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Output Devices - II



The human senses need specialized interfaces

- Visual displays for visual feedback
- 3-D audio hardware for localized sound
- Haptic interfaces for force and touch feedback
- …

- In addition to the visual displays, sound:
  - enhances the presence
  - enhances the display of spatial information
  - can convey simulated properties of elements of the environment (e.g. mass, force of impact...)
  - can be useful in designing systems where users monitor several communication channels (selective attention)

Aural Displays

- Auditory displays are another approach to presenting information to the user

- Sound displays are computer interfaces that provide synthetic sound feedback to the user interacting with the virtual world

The sound can be :

- monoaural (both ears hear the same sound)

  or

- binaural (each ear hears a different sound)

Aural Displays: a taxonomy (Sherman and Craig, 2003)

- Stationary displays
- Head-based displays

- High-fidelity audio devices are less expensive than visual displays

- The addition of high-quality sound can help in creating a compelling experience, even when the quality of the visual presentation is lacking

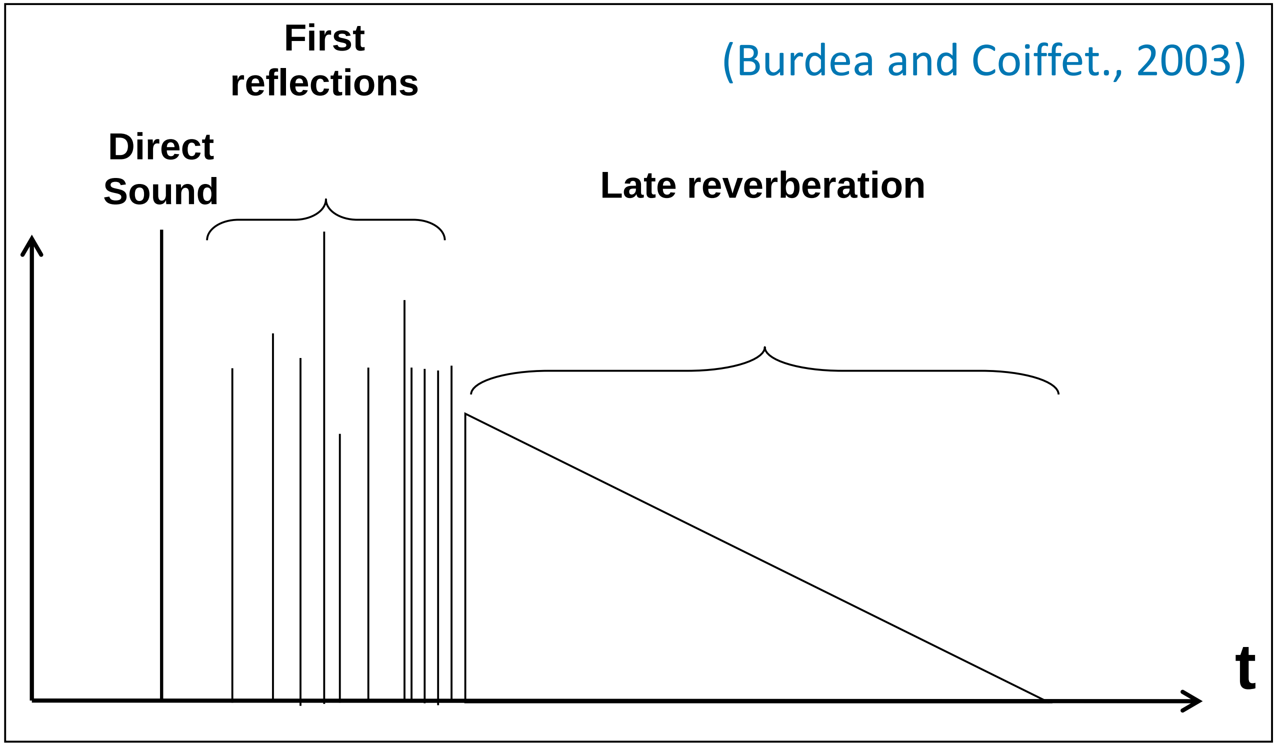
3-D Aural Displays

- Spatialized 3D sound enables users to take advantage of their auditory localization capabilities

- Localization cues allow to determine the direction and distance of a sound source:
  - binaural cues,
  - spectral cues,
  - Head Related Transfer Functions (HRTFs),
  - sound intensity,
  - reverberation, …

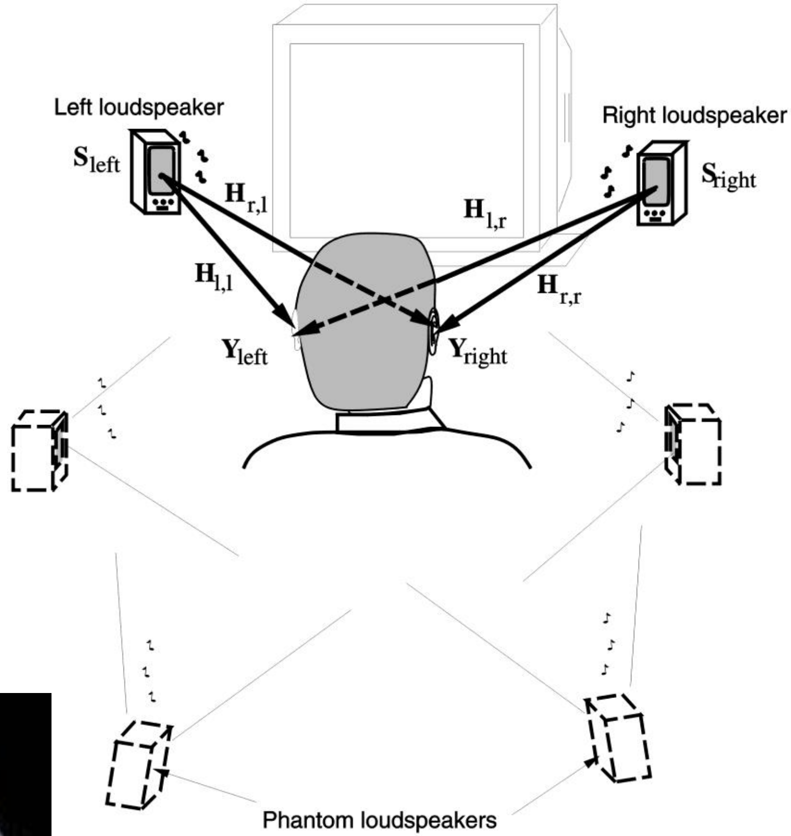
Auralization

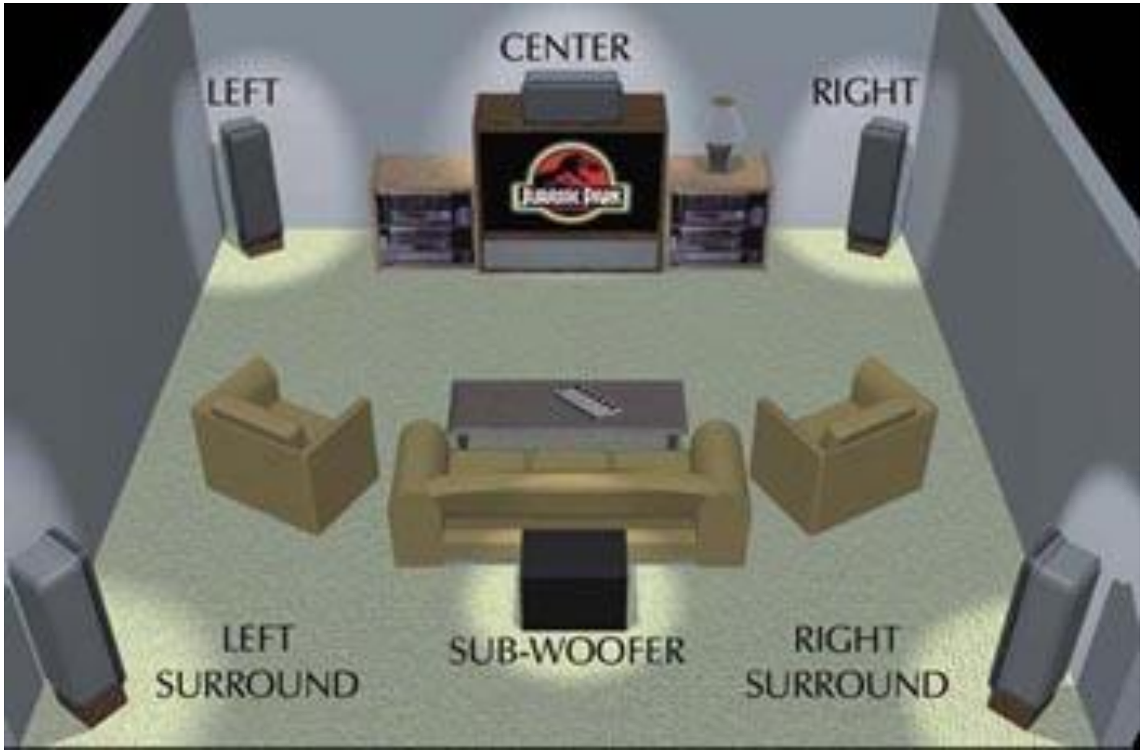
- Auralization: recreation of the acoustic environment.
- Produces a 3D sound space by digital means based on binaural human hearing principles (psycho-acoustic)



(Burdea and Coiffet., 2003)

3-D Audio Displays





- We gain a significant amount of information via sound
- Sound often tells our eyes where to look
- We use our hearing to keep us constantly aware of the world
- Given the importance of sound and relatively low cost to implement in VR:

VR application designers should consider how sound might be used to positive effect in the applications they build

Haptic Interfaces

- Greek *Hapthai* means the sense of touch (physical contact)
- Haptics perception groups **taction** and **kinesthesia** sensations

  touch feedback and **force feedback**
- the haptic sense is powerful to believe something is "real"
- Is very hard to fool; creating a satisfactory display device is difficult
- Haptic interfaces are **generally both input and output**

- **Kinesthesia** is the perception of movement or strain from within the muscles, tendons, and joints of the body.

- Proprioception, also refers to an individual's ability to sense their own body posture, even when no forces are acting upon it

- **Taction** is the sense of touch that comes from sensors at the surface of the skin

- **Tactile display** includes stimuli for temperature and pressure on the skin:

  Thermoreception

  Mechanoreception (immediate and long-term changes in pressure)

Touch Feedback

- Relies on sensors in and close to the skin
- Conveys information on contact surface
- Geometry, roughness, slippage, temperature
- Easier to implement than force feedback
- Most devices focus specifically on the fingertips

Force Feedback

- Relies on sensors on muscle tendons and bones/joints proprioception
- Conveys information on contact surface compliance, object weight, inertia
- Actively resist user contact motion
- More difficult to implement than touch feedback
- Most displays focus on the limbs (e.g. manipulation arm)

- Haptic displays are significantly more difficult to create than are visual or aural displays, because our **haptic system is bidirectional**

- It not only senses the world, **it also affects the world**

- Touch is the only bidirectional sensory channel and, apart from taste, it is the only sense that **cannot be stimulated from a distance**

Herein lies part of the difficulty:
the display requires direct contact with the human body

Main methods of haptic interface in virtual reality

- Tactile displays
(touching, grasping, feeling surface textures, or sensing temperature)

- End-effector displays
(provide resistance and pressure)

- 3D Hardcopy
(provides haptic and visual representation objects; works only as output)

Touch Feedback Interfaces...

https://www.ifeelpixel.com/description/

- Can be desktop or wearable;

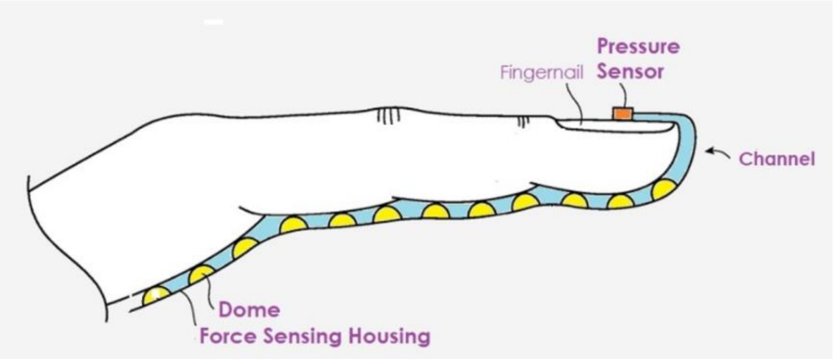
  - touch feedback mice;

  - gloves;

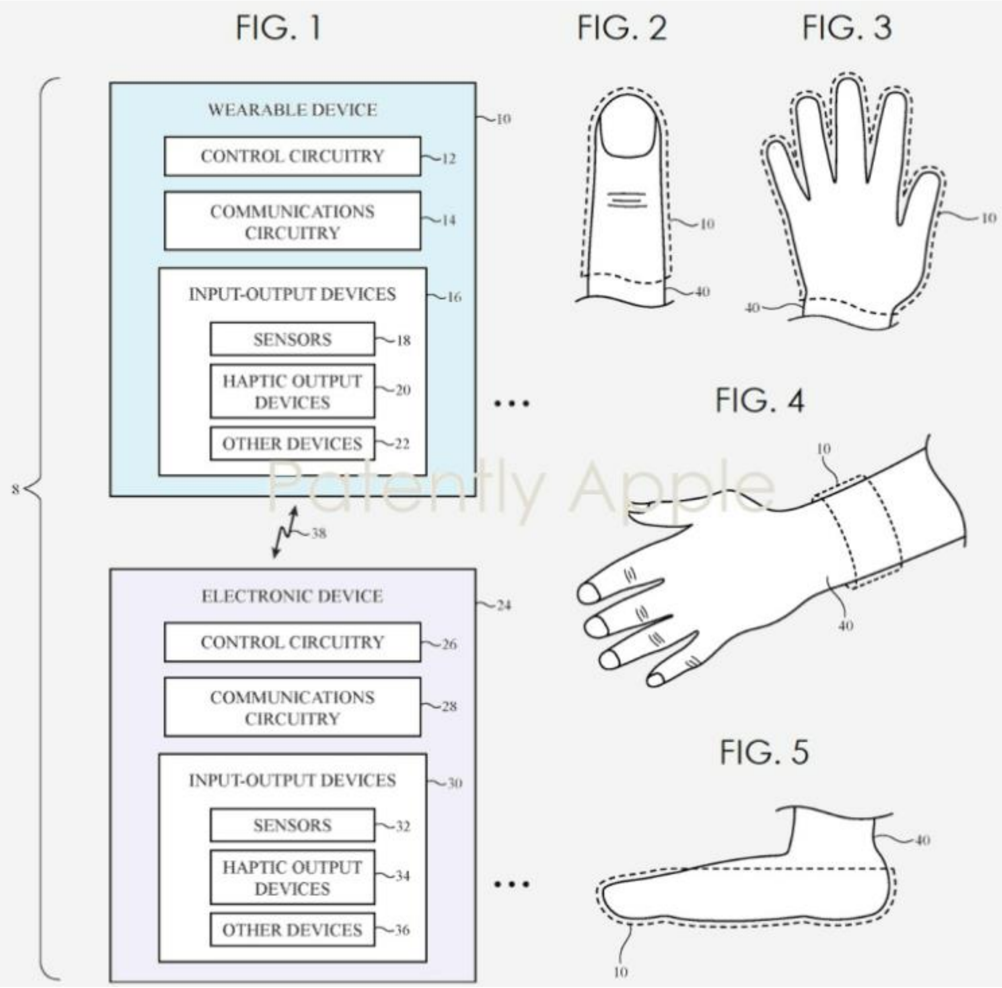
  - temperature feedback actuators; …

https://haptx.com/

Apple patent for force-sensing gloves and foot ware, 2022



Potential force-sensing component position in a glove



https://www.patentlyapple.com/2022/03/apple-has-won-a-patent-for-wearable-force-sensing-vr-accessories-in-the-form-of-finger-mounts-gloves-bands-and-footwear.html

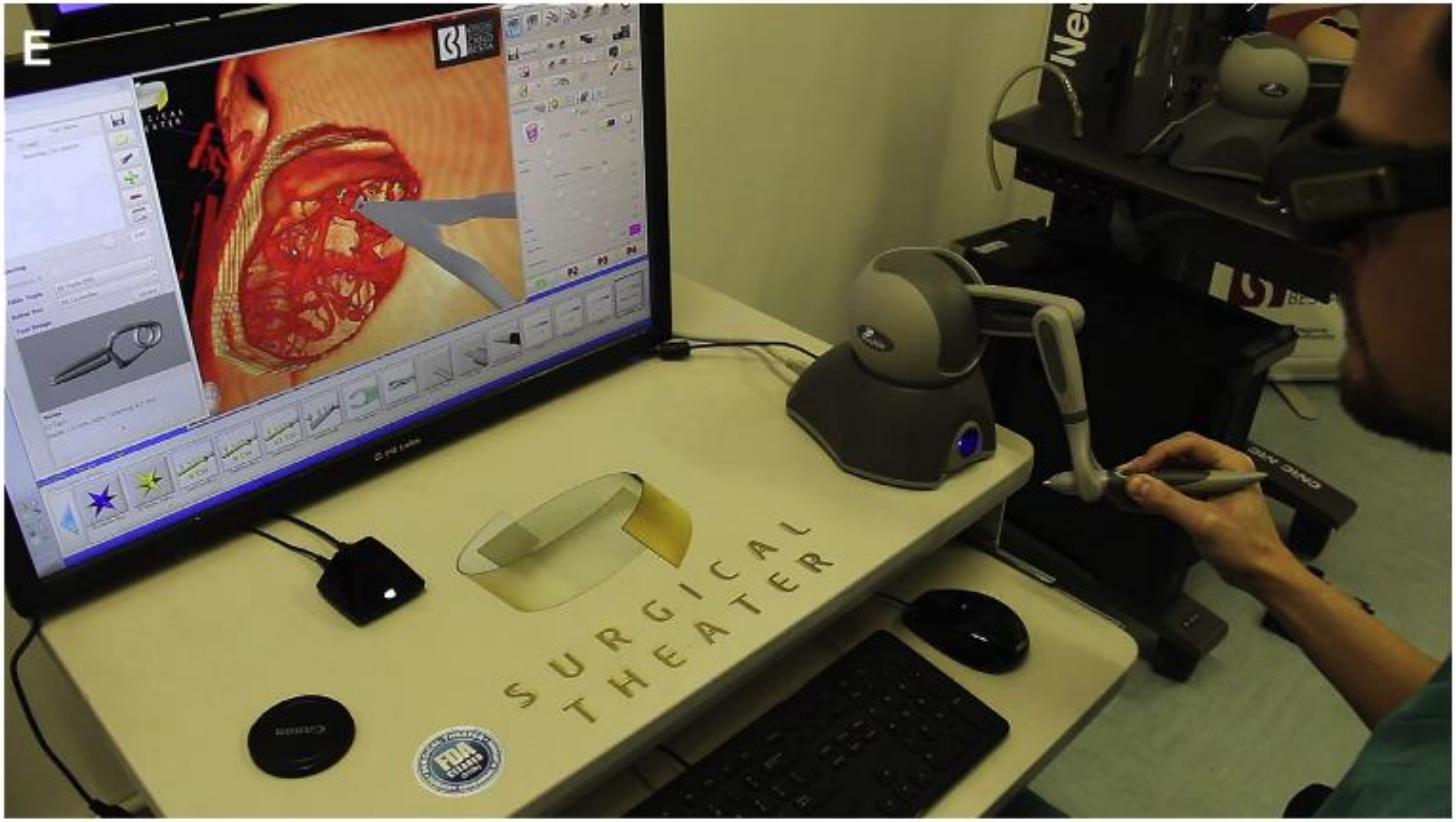
Temperature feedback

- Added simulation realism by simulating surface thermal “feel”
- No moving parts
- Uses thermoelectric pumps made of solid-state materials sandwiched between “heat source” and “heat sink”
- Single pump can produce 65°C differentials

Medical Training
Bimanual Haptic Simulator for Medical Training

https://dl.acm.org/citation.cfm?id=2386090
https://www.youtube.com/watch?v=QmtHecrOVXo

Virtual Reality Cerebral Aneurysm Clipping Simulation With Real-Time Haptic Feedback



Perin, A. et al., "The "STARS-CASCADE" Study: Virtual Reality Simulation as a New Training Approach in Vascular Neurosurgery", *World Neurosurgery*, vol. 154, 2021
https://doi.org/10.1016/j.wneu.2021.06.145

Training in veterinary
Haptic Cow and Haptic Horse

https://norecopa.no/norina/the-haptic-cow-simulator

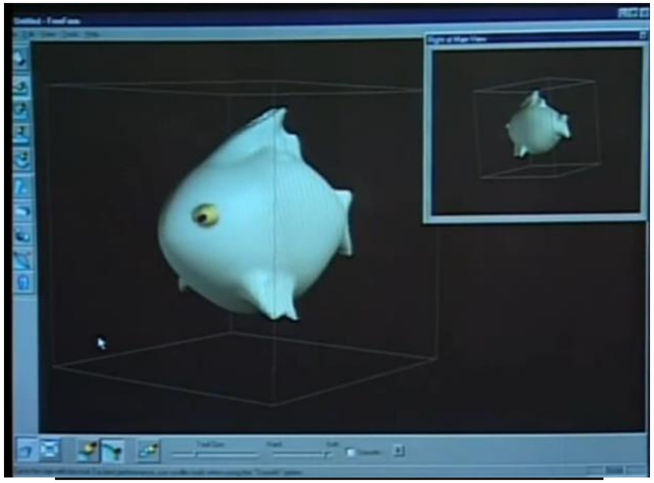
Force Feedback Interfaces: Geomagic Touch (former PHANToM Omni)

- Main application:

- Medical simulations and training exercises
stylus emulates physical sensations (puncturing, cutting, probing or drilling) of using a syringe, scalpel, …

- Other commercial, and scientific applications:
  - Robotic Control
  - Virtual Reality
  - Teleoperation
  - Training and Skills Assessment
  - 3D Modeling
  - Applications for the Visually Impaired
  - Entertainment
  - Molecular Modeling
  - Rehabilitation
  - Nano Manipulation, ...

- Haptic devices vary according to workspace size, force, DOFs, inertia and fidelity



http://www.youtube.com/watch?v=0_NB38m86aw

Olfatory Interfaces

The harbinger of smell interfaces: Sensorama, 1962

Contains different odorants and
a system to deliver them through air
and a control algorithm to determine

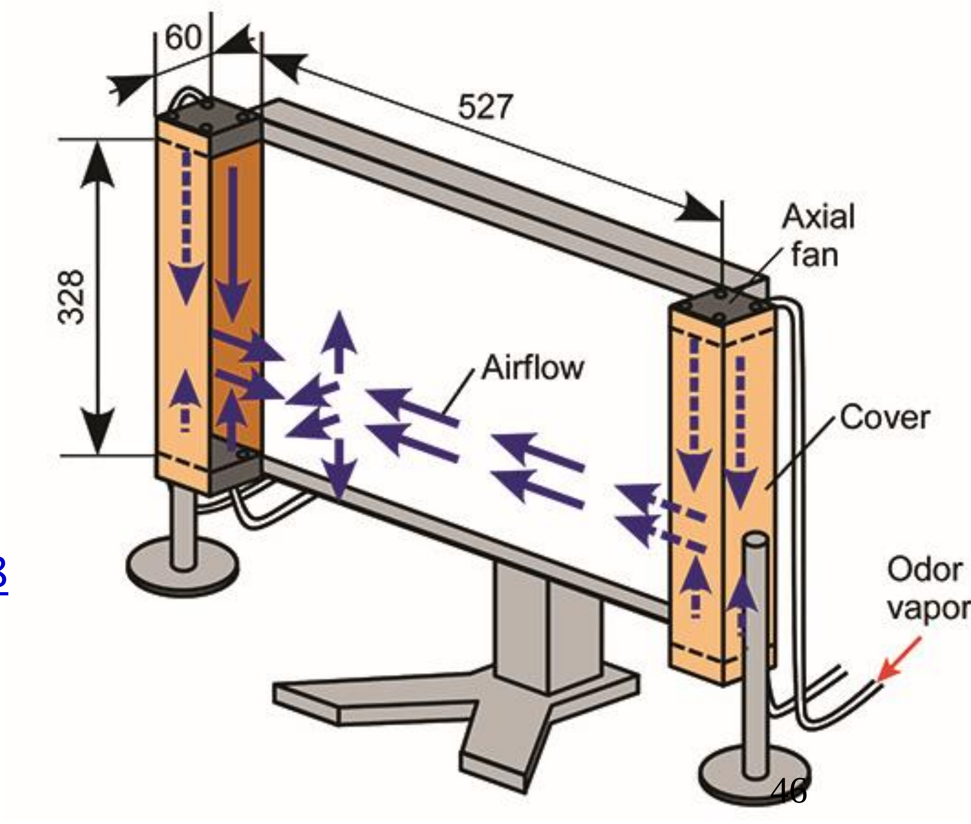
- the mix of odorants
- its concentration and
- the time of the stimulus

- Smelling Screen

(Matsukura, Yoneda, & Ishida, 2013)
delivers odorants through a four fans system
in arbitrary positions of the screen.

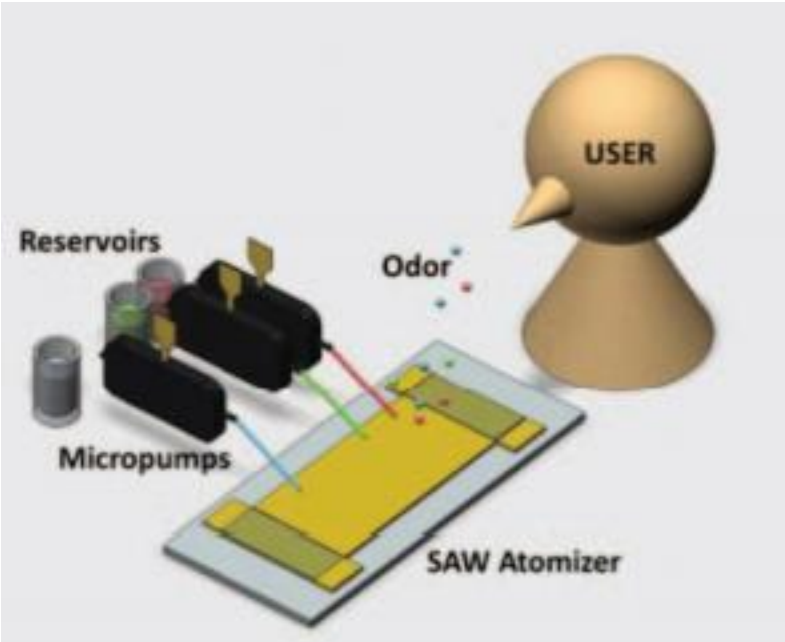
Smelling Screen

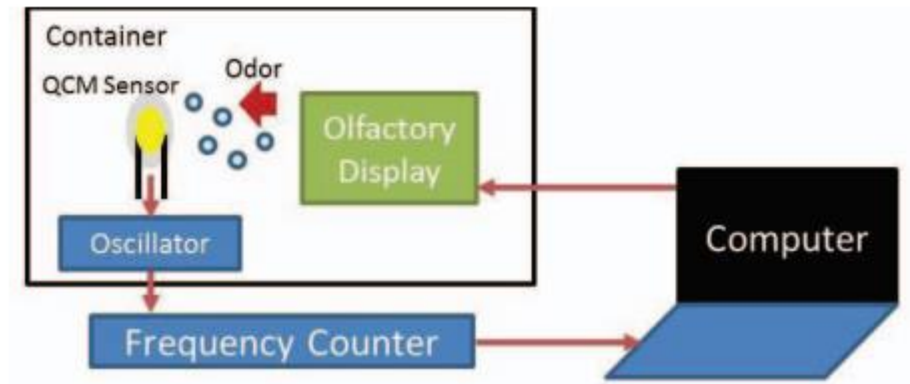
- Releases scents into the air with directional accuracy
- It is regular television with four fans mounted along its edges that pump odors in the right direction
- It generates scent from hydrogel "aroma chips," heated to produce vapor



http://www.theverge.com/2013/3/31/4166884/japanese-smelling-screen-might-be-the-next-big-thing-in-advertising

Olfactory Display Using Surface Acoustic Wave Device and Micropumps for Wearable Applications





Measurement using QCM sensor.

Hashimoto, K. & T. Nakamoto (2016). Olfactory Display Using Surface Acoustic Wave Device and Micropumps for Wearable Applications. In *IEEE Virtual Reality 2016* (pp. 179–180). http://doi.org/10.1109/JSEN.2016.2550486

A graspable olfactory display for virtual reality

A virtual wine cellar game, with wine glasses to be grasped and sniffed (a). By pressing the trigger button on the HTC Vive hand controller, the player releases wine bouquet from a virtual glass (b)

Simon Niedenthal, S et al., "A graspable olfactory display for virtual reality", *International Journal of Human-Computer Studies*, vol. 169, 2023

https://doi.org/10.1016/j.ijhcs.2022.102928

Vestibular Interfaces

- The vestibular perceptual sense provides the leading contribution about the sense of **balance** and **spatial orientation**

- The human organ that provides this perception is located in the inner ear, but it does not respond to aural stimuli

- Helps humans sense **equilibrium**, **acceleration**, and **orientation** with respect to gravity

- Allows to coordinate movement with balance

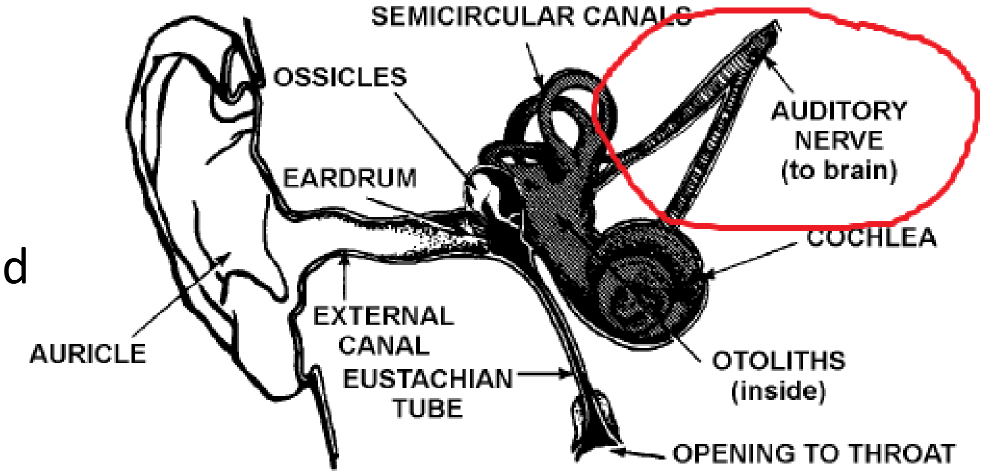
- **Inconsistency between visual cues** such as the horizon line and **balance** can lead to nausea and other symptoms of **simulator sickness**

Vestibular sense

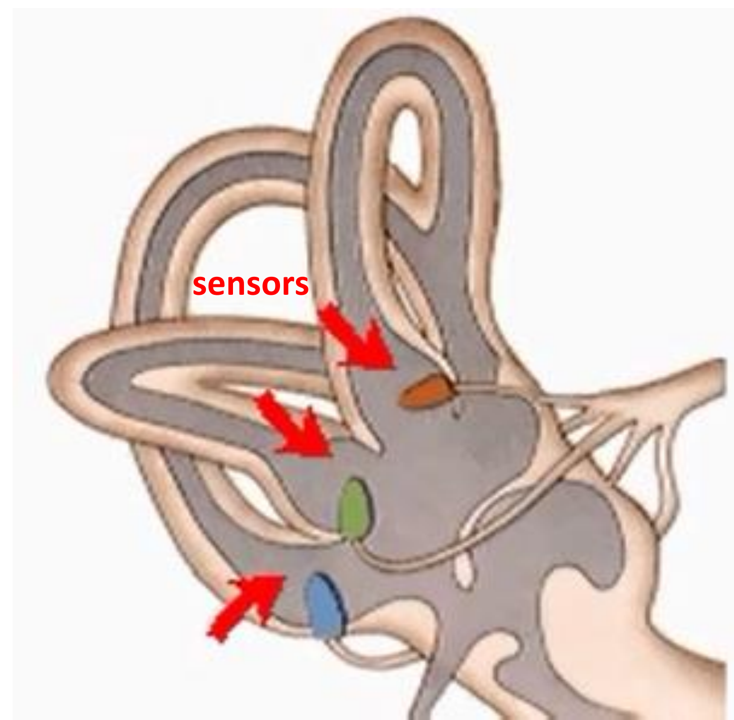
The brain uses information from:

- vestibular system in the head and
- proprioception throughout the body

to understand the body's dynamics and kinematics (including its position and acceleration)



Semicircular canals-> rotational movements
Otoliths -> linear accelerations



https://psychlopedia.wikispaces.com/Vestibular+Sense

Vestibular displays

- Are accomplished by physically moving the user

- Motion platforms, can move the floor or seat occupied by the user or group

- Are common in:
  - large flight simulator systems
  - entertainment venues

https://en.wikipedia.org/wiki/Flight_simulator

https://xinreality.com/wiki/Proprioceptive_system

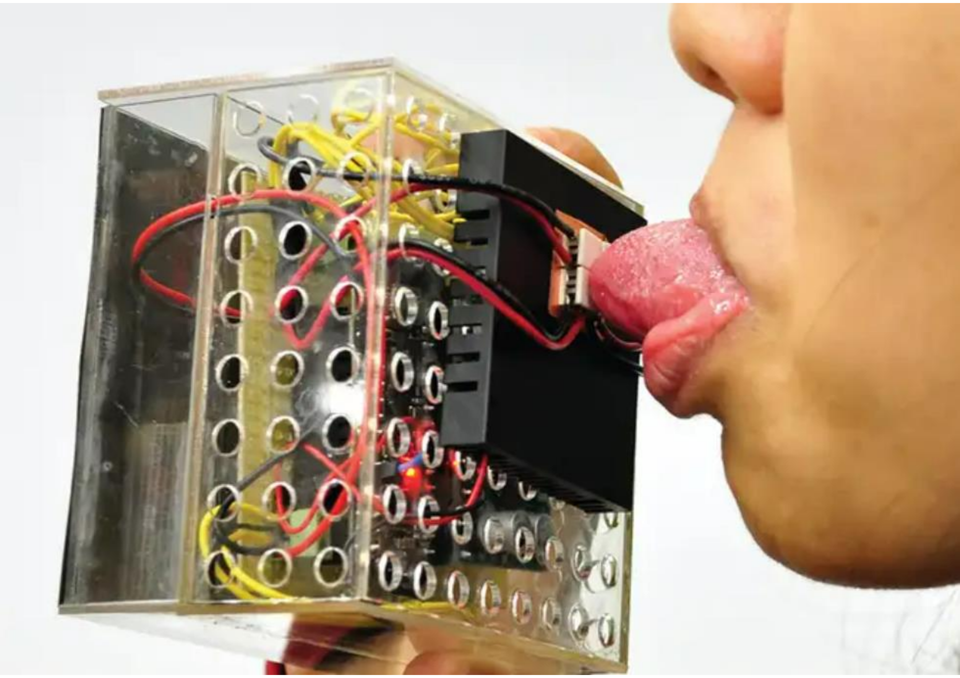
Taste Interfaces – first experiments

- Taste is very difficult to display as it is multi-modal sensation composed of chemical substance, haptics and sound
- Marginally addressed
- Few taste interfaces can be found in literature
- Food simulator addresses chewing simulation
  - releasing flavoring chemicals
  - resistance to the mouth
  - playing sound

Iwata, Hiroo, Yano, Hiroaki, Uemura, Takahiro, Moriya, Tetsuro (2004): Food Simulator: A Haptic Interface for Biting. In: IEEE Virtual Reality Conference 2004 VR 2004, 27-31 March, 2004, Chicago, IL, USA. pp. 51-58. http://doi.ieeecomputersociety.org/10.1109/VR.2004.40

Taste Interfaces

Virtually simulate the sensation
of sweetness by applying thermal
stimulation to the tip of the tongue



Ranasinghe , N. & E. Yi-Luen Do, “Virtual Sweet: Simulating Sweet Sensation Using Thermal Stimulation on the Tip of the Tongue”, User Interface Software and Technology (UIST '16 Adjunct), pp, 127–128, 2016

https://doi.org/10.1145/2984751.2985729

https://www.newscientist.com/article/2111371-face-electrodes-let-you-taste-and-chew-in-virtual-reality/

Main bibliography

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- http://vr.cs.uiuc.edu/