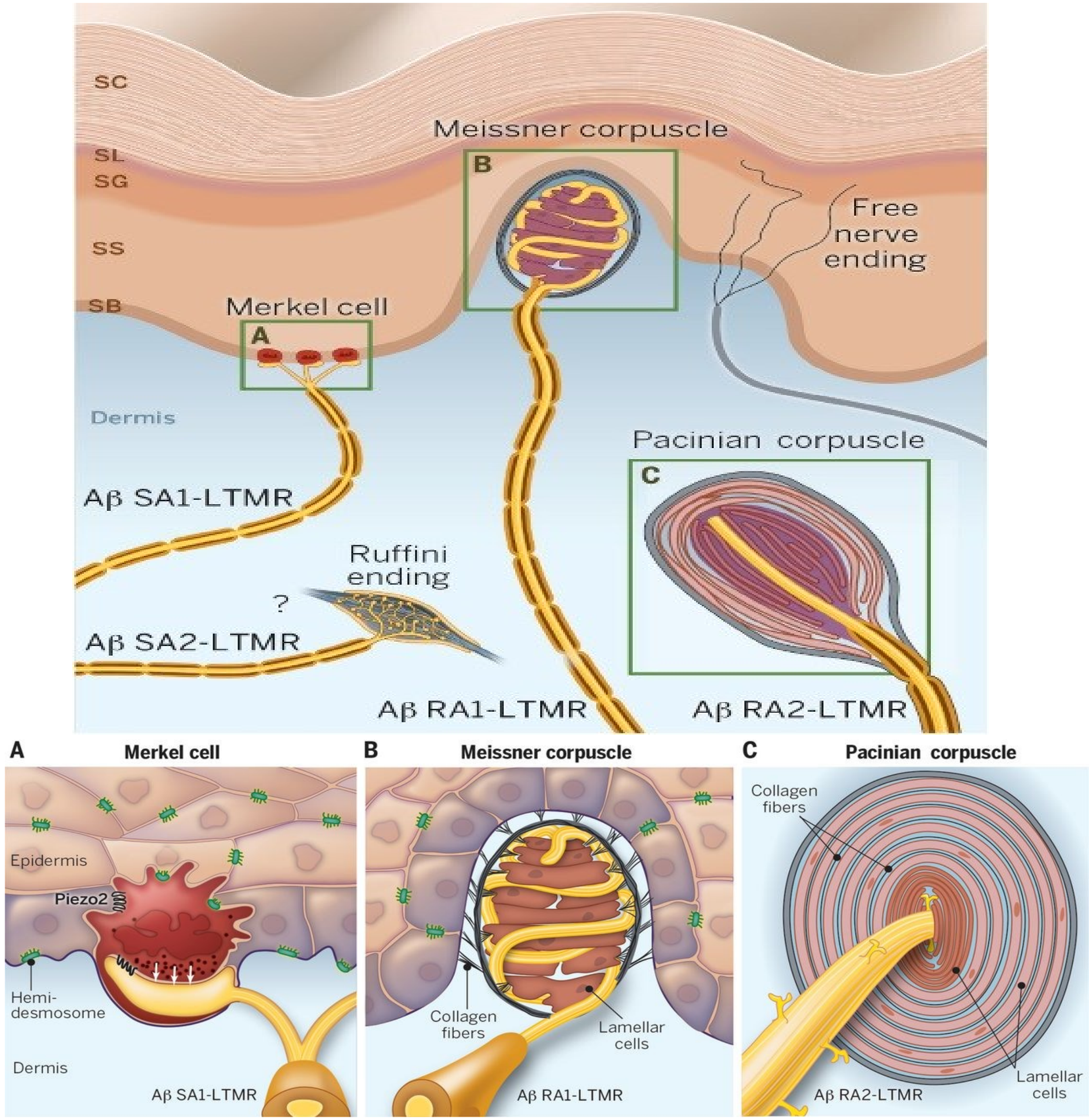


Touch: Receptors



4 mechanoreceptors to detect tactile information: Merkel receptor and Meissner corpuscle (both located close to skin surface, near epidermis.

Merkel receptors: Pressure stimulus - > fires to continuous pressure (a long as stimulus is on). Senses fine detail.
Meissner corpuscle -> fires only when stimulus first applied and when removed (fires to on and off). Senses for e.g., controlling handgrip.

Ruffini cylinder and Pacinian corpuscle located deeper in skin.
Ruffini cylinder- responds continuously to stimulation. Senses stretch of skin.
Pacinian corpuscle- responds when stimulus applied and removed. Senses rapid vibrations and fine texture.

From: Calvo, S.S.C. & Egan, J.M., 2015. Nat. Rev. Endocrinol., 11, 213-227.

Interaction of Taste and Olfaction

Flavour = Taste + Olfaction

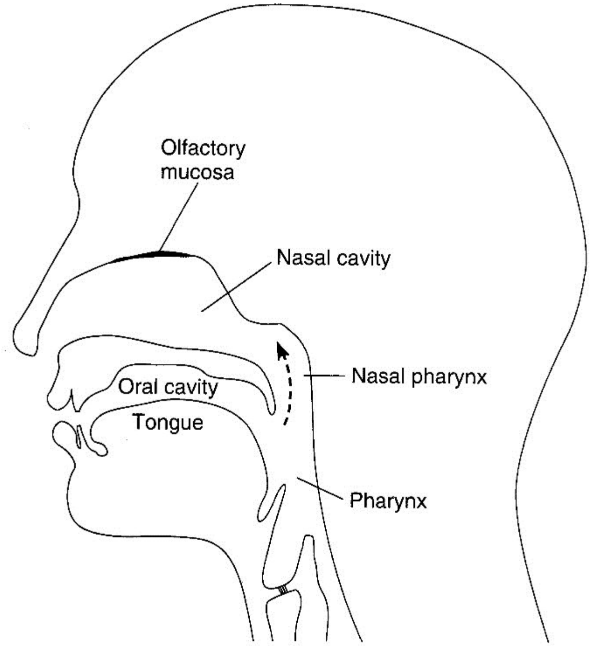


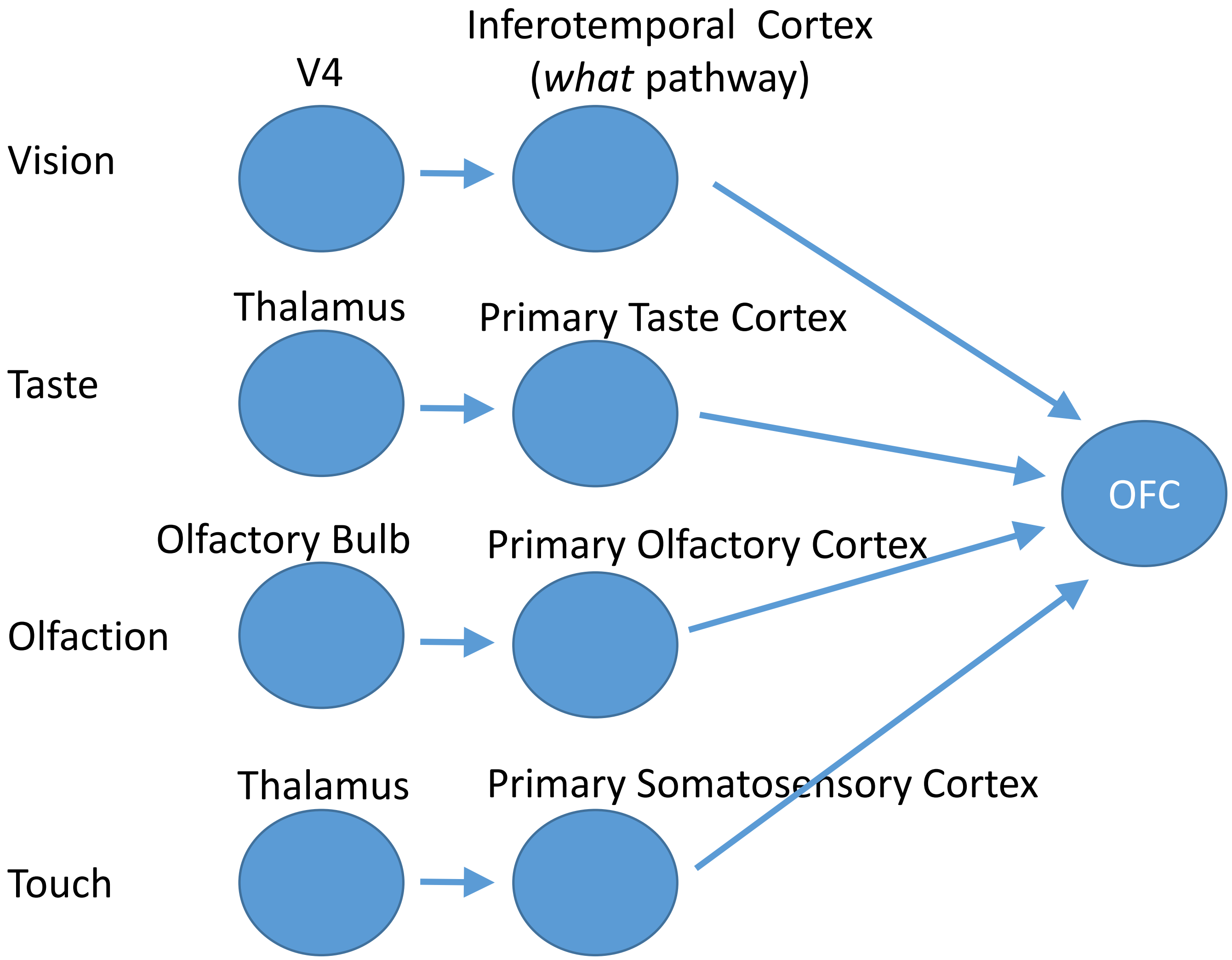
Figure 14.24
Odorant molecules released by food in the oral cavity and pharynx can travel through the nasal pharynx (dashed arrow) to the olfactory mucosa in the nasal cavity. This is the retronasal route to the olfactory receptors.

Retronasal route: odor stimuli can reach olfactory mucosa by this route from mouth to nasal pharynx (connects oral & nasal cavities). If close nose, reduces air circulation -> reduces intensity of taste.

Taste sensation can be greatly influenced by stimulation of olfactory receptors. Can mislocate source of sensation as being mouth.

Physiology of flavour perception: Area of brain [orbitofrontal cortex (OFC)], where responses from taste & smell are 1st combined.

Interaction of Taste and Olfaction



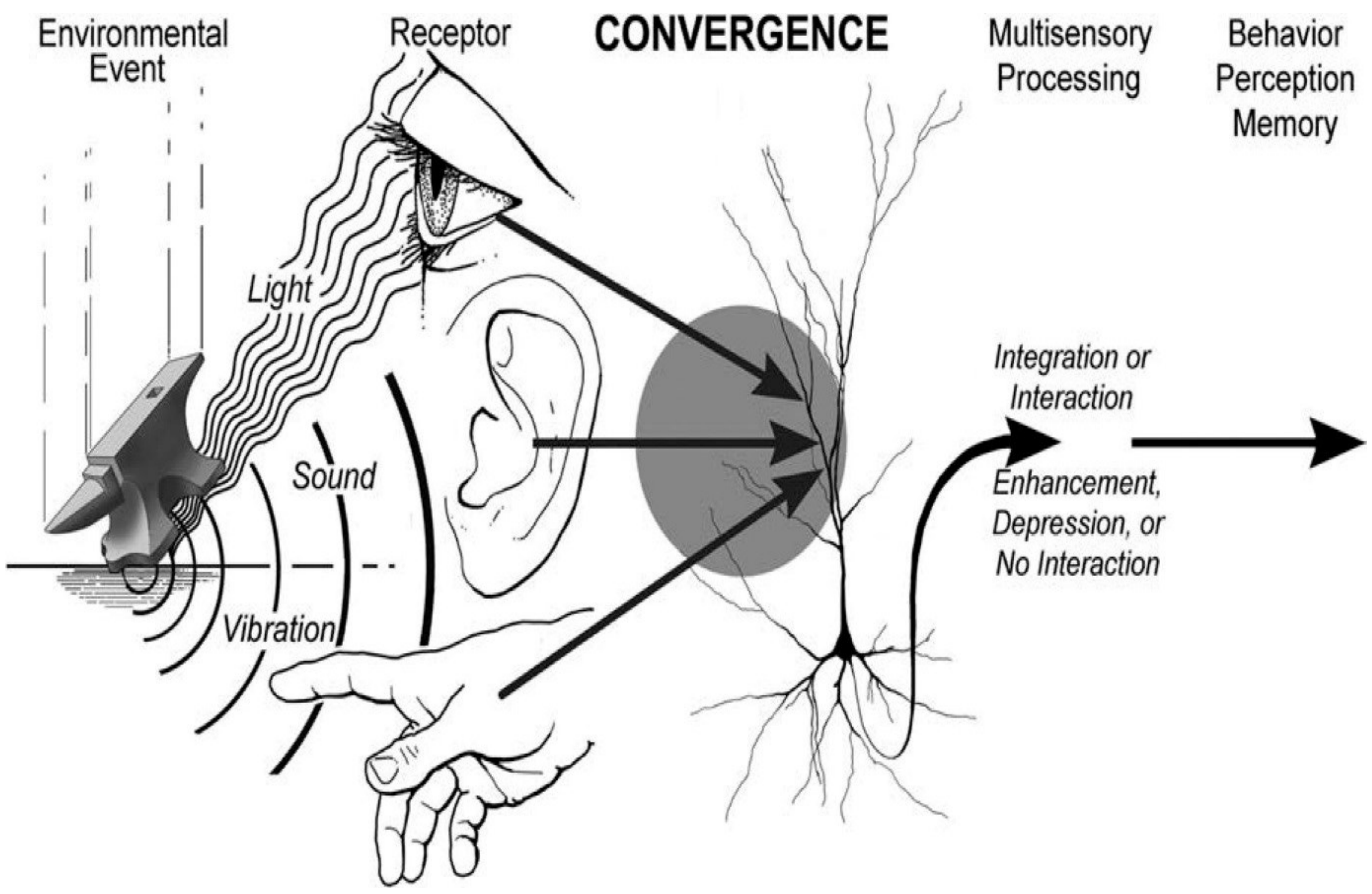
The orbitofrontal cortec (OFC) receives inputs from primary cortical areas for vision, taste, olfaction, and touch.

It is the 1st area where signals from taste and smell systems meet.

OFC- many bimodal neurons (neurons that respond to > 1 sense)

Suggestion- OFC is cortical centre for detecting flavour.

Multisensory Neural Convergence



From: The New Handbook of Multisensory Processing by B.E Stein. (2012).

Studying Multisensory Interaction

Concept	Meaning	Examples	Possible implications for multisensory experiences
Temporal congruence	Whether or not two or more senses are presented with information at the same time.	When you watch a movie and the sound is dubbed (the lips of the actor and the sound do not match), the experience of the movie does not feel as right as when you view the original.	***Sub-additive:*** Incongruence in terms of these four concepts can lead to less-compelling experiences. ***Non-additive:*** Sometimes congruence or incongruence may not lead to more- or less-compelling experiences. ***Super-additive:*** Alignment in terms of these concepts can lead to more compelling experiences.
Spatial congruence	Whether or not information presented to two or more senses comes from the same place (source in space).	When you hear the bell of a bicycle, you would usually attribute the sound to the bike that is 'closer' to the listener.	
Semantic congruence	When information presented to two senses shares the same identity or meaning.	If you taste tomato-flavoured crisps, it is likely that you associate them with the colour red (or perhaps green), because both flavour and colour map onto the concept/ meaning of 'tomato'.	
Crossmodal cor-respondences	Refers to the associations/ compatibility of features (such as colour brightness, shape curvature, sound pitch) across the senses.	Most people associate sweet tastes with rounder shapes and sour tastes with angular ones. There are some surprising connections between features across the senses.	
Sensory dominance	There are certain situations where one sense may dominate over the others.	If you buy a coffee maker, it is likely that, at first, what you see is the most important element in how you experience it. With time and use, though, what you hear (the sound of the machine) may become more important in how you experience the coffee machine.	Not all senses are equally 'weighted' in all our experiences.
Sensory overload	When 'too much' sensory information is presented to one or more senses, we may be overloaded, which can negatively affect our experience.	Imagine visiting a place like Times Square in New York City for the first time. At first, it is difficult to make sense of the environment because of all the lights, sounds, smells, etc. Therefore, it may be difficult to relive the experience of a sunflower field in this context, at least relative to other contexts.	Sometimes 'too much' sensory information can have detrimental effects for the expe-rience.

Concepts that help analyse and explain how the senses interact with each other while we perceive the world around us and their possible implications for multisensory experiences.

How to study multisensory interactions.

Experimental design.

Experimental terminology and concepts:
Assist in describing and analysing multisensory interactions.

From: C. Velasco and M. Obrist. (2020). Multisensory Experiences: Where the senses meet technology

Temporal Congruence

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Crossmodal Correspondences

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Possible Implications for Multisensory Experiences

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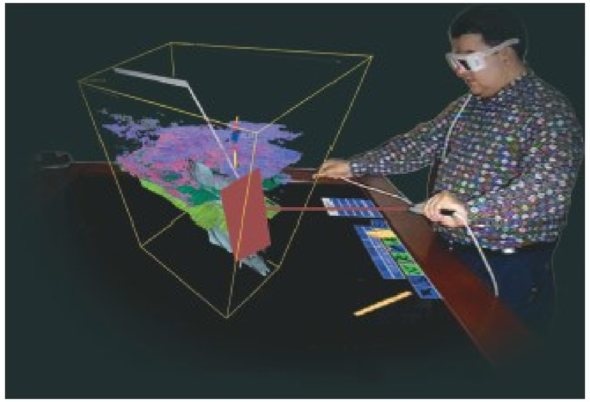
Multisensory Approaches and Technology

Experiencing Heritage

Marto, A., et al. 2021. *IEEE Access*, *9*, pp.16419-16434.

Data Visualization



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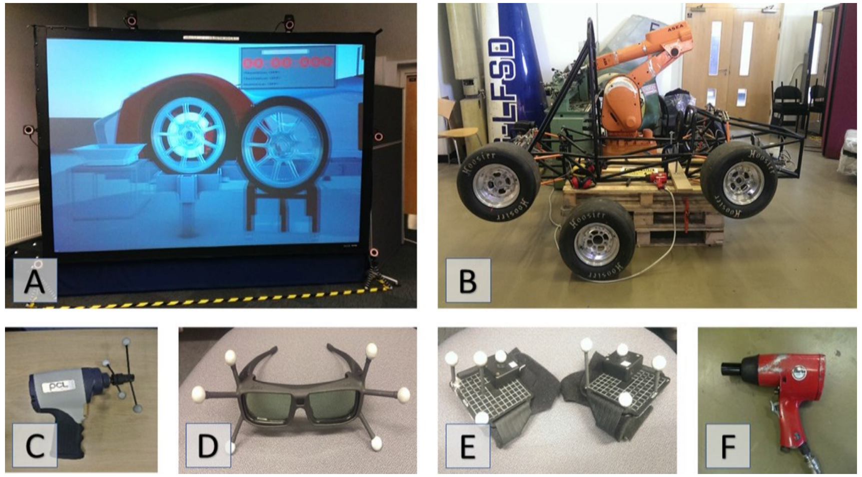
Training



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Experiences

Visualization

Interaction and behaviour

Training

Knowledge

Robots

Gaming

Overall Summary

Description of multisensory processing.

Overview of the main senses.

Multisensory convergence.

Multisensory Approaches.

Relevance to technological developments.

Resources

<u>Essential:</u>
Sensation and Perception- E. Bruce Goldstein: Chapter “Perceiving Objects and Scenes”. [8th Edition] Relevant pages relating to the five receptors in Chapters 3, 11, 13, 14, 15.

The New Handbook of Multisensory processing (2012), Barry E Stein. MIT Press. Part II. and IV.

Multisensory experiences: where the senses meet technology (2020), C. Velasco and M. Obrist. Oxford University Press. Chapters 1 and 2.

<u>Supplementary:</u>

Giordano, B.L., Visell, Y., Yao, H.Y., Hayward, V., Cooperstock, J.R. and McAdams, S., 2012. Identification of walked-upon materials in auditory, kinesthetic, haptic, and audio-haptic conditions. *The Journal of the Acoustical Society of America*, *131*(5), pp.4002-4012.

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