



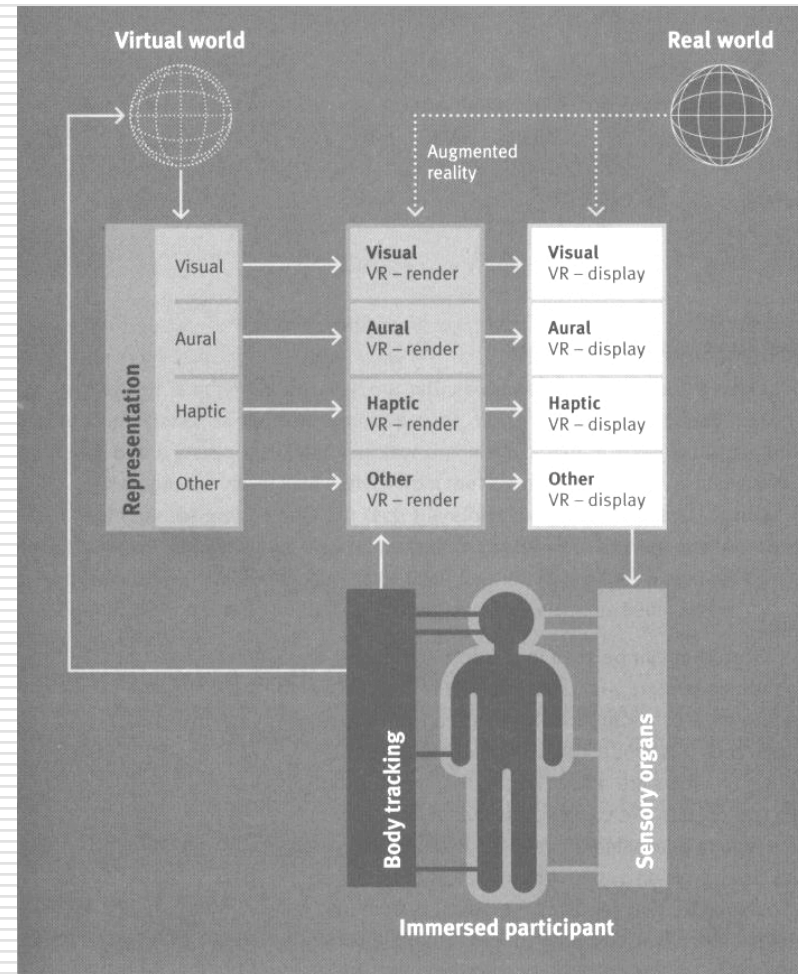
CS-525V:
Building Effective
Virtual Worlds
Output Devices: Audio,
Haptics, Olfactory, Gustatory

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Overview

- Here we are concerned with technology for stimulating the senses



Audio Displays

- ❑ Spatialization vs. Localization
- ❑ *Spatialization* is the processing of sound signals to make them emanate from a point in space
- ❑ *Localization* is the ability of people to identify the source position of a sound

Audio Display Properties

Presentation Properties

- Number of channels
- Sound stage
- Localization
- Masking
- Amplification

Logistical Properties

- Noise pollution
- User mobility
- Interface with tracking
- Environmental requirements
- Integration
- Portability
- Throughput
- Cumber
- Safety
- Cost

Channels & Masking

- Number of channels
 - Stereo vs. mono vs. quadrophonic
 - 2.1, 5.1, 7.1

- Two kinds of masking
 - Louder sounds mask softer ones
 - Physical objects mask sound signal
 - Happens with speakers, but not with headphones

Audio Displays

□ Head-worn



Ear Buds



On Ear



Open Back



Closed



Bone
Conduction

Haptic Displays

- Haptic sense is most complex
 - Tactile
 - Stimuli on the skin
 - Different kinds of mechanoreceptors, each with varying types of sensitivity
 - Temperature
 - Actually part of tactile
 - Kinesthetic
 - Force on the muscles and tendons
 - Proprioception
 - Force feedback
 - Wind
 - Pain

Haptic Sense

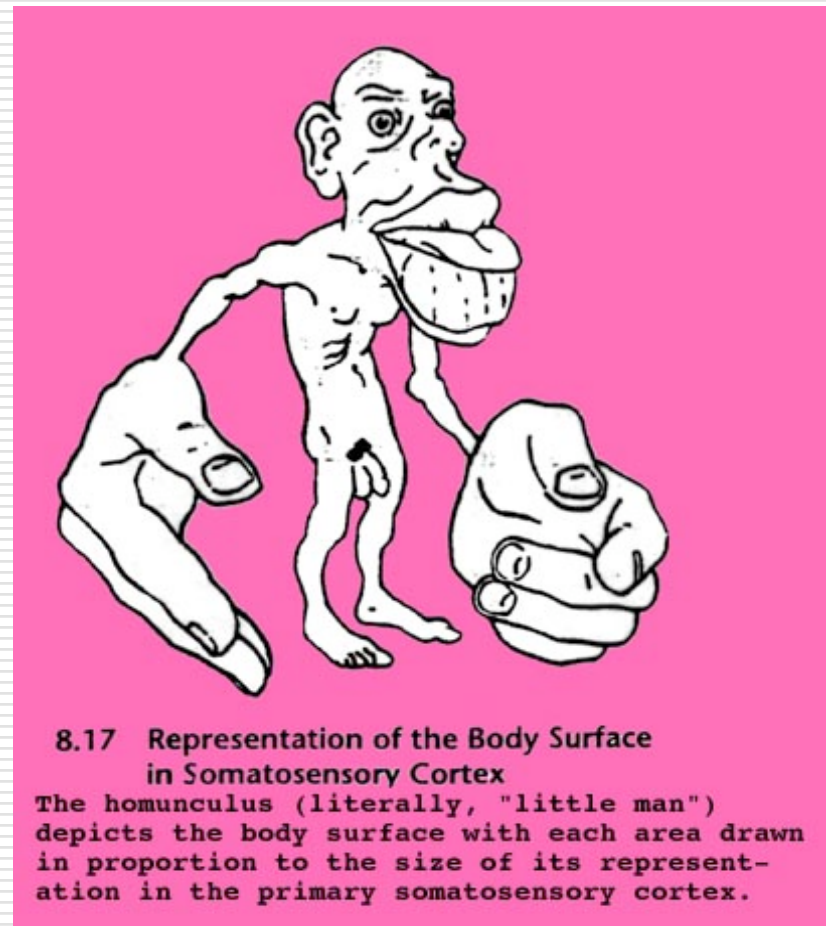
- The haptic sense is bidirectional
 - Senses the environment
 - Acts on the environment
 - Tight coupling between the two
- Skin is the largest organ

Haptic Devices

- Pin arrays for the finger(s)
- Force-feedback "arms"
- "Pager" motors
- Particle brakes
- Passive haptics
- Many devices are application specific
 - Like surgical devices

Haptic Feedback in VR

- Tactile: Surface properties
 - Most densely populated area is the fingertip (okay, it's the tongue)
- Kinesthetic: Muscles, Tendons, etc.
 - Also known as proprioception



Haptic Sense (cont)

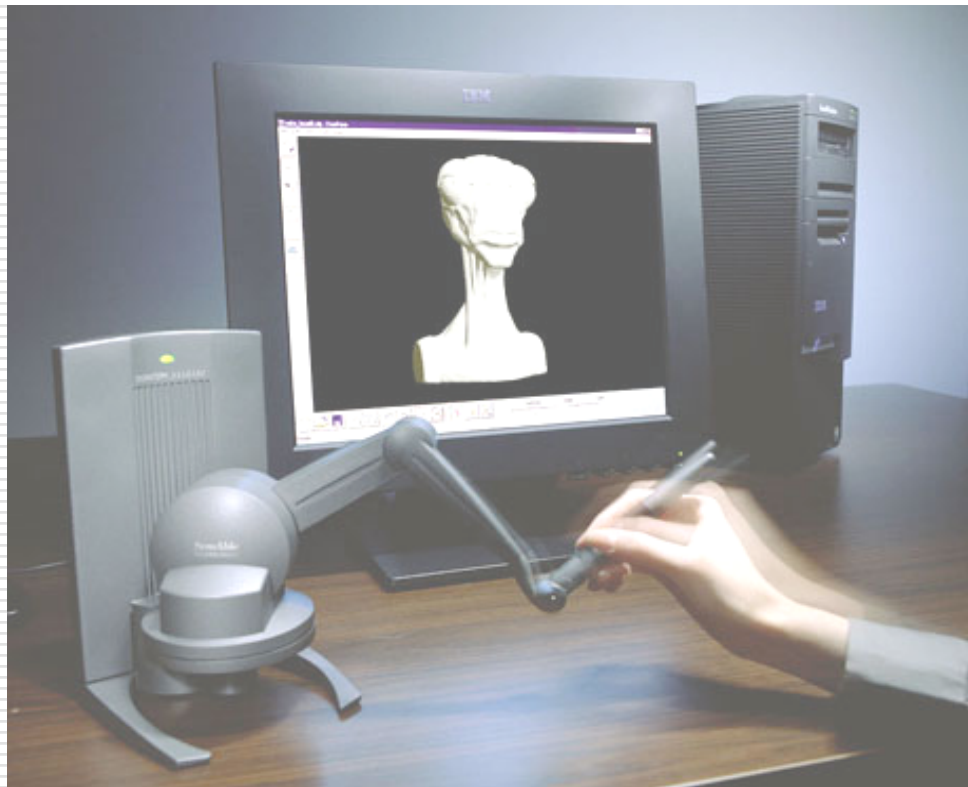
- Sensitivity varies greatly
 - Two-point discrimination



Body Site	Threshold Distance
Finger	2-3mm
Cheek	6mm
Nose	7mm
Palm	10mm
Forehead	15mm
Foot	20mm
Belly	30mm
Forearm	35mm
Upper Arm	39mm
Back	39mm
Shoulder	41mm
Thigh	42mm
Calf	45mm

<http://faculty.washington.edu/chudler/chsense.html>

SensAble *PHANToM*



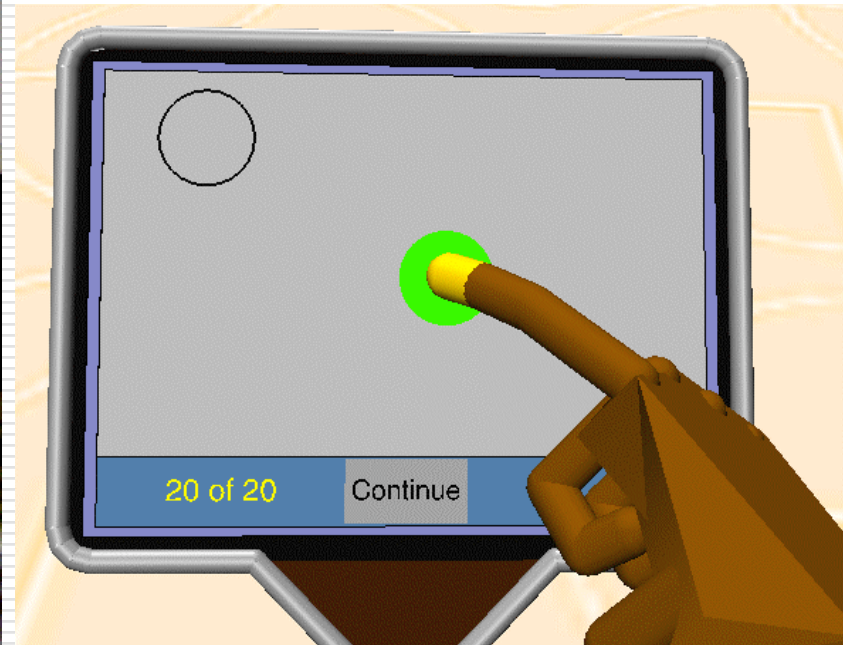
<http://www.sensable.com/>

Immersion *CyberGrasp*



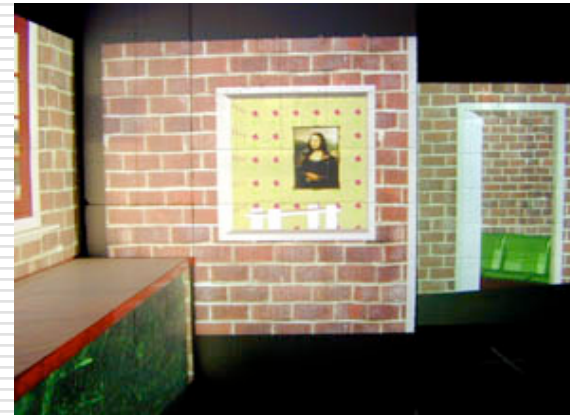
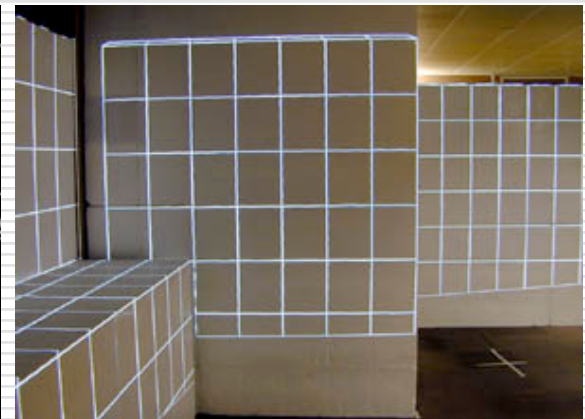
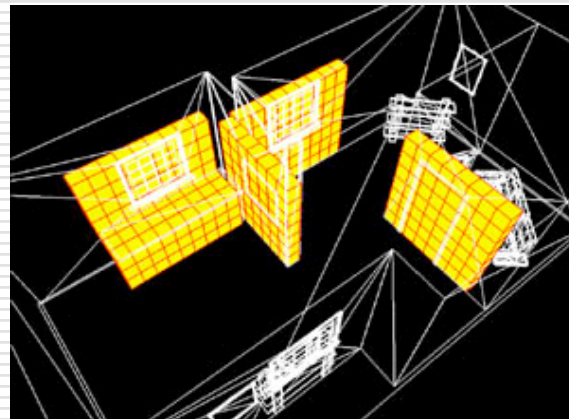
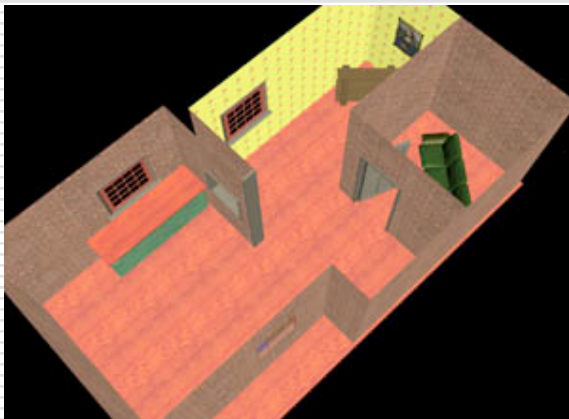
<http://www.immersion.com/>

Passive Haptic Paddle



<http://www.cs.wpi.edu/~gogo/hive/>

UNC Being There Project

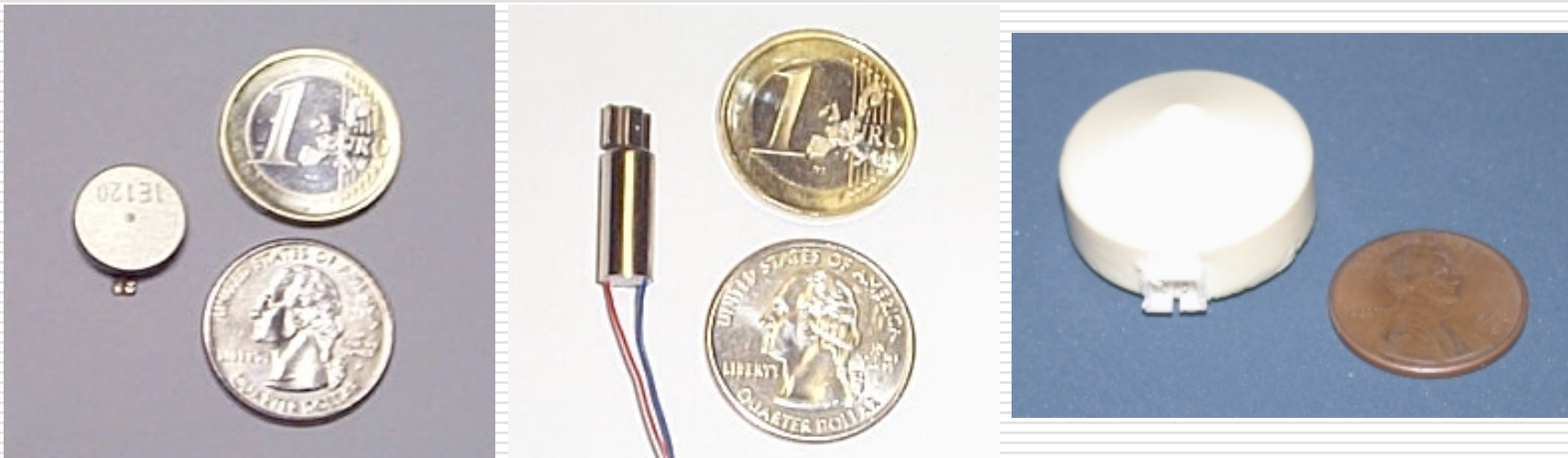


Haptic Feedback in VR

- Virtual contact
 - What should we do when we know that contact has been made with a virtual object?
 - The *output* of collision detection is the *input* to virtual contact
 - Cues for understanding the nature of contact with objects are typically over-simplified (*e.g.*, sound)
- Training aids
 - Can we convey additional information using the haptic channel?

Vibrotactile Cueing Devices

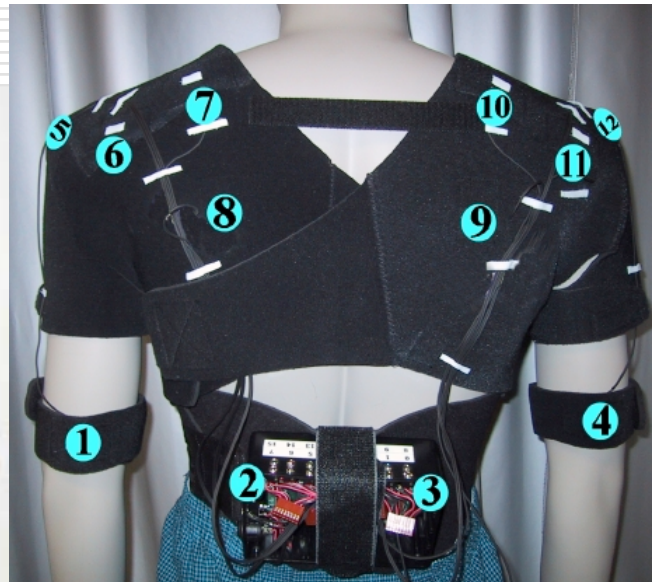
- ❑ Vibrotactile feedback has been incorporated into many devices
- ❑ Can we use this technology to provide scalable, wearable touch cues?



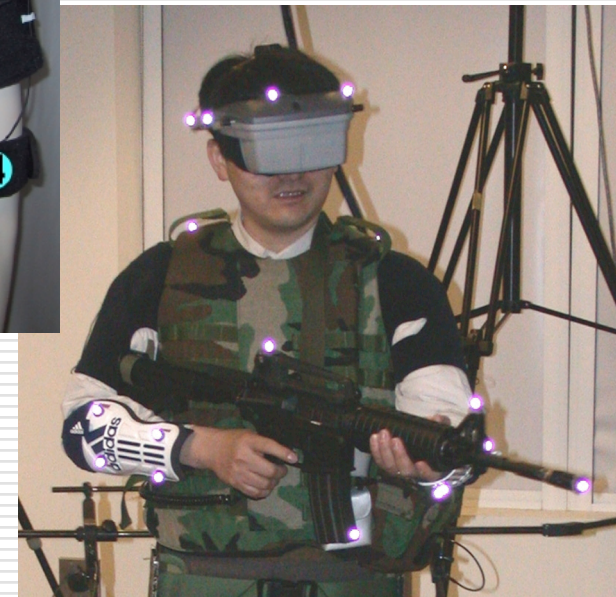
Vibrotactile Feedback Projects



Navy TSAS Project

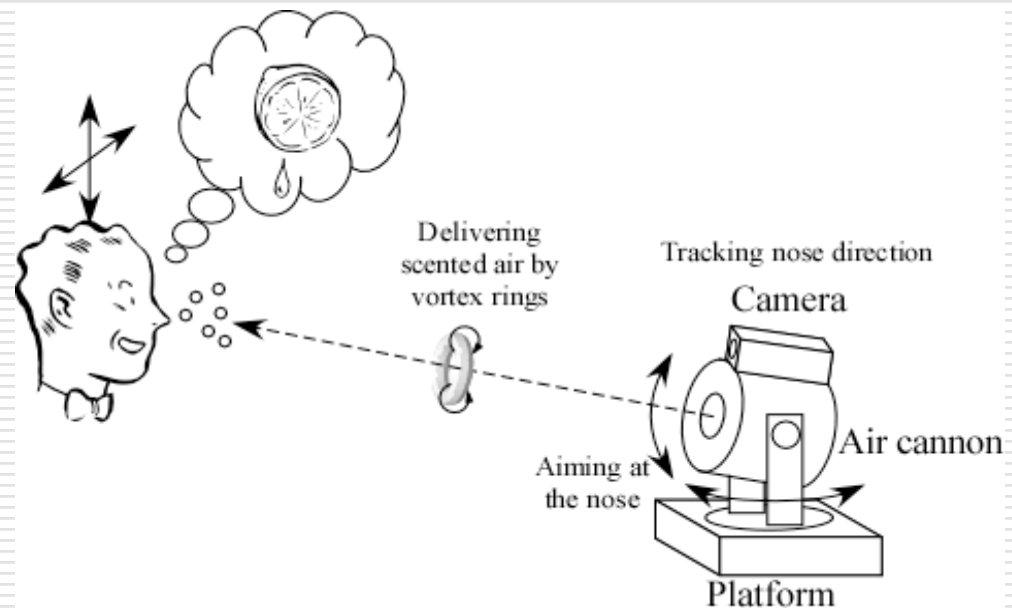


**TactaBoard and
TactaVest**

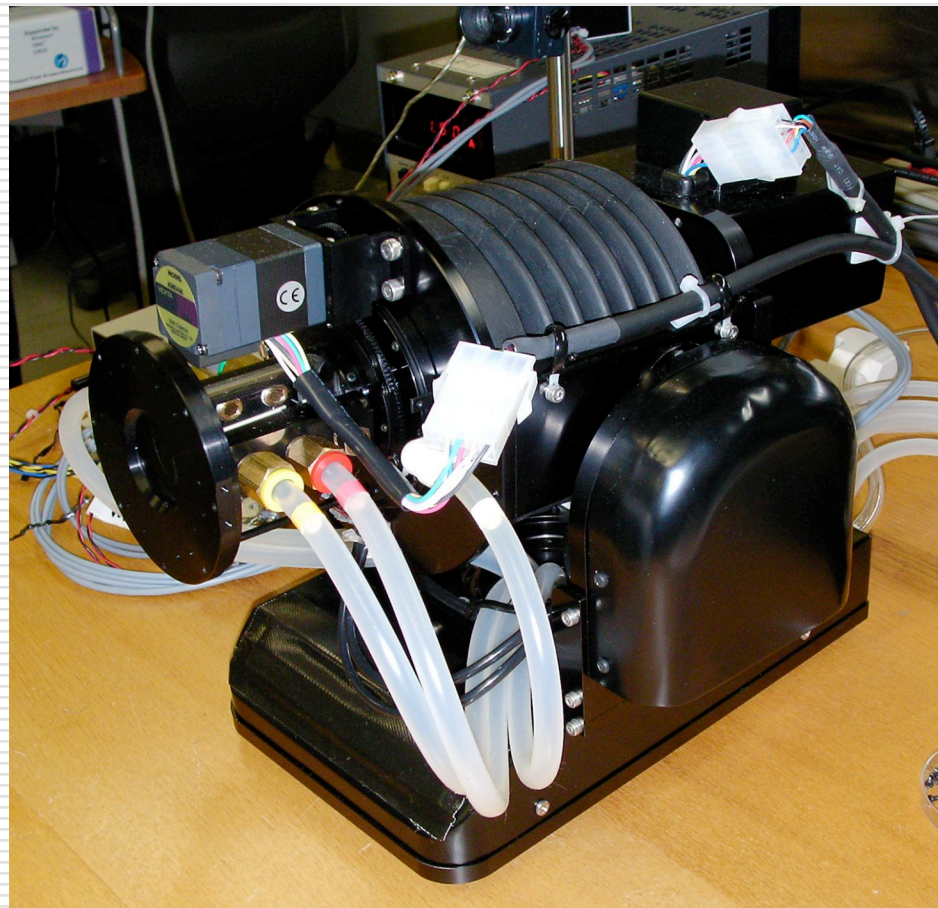
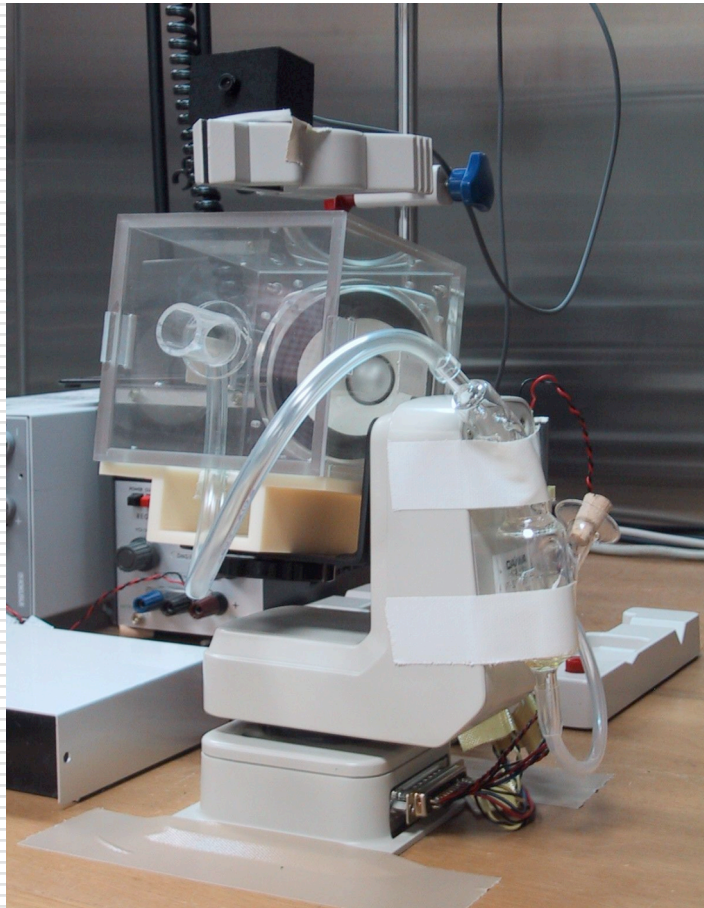


Olfactory Sense

- Two main problems
 - Scent generation
 - Tens of thousands of receptor types
 - Scent delivery
 - Easier problem

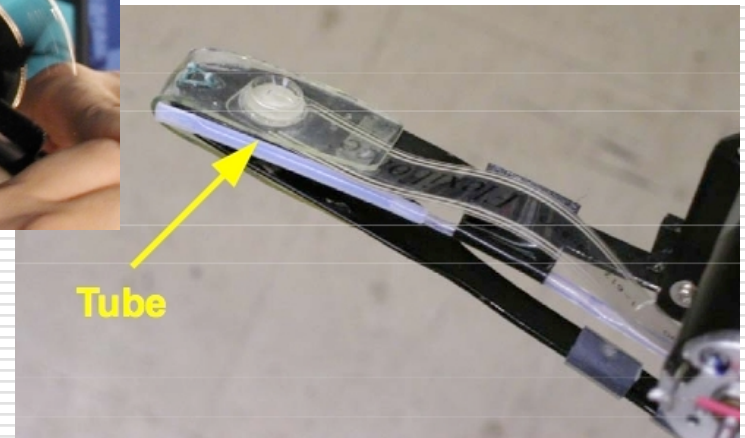


Air Cannon (Yanagida, 2004)



Gustatory

- Not much research here, but some interesting stuff



Summary

- There is lots of cool stuff left to try in order to fool the senses
- It's an engineering problem
- It's a human-physiology problem
- It's a human-perception problem