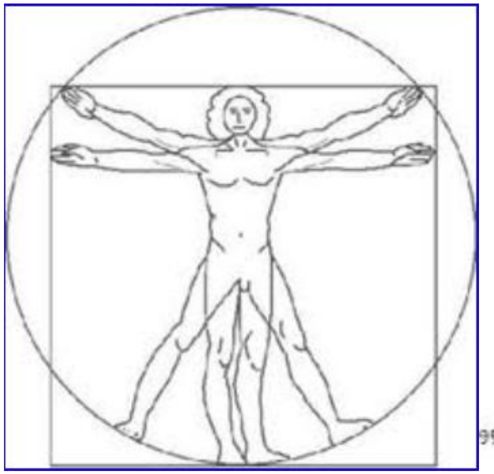
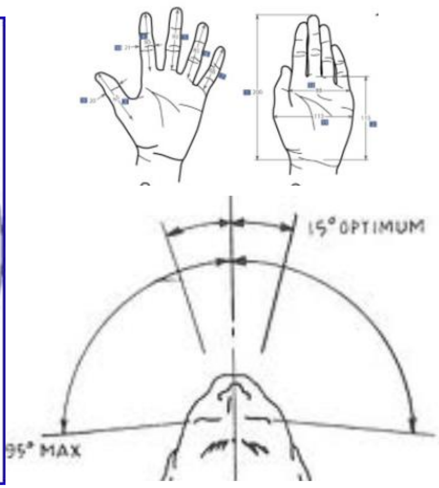
Universidade de Aveiro
Departamento de Electrónica,
Telecomunicações e Informática

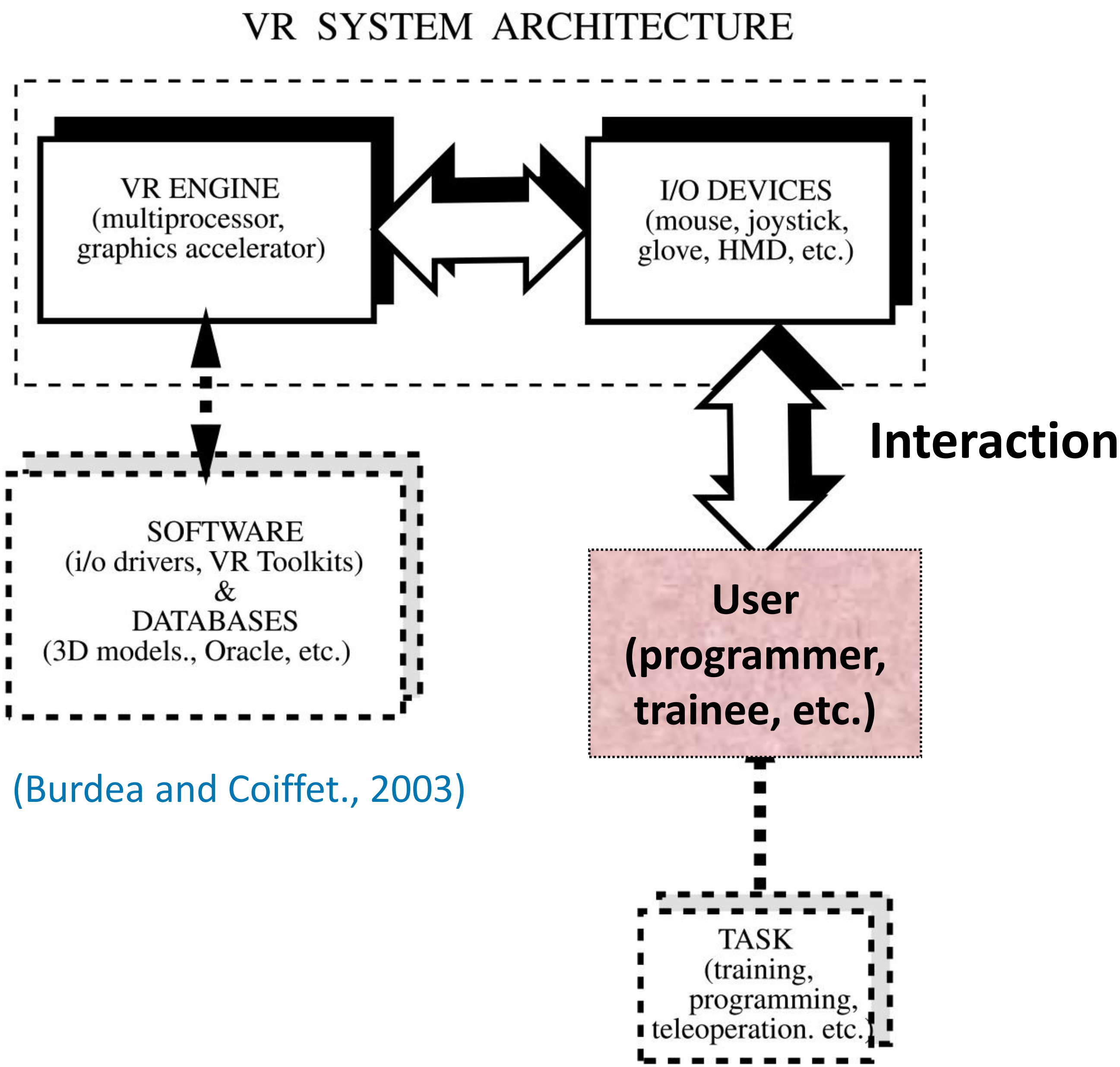
Human Factors in Virtual and Augmented Reality





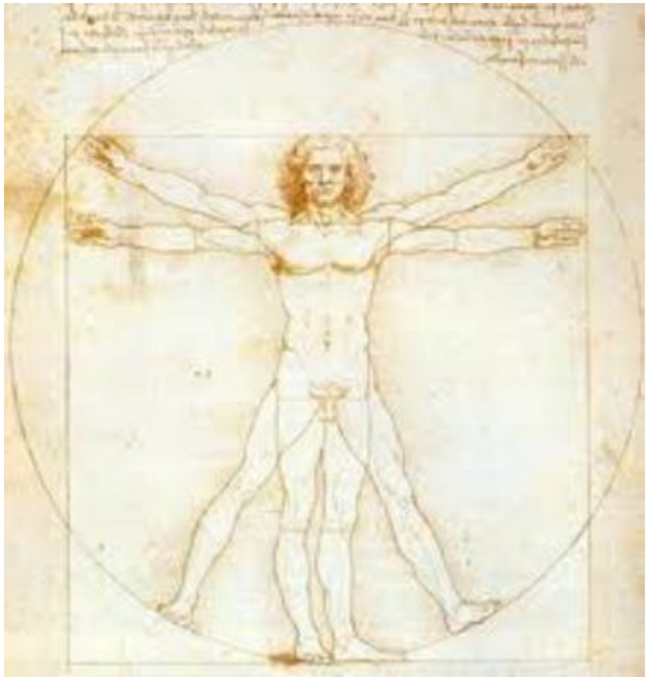
Realidade Virtual e Aumentada 2016/2017

Beatriz Sousa Santos



(Burdea and Coiffet., 2003)

Human factors (or ergonomics)



- It is the study of designing equipment and devices that fit human:

  - body
  - cognitive abilities

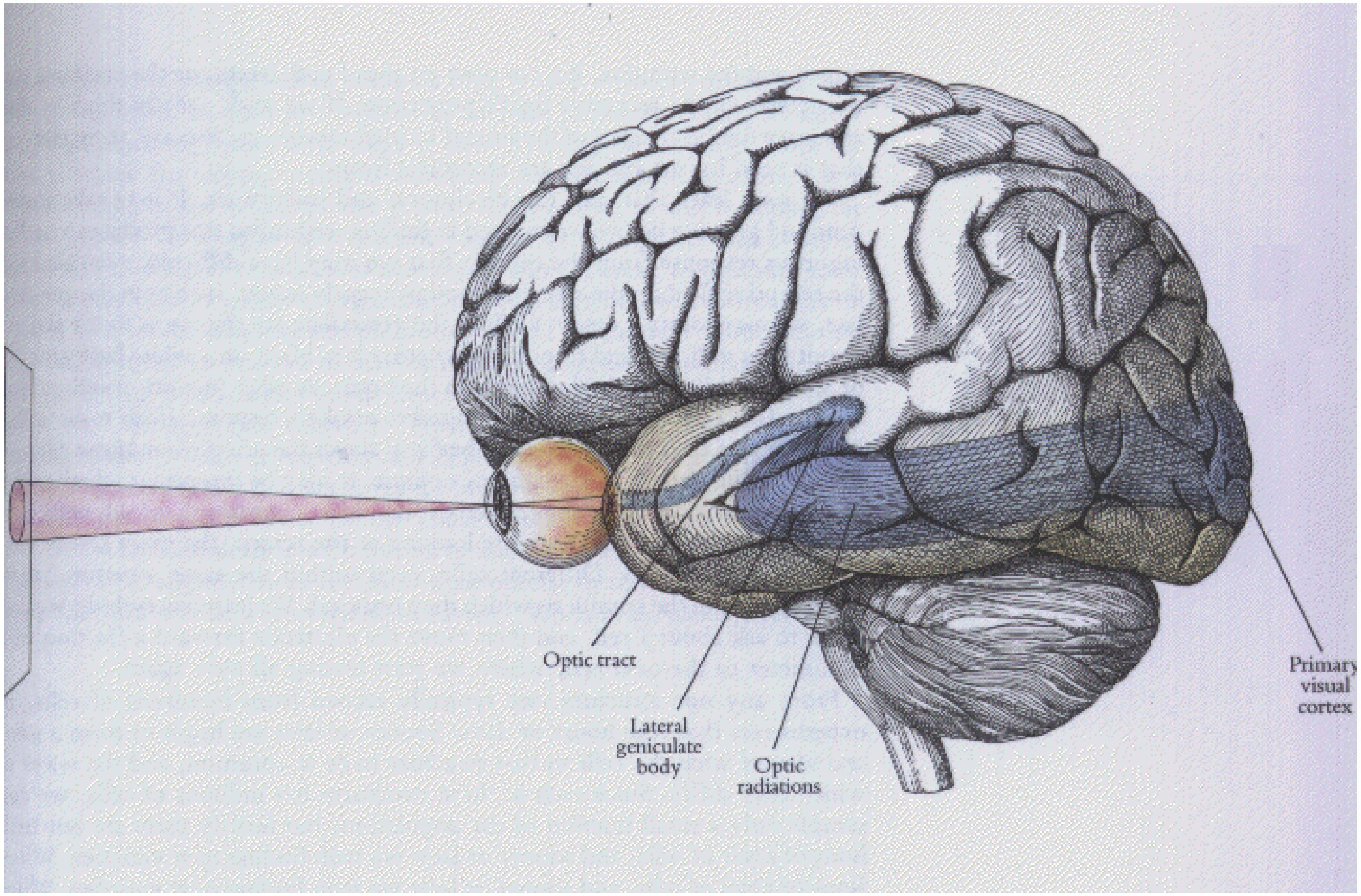
- The two terms "human factors" and "ergonomics" are essentially synonymous

- It aims at fulfilling the goals:

  - health
  - safety
  - productivity

The Human Visual System

The eyes are sensors; most processing occurs at the visual cortex



(Hubel, 1988)

Some characteristics of the eye:

100 millions of rods in each eye

6 million cones in each eye

1 million nervous fibers in each optic nerve

Distance between the center of the lens and the fovea: 17mm

Distance between pupils: 50 - 70mm

Rod sensitivity 500 higher then the cone sensitivity

Maximum rod sensitivity at 0,51 µm (geen)

Maximum cone sensitivity at 0,56 µm (orange)

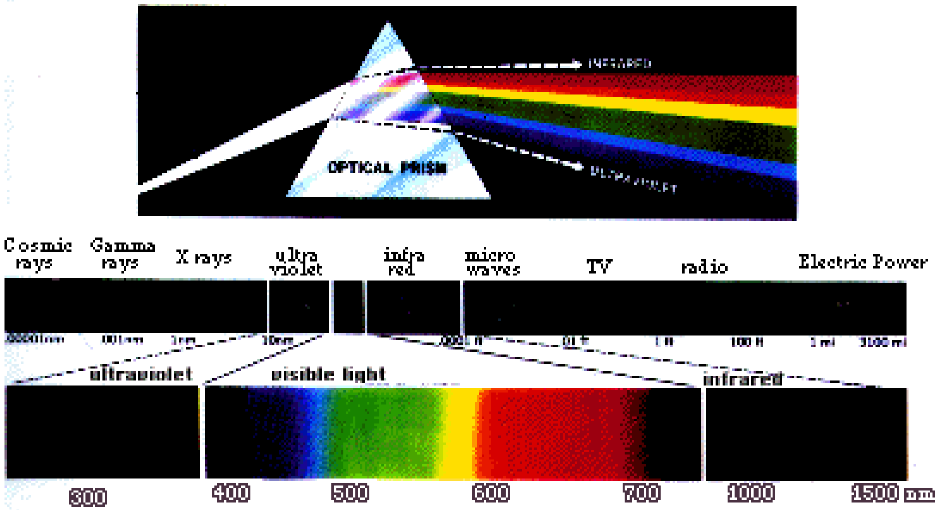
Dynamic range: 10^{16}

The human eye is an amazing “instrument” as to sensitivity and resolution:

In a clear night the flame of a candle can be seen from 15km away

Resulted from a long evolution; it is a “camara type eye”

It is sensitive only to a small part of the elcetromagnetic spectrum

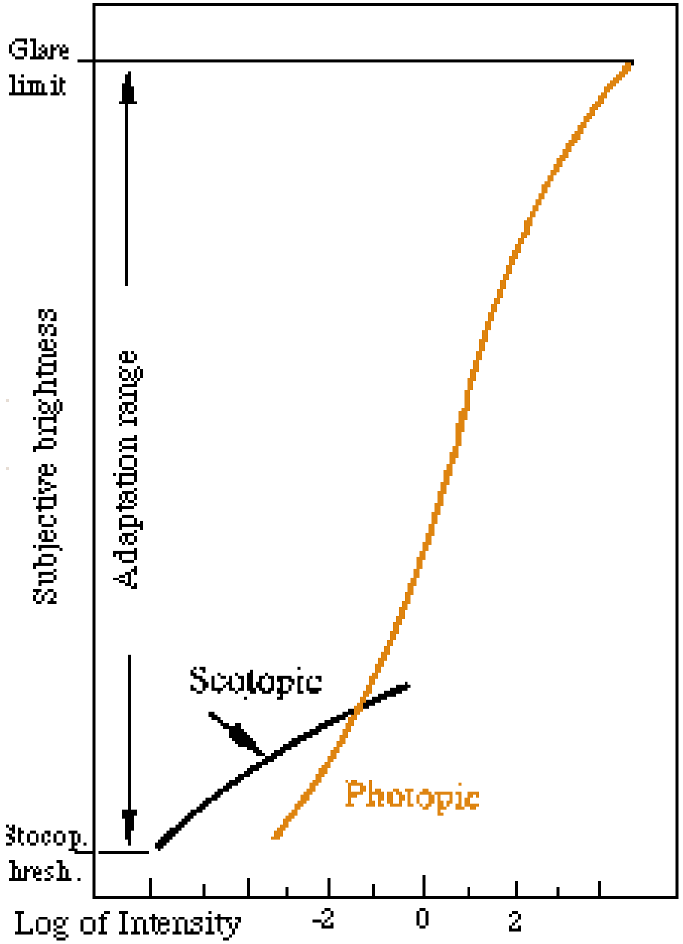


(Gonzalez e Woods, 1992)

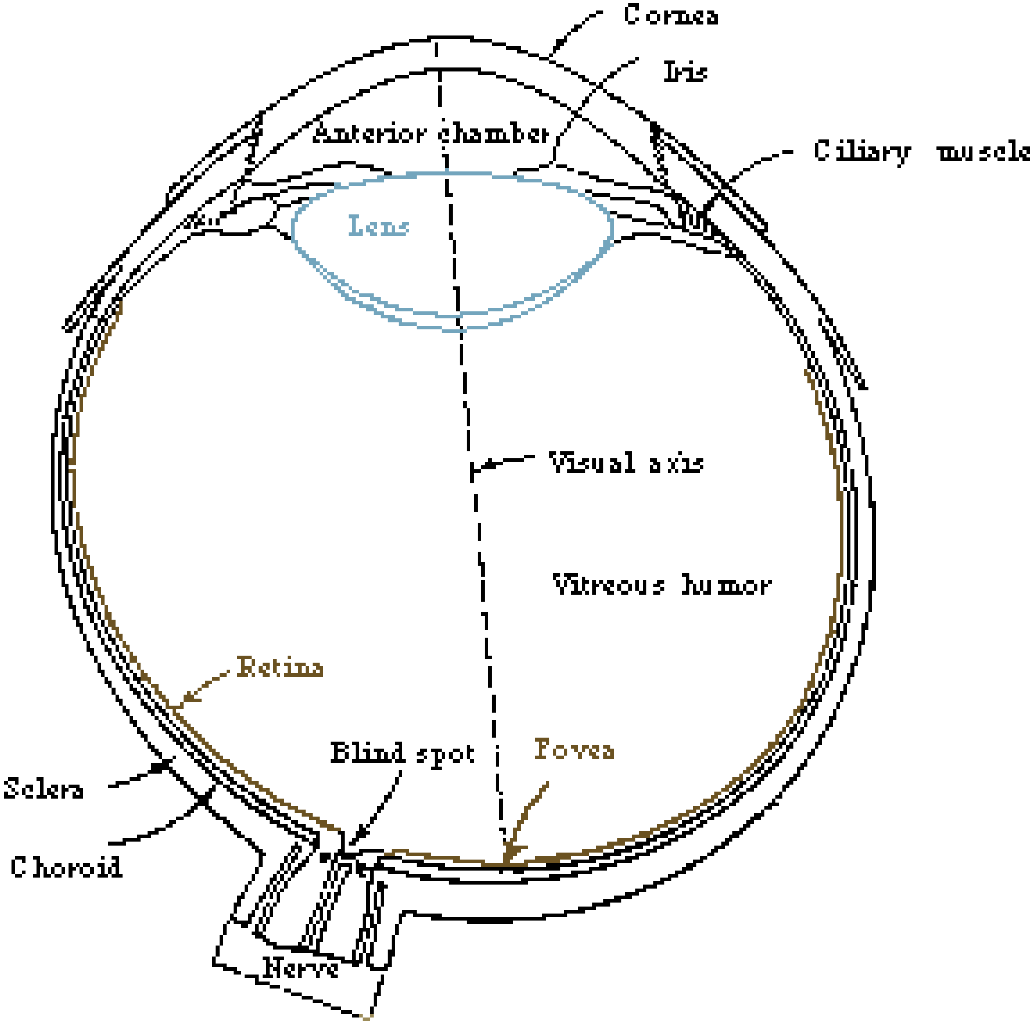
The Human Visual system has in fact two types of vision:

Scotopic –works at low light levels and is not sensitive to wave length (λ)

Photopic – that works at higher light levels and is sensitive to wave length (λ)

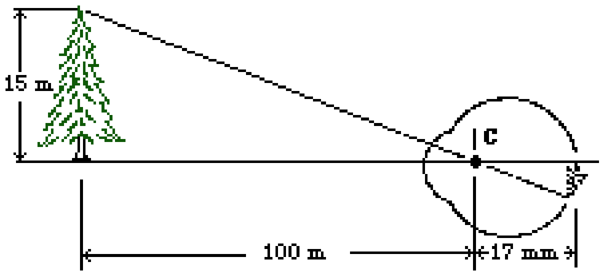


The light goes into the iris, is focused by the lens, and an image is projected on the retina

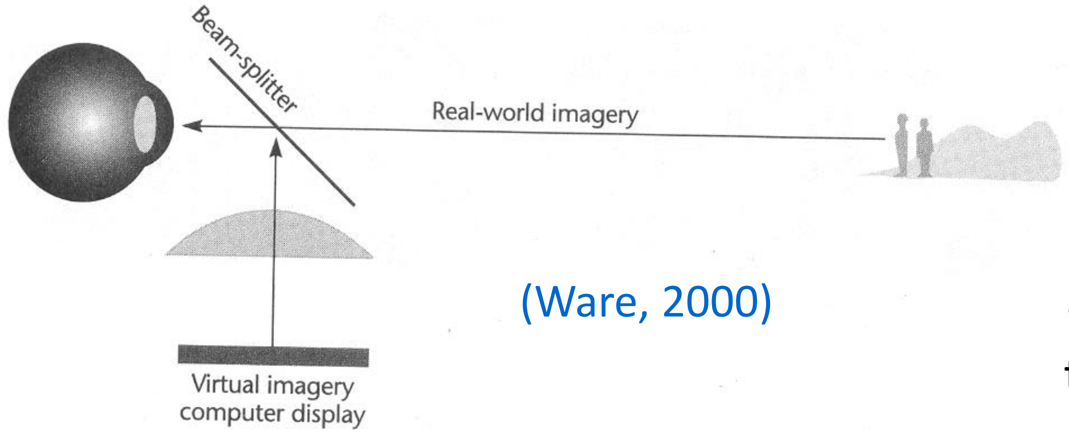


- Focusing is done mainly by the eye flexible lens

- It is an important issue in Virtual and Augmented Reality systems



Eye seing a tree:
C is the lens optic center óptico



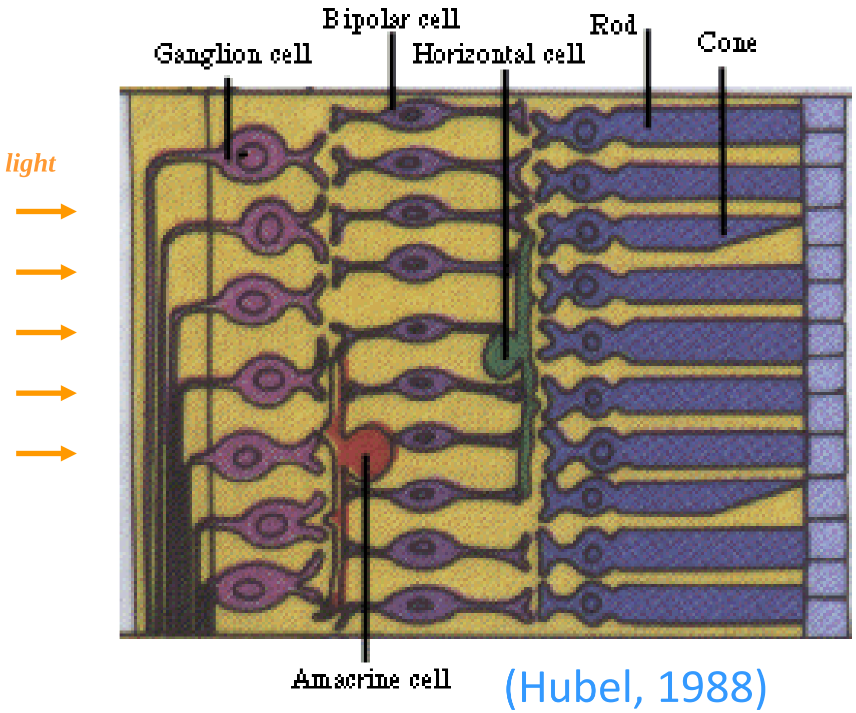
(Ware, 2000)

- Superimposing synthetic images to real images poses technical challenges is Augmented Reality

- The retina is a very complex structure (several layers of cells)

- It has two types of photoreceptors

  - Cones (sensitive to λ)
    the basis of Photopic (colour) vision
  - Rods (not sensitive to λ)
    the basis of Scotopic vision

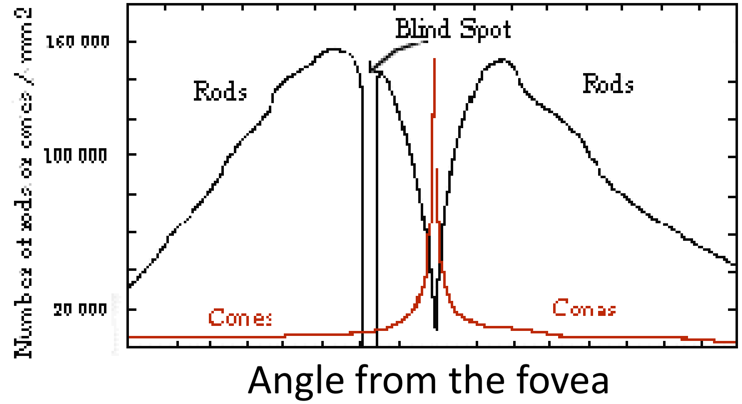


(Hubel, 1988)

- Rods outnumber cones and work at low intensity levels

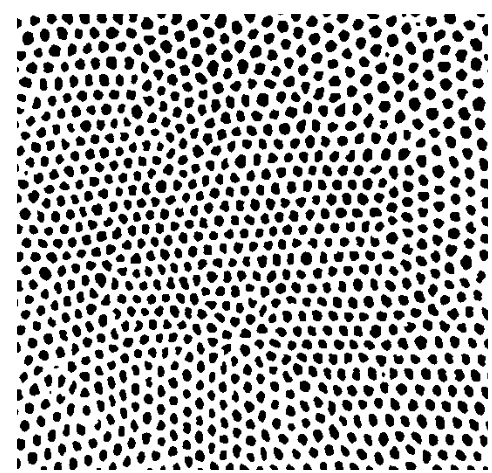
- Cones do not respond at low intensity levels

- There are thee types (in different number)
  - “Red” – 64%
  - “Green” - 34%
  - “Blue” – 2%



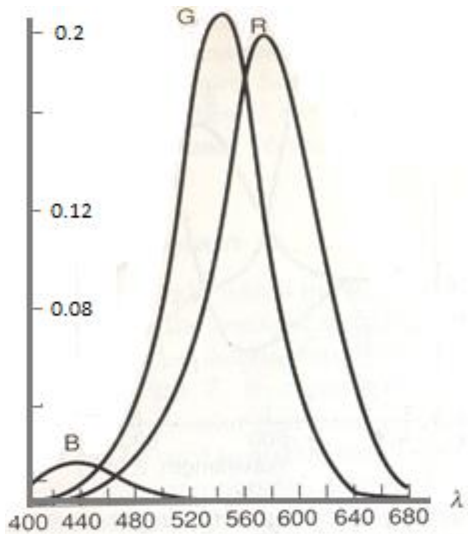
- Cones and Rods have an uneven distribution on the retina

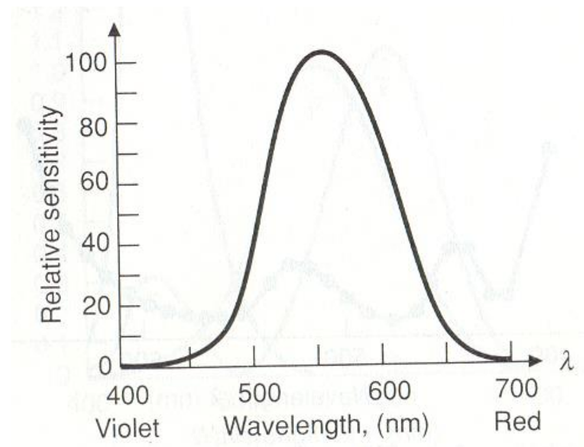
- At the fovea (0,5mm diameter) there are only cones



Pattern of cones on the fovea

(Hubel, 1988)



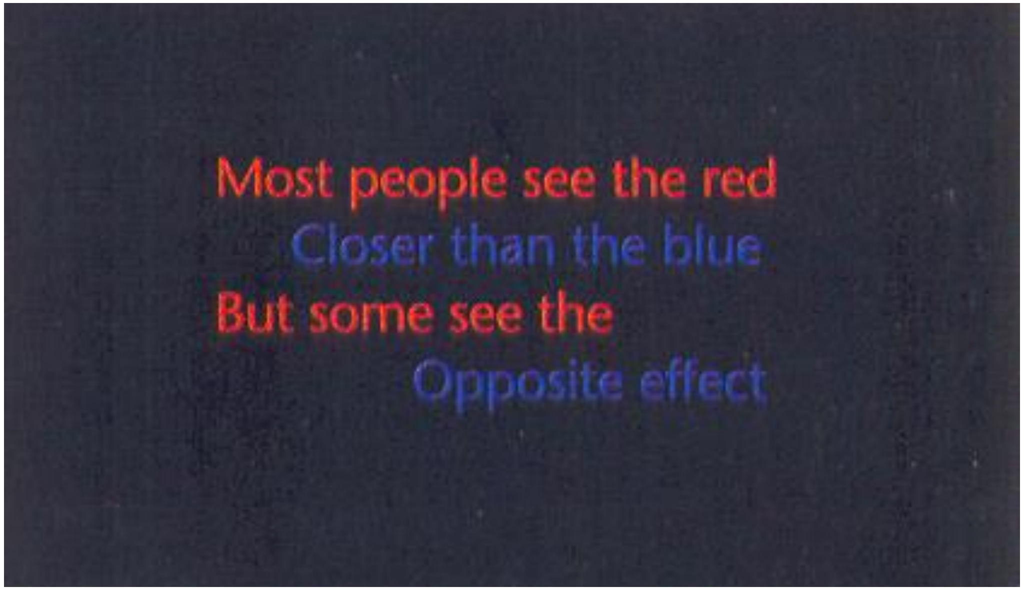


Response of each cone type along the spectrum (Fraction of light absorbed)

Human eye efficiency function

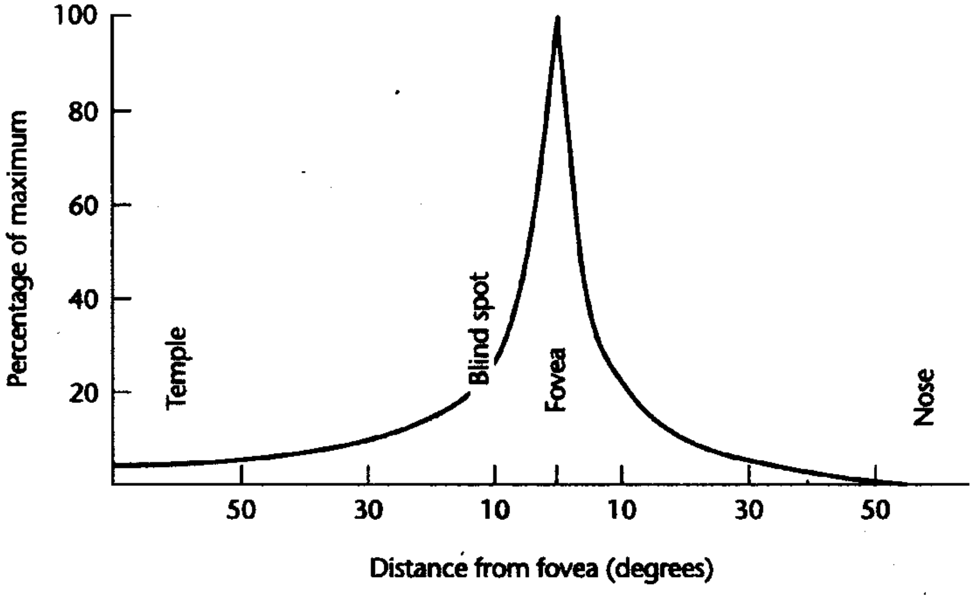
Wavelength (nanometers)	Relative Sensitivity	Wavelength (nanometers)	Relative Sensitivity	Wavelength (nanometers)	Relative Sensitivity
400	.0004	510	.5030	620	.3810
410	.0012	520	.7100	630	.2650
420	.0040	530	.8620	640	.1750
430	.0116	540	.9540	650	.1070
440	.0230	550	.9950	660	.0610
450	.0380	560	.9950	670	.0320
460	.0600	570	.9520	680	.0170
470	.0910	580	.8700	690	.0082
480	.1390	590	.7570	700	.0041
490	.4652	600	.6310	710	.0010
500	.3230	610	.5030	720	.0005

- The human eye is not corrected to chromatic aberration
- Light of different wave length focus at different distances within the eye
- Blue light is more refracted than red light
- If we focus a red spot on the screen, a contiguous blue spot will be out of focus
- It is not advisable to use thin blue patterns near red or green patterns (attract the focusing mechanism)



(Ware, 2000)

- The eyes acuity decreases quickly from the fovea
- Thus: we may show more detail on the area focused and projected on the retina
- This implies eye tracking, but allows saving resources



(Ware, 2000)

- In stereoscopic displays the interpupillary distance is an important parameter and should be adjustable

- The human eye has ~180 receptors per degree at the fovea

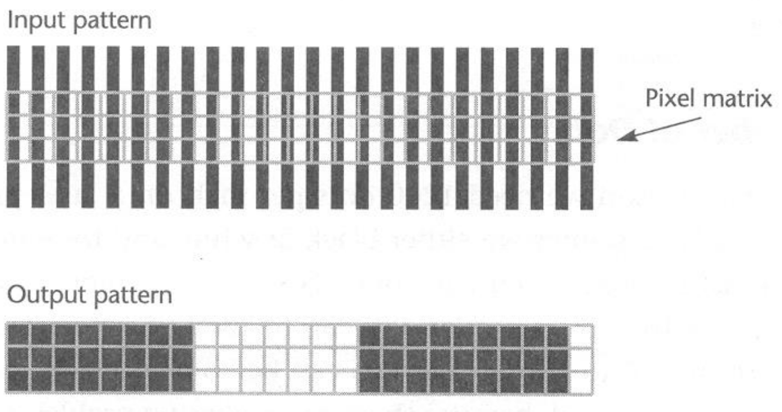
- Thus, not considering super-acuities:

  a monitor with 4000 x 4000 will be enough for any visual task

- Considering the sampling theorem we get a similar value: the human eye can tell apart ~50 cycles per degree

- Aliasing is particularly serious when a regular pattern is sampled with another regular pattern

- May be this is why photo receptors are irregularly placed on the retina



- It is possible to establish temporal requirements for the “ideal display”

~50 Hz is the lower value for image refresh

- Below this refresh rate individual images start to be noticeable

- It is also possible to use temporal anti-aliasing

Images produced by most displays are very poor when compared to the real world

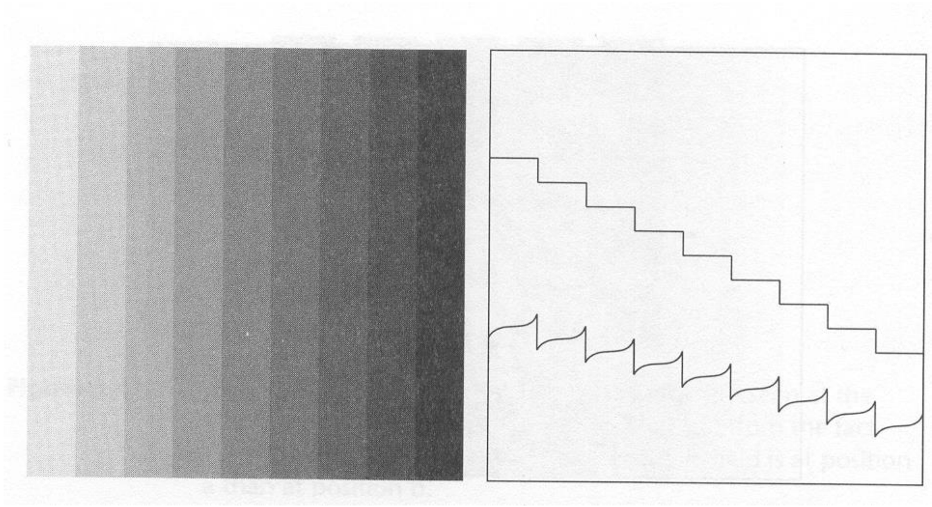
It is amazing what is possible with such simple devices

Displays have various limitations:

- Low intensity
- Small field of view
- Lack of information concerning focusing distance
- Lack of tactile interaction

More serious!

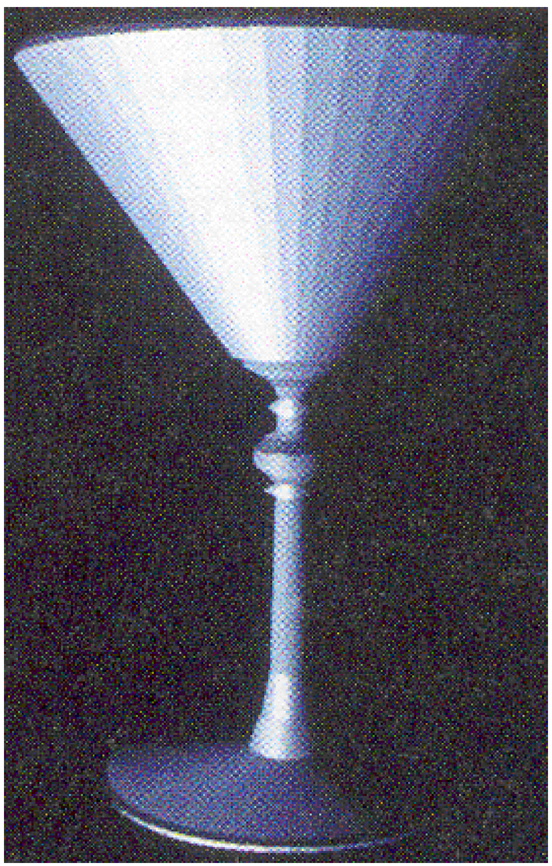
- The Human Visual System does not measure the amount of light, it measures variations
- This means that the light perception is non-linear
- And corresponds to a high-pass filtering; i.e. discontinuites are more visible

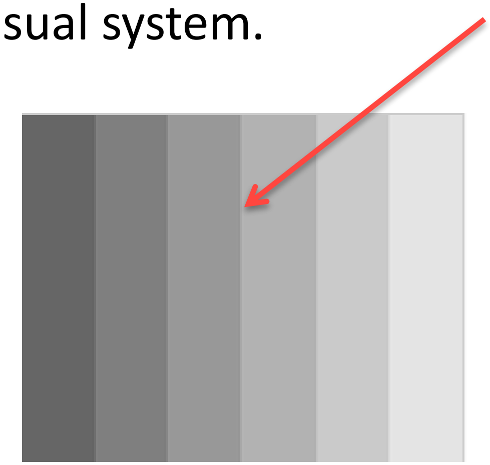


Chevreul illusion: left – measured pattern; right – perceived pattern

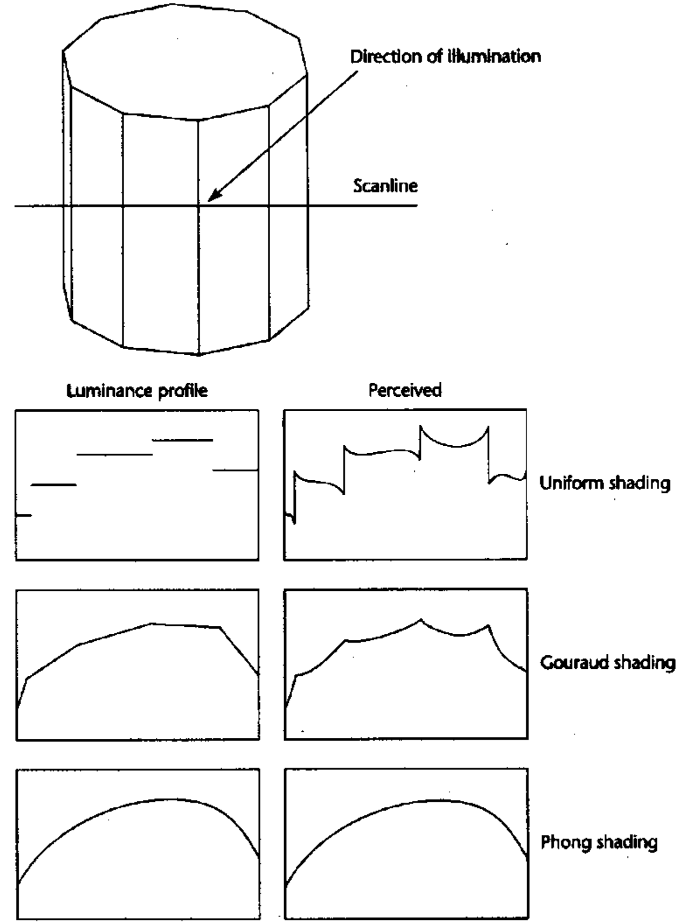
Mach Bands

Eexaggerate the contrast between edges of slightly differing shades of gray, as soon as they contact one another, by triggering edge-detection in the human visual system.





Along the boundary between adjacent shades of grey darker areas falsely appear even darker and the lighter area falsely appear even lighter [wikipedia]

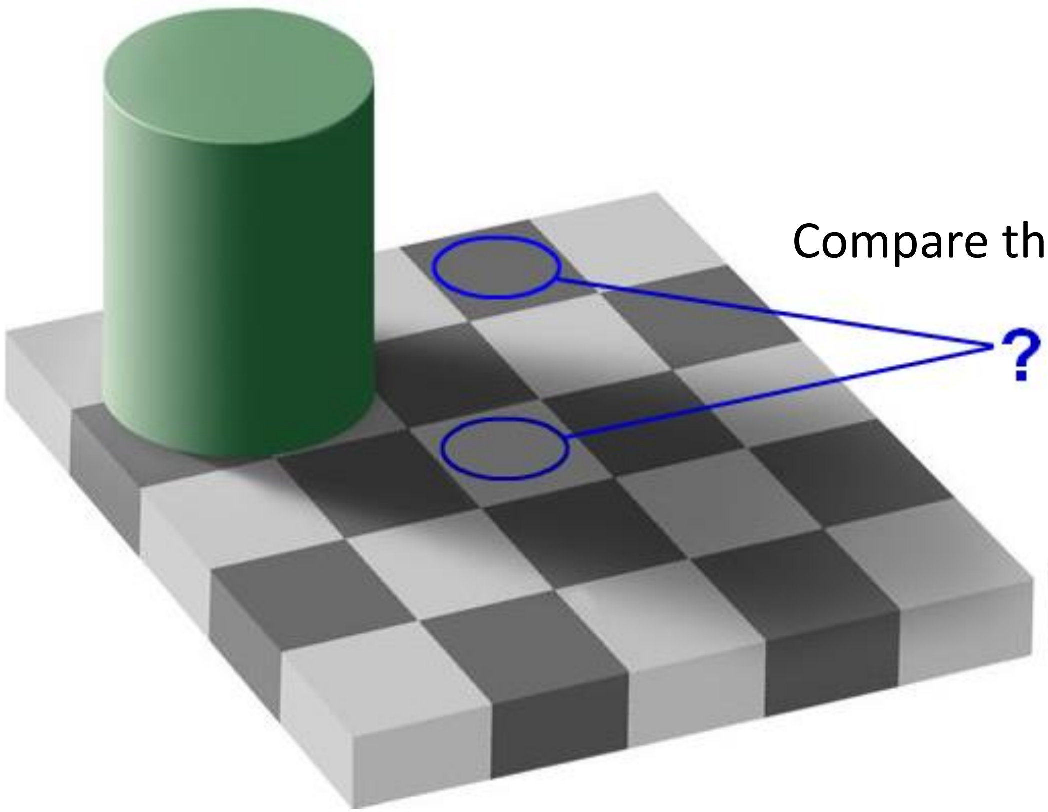


This type of effects tend to show deficiencies in shading methods used in Computer Graphics

Visual illusions

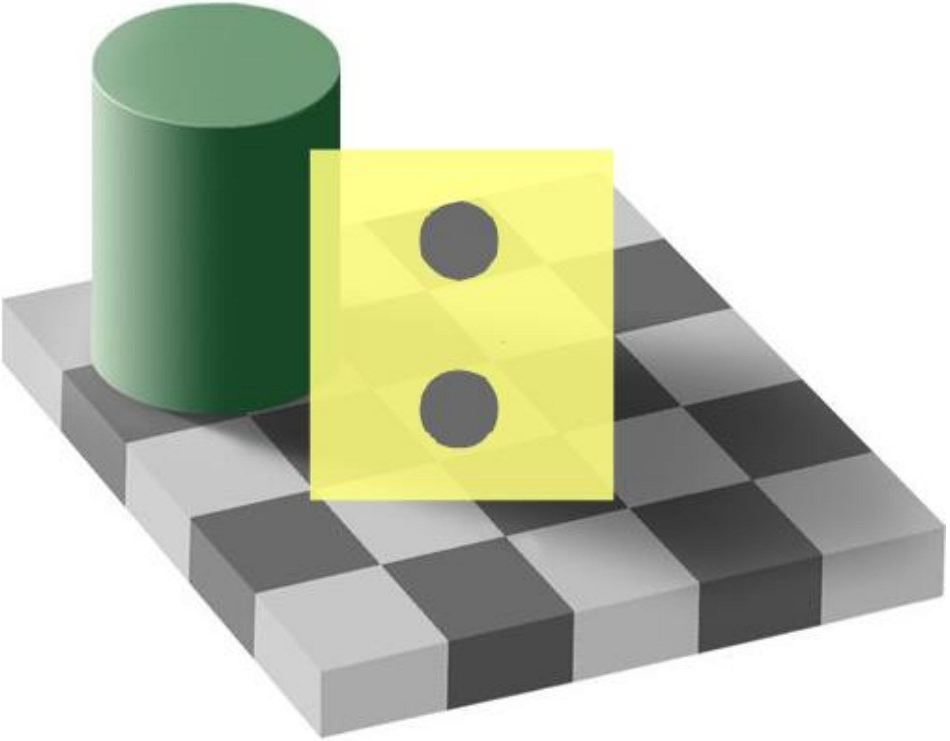
What we see does not depend only on the grey level

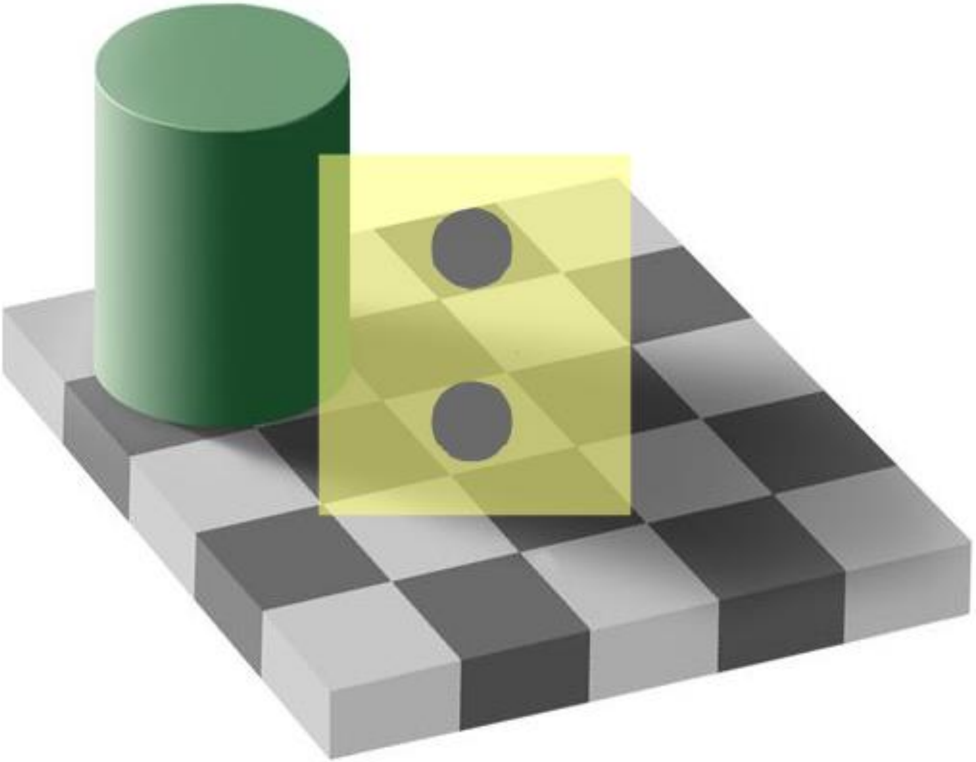
Compare the relative brightness



http://www.michaelbach.de/ot/

http://web.mit.edu/persci/people/adelson/checkershadow_illusion.html





For 3D scenes, the visual system estimates a lighting vector and uses it to judge the material

Visual illusions have helped understand visual perception

http://www.youtube.com/watch?v=AuLJzB_pfgE

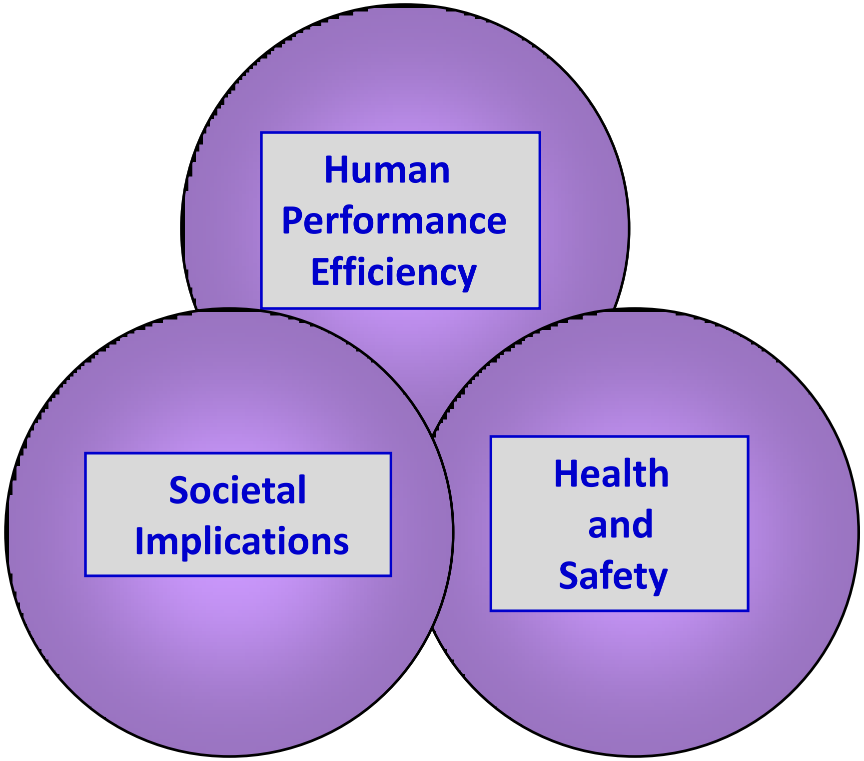






http://www.michaelbach.de/ot/fcs_hollow-face/index.html

Human factors in VR



(Stanney et al., 1998)

Human Factors/ Ergonomics

Human factors the study of designing equipment and devices that fit the human body and its cognitive abilities

The two terms "human factors" and "ergonomics" are often considered synonymous

Human factors in VR

- Will the user get sick in VR?
- Which tasks are most suitable for users in VR?
- Which user characteristics will influence VR performance?
- Will there be negative societal impact from user's misuse of the technology?
- How should VR technology be improved to better meet the user's needs?
- How much feedback from VR can the user process?
- Will the user perceive system limitations?
- What kind of designs will enhance user's performance in VR?

(Stanney et al., 1998)

Human factors vocabulary

HF study – series of experiments in very rigorous conditions aimed at the user (can be controlled or case study)

Experimental protocol – establishes a structured sequence of experiments that all participants need to perform

Trial – a single instance of the experiment

Session - a sequence of repeated trials

Experimental database – files that store experimental data

Subject - a participant in a HF study (male or female, age, volunteer or paid, right handed or left handed, normal or disabled, etc.)

H. F. vocabulary - continued

Experimental group – subjects on which the experiments are done

Control group – a number of subjects used for comparison with the experimental group

Controlled study – a study that uses both an experimental and control group

Case study (also called pilot study) – smaller study with no control group

Consent form – needs to be signed by all participants into the study

Baseline test – measurement of subject’s abilities before trial

Evaluation of 3D User Interfaces

Evaluation is the analysis, assessment, and testing of the entire UI or part of it (e.g. an input device or interaction technique)

Generally the main purpose of evaluation is the identification of usability problems or issues, leading to changes in the UI design

Design and evaluation should be performed iteratively

design

evaluation

redesign

evaluation, …

until the UI is "good enough" based some metrics

Main goals of evaluation:

- **problem identification**
- **redesign of a UI**

Secondary purposes:

- development of **performance models**
- more general **understanding** of the usability of a technique, device, or metaphor

leading to **design guidelines**

Distinctive Characteristics of 3D User Interface Evaluation

Many of the fundamental evaluation concepts and goals are similar to traditional 2D UIs, but there are issues specific to 3D UIs concerning:

- Physical Environment
- Evaluator
- User
- Evaluation type ...

Evaluation methods

A classification of methods according to three characteristics:

- involvement of users
  - requiring users (empirical methods)
  - not requiring users (analytical methods)
- context of evaluation
  - generic
  - application specific
- types of results produced
  - quantitative
  - qualitative

Main evaluation methods used in VEs

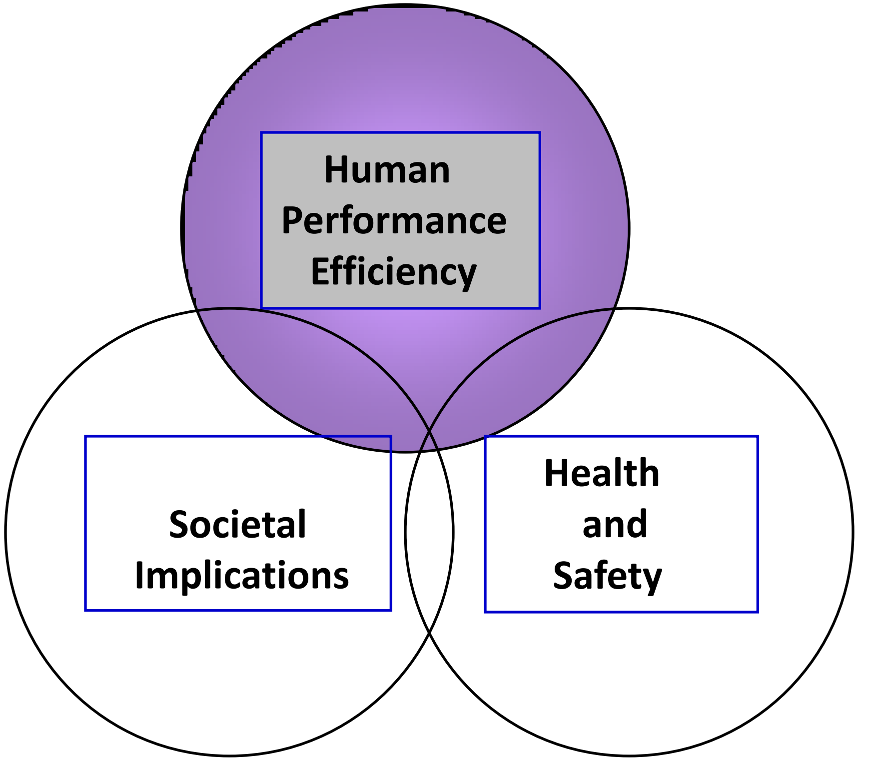
- Requiring users (empirical)
  - observation
  - questionnaire
  - interview

- Not requiring users (analytical)
  - heuristic evaluation
  - cognitive walkthrough

A classification of methods according to three characteristics

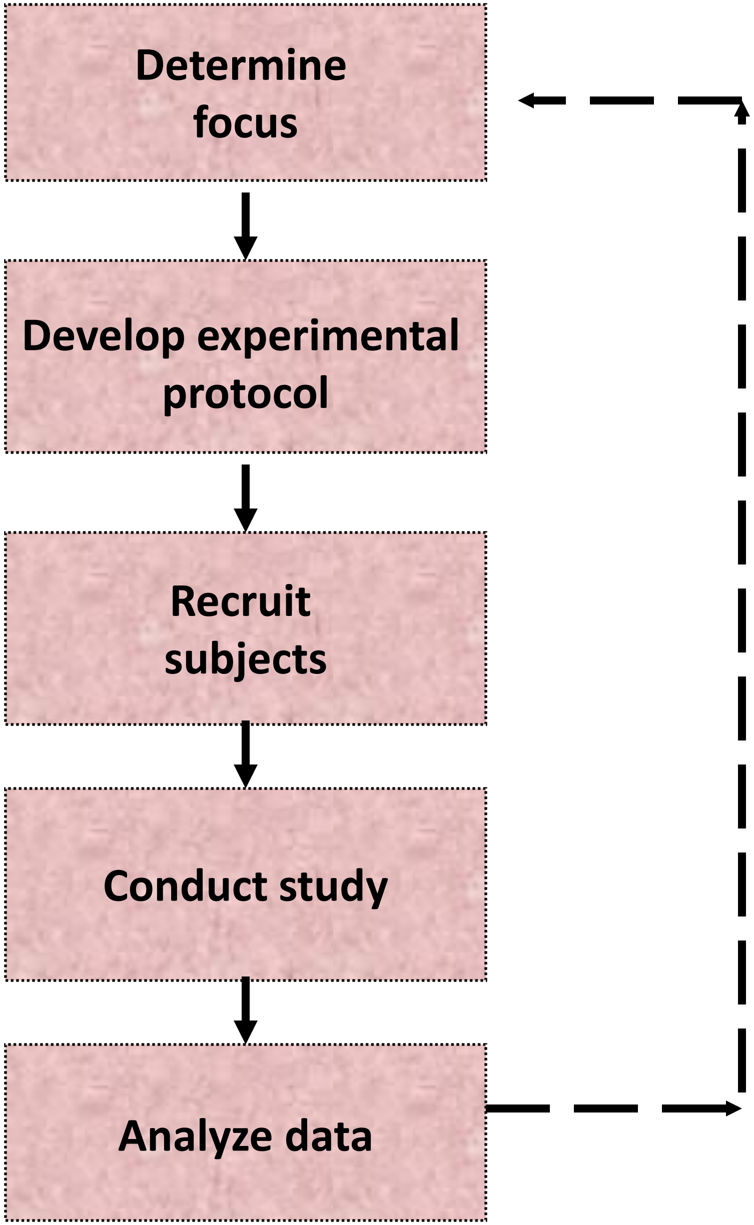
Context of Evaluation	User Involvement: Requires Users	User Involvement: Does Not Require Users	Type of Results
Generic	• Formal Summative Evaluation • Post-hoc questionnaire	• (generic performance models for VEs [e.g., Fitts's law])	Quantitative
Generic	• Information Summative Evaluation • Post-hoc questionnaire	• Heuristic Evaluation	Qualitative
Application Specific	• Formative Evaluation • Formal Summative Evaluation • Post-hoc questionnaire	• (application-specific performance models for VEs [e.g., GOMS])	Quantitative
Application Specific	• Formative Evaluation (informal and formal) • Post-hoc questionnaire • Interview/Demo	• Heuristic Evaluation • Cognitive Walkthrough	Qualitative

(Bowman et al, 2005)



(Stanney et al., 1998)

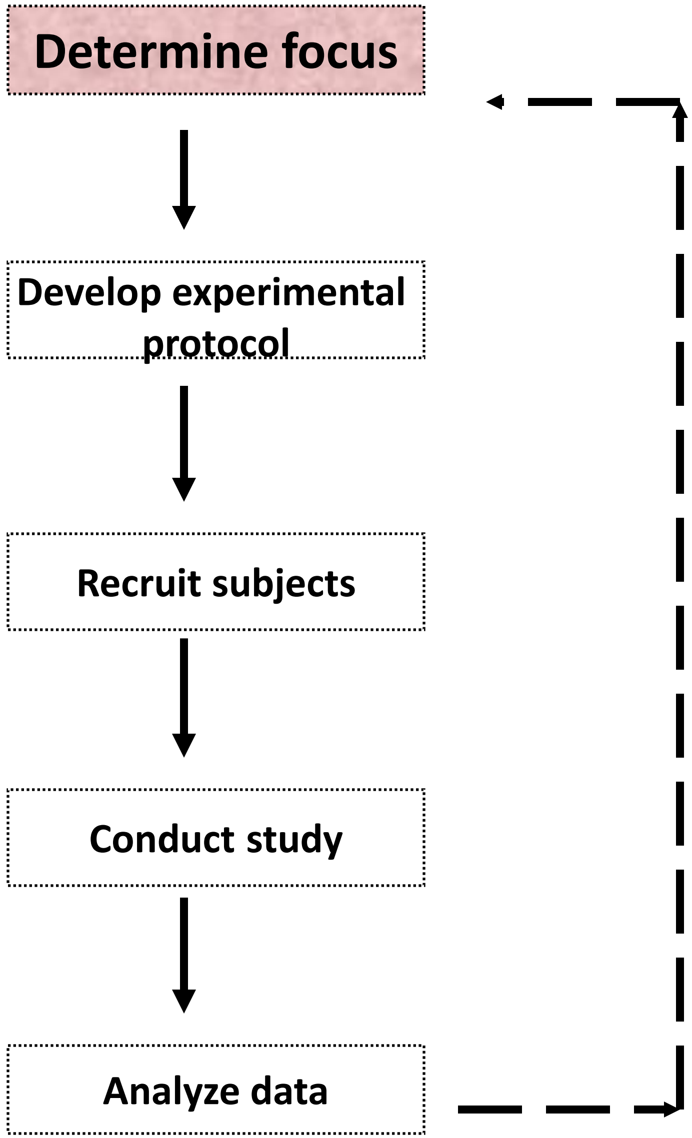
The stages of human factors studies



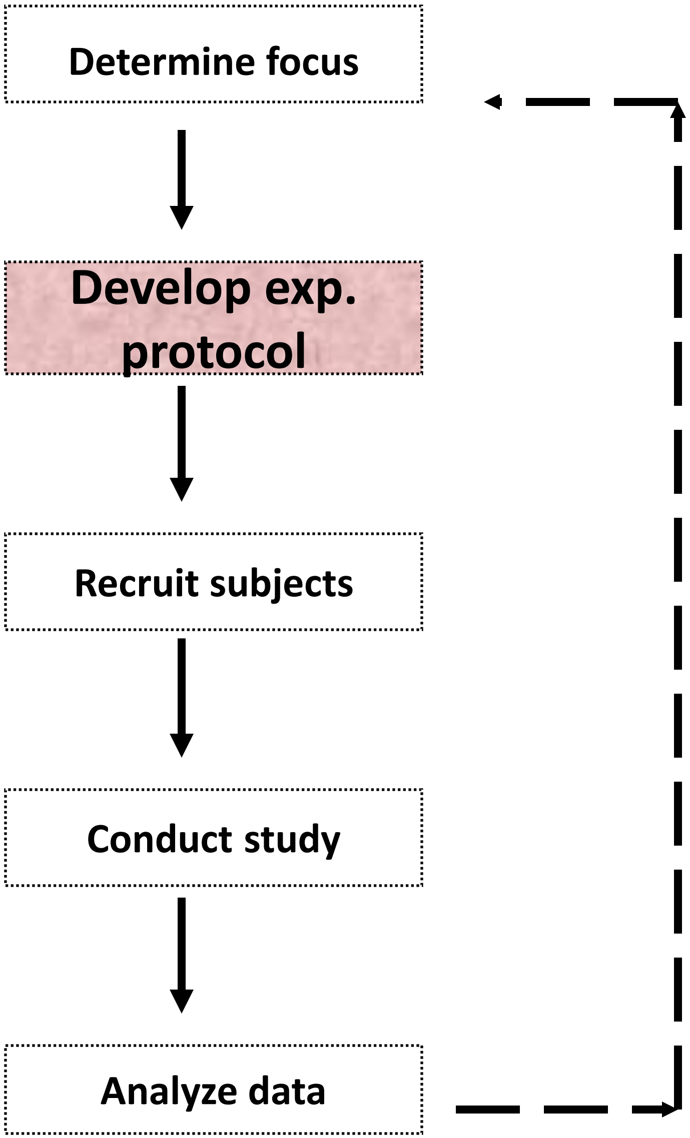
(Burdea, Coiffet, 2003)

Human factors focus

- What is the problem?
  (e.g. People get headaches)
- Determine the hypothesis and variables
  (e.g. Faster graphics is better)
- Establish type of study
  (usability, sociological, etc.)
- What kind of evaluation?
- …



Experimental protocol



- What tasks are done during one trial?
- How many trials are repeated per session?
- How many sessions per day,

  and how many days for the study?
- How many subjects in each group?
- What pre and post-trial measurements?
- What variables are measured?
- What questions on the subjective evaluation

  form?

Participants recruitment

- Sufficient number of subjects need to be enlisted in the study to have statistical significance
- Place advertisements, send targeted emails, web posting, go to support/focus groups, friends, etc.
- Subjects are screened for unsuitability to study
- Subjects sign consent form
- Subjects are assigned a code to protect their identity
- Subjects sign release for use of data in research
- Subjects may get “exposure” to technology

Data Collection

- Data recorded online can be played back during task debriefing and researchers do not have to be co-located with the subjects (remote measurements)

- Measurements need to be:
  - ***sensitive*** (to distinguish between novice and expert users)
  - ***reliable*** (repeatable and consistent)
  - ***valid*** (truthful)

- Latencies and sensor noise adversely affect these requirements

Data Analysis

Experiments store different variables, depending on the type of test:

task completion time – time needed to finish the tasks

task error rate – number or percentage of errors done during a trial

task learning – a decrease in error rate, or completion time over several trials

Statistical analysis used to analyze data and determine if statistical difference exists between trials or conditions

Usability Engineering

- A subclass of human factors research to determine the ease (or difficulty) of use of a given product

- It differs from general-purpose VR human factors studies which are more theoretical in nature

- Usability studies are product-oriented and part of the product development cycle

- There are no clear standards for VR/AR, as this is an area of active research

Controlled experiments

The “work horse” of science ...

Important issues to consider:

- Hypothesis
- Variables (input or independent; output or dependent)
- Secondary variables
- Experimental design (within groups; between groups)
- Participants (number, profile)
- Experimental protocol
- Statistics

Controlled experiment:

Define an hypothesis

Define the input, output and secondary variables

Define experimental design

Select the participants

Prepare all the documentation:

- list of tasks and perceived difficulty
- final questionnaire
- list of tasks for the observer to take notes

To the user

To the observer

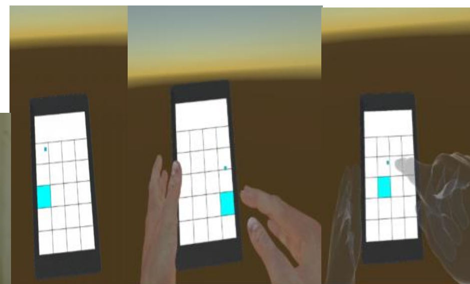
Run a pilot test

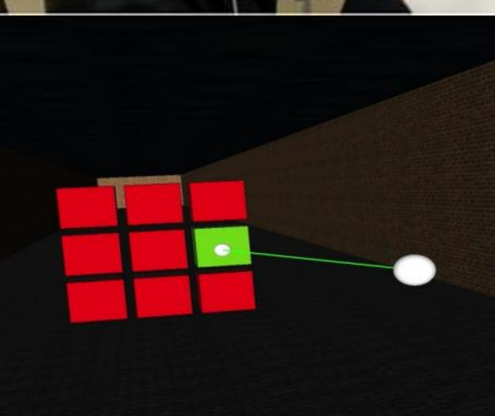
Take care of the logistics

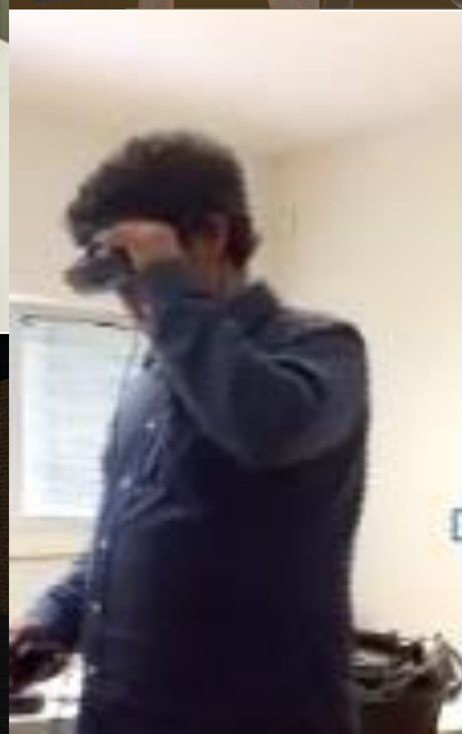
Examples of controlled experiments (made in UA):

comparing:

- 3D selection techniques (in na immersive VE using a controller)
- 3D manipulation techniques (using gestures and a large display)
- different hand avatars (in a Immersive VE using a tablet as input)







Details at:

Danilo Souza, Paulo Dias, Beatriz Sousa Santos. "Choosing a Selection Technique for a Virtual Environment". *Virtual, Augmented and Mixed Reality. Designing and Developing Virtual and Augmented Environments*, Lecture Notes in Computer Science, Volume 8525, 2014, pp 215-225 http://link.springer.com/chapter/10.1007%2F978-3-319-07458-0_21

Paulo Dias, João Parracho, João Cardoso, Beatriz Quintino Ferreira, Beatriz Sousa Santos, "Developing and evaluating gestural virtual environment navigation methods for large displays". *Distributed, Ambient, and Pervasive Interactions, N. Streitz and P. Markopoulos (Eds.), DAPI 2015*,LNCS 9189, pp. 141– 151 http://link.springer.com/chapter/10.1007%2F978-3-319-20804-6_13

Comparing two 3D methods to navigate in VEs using gestures and a large display

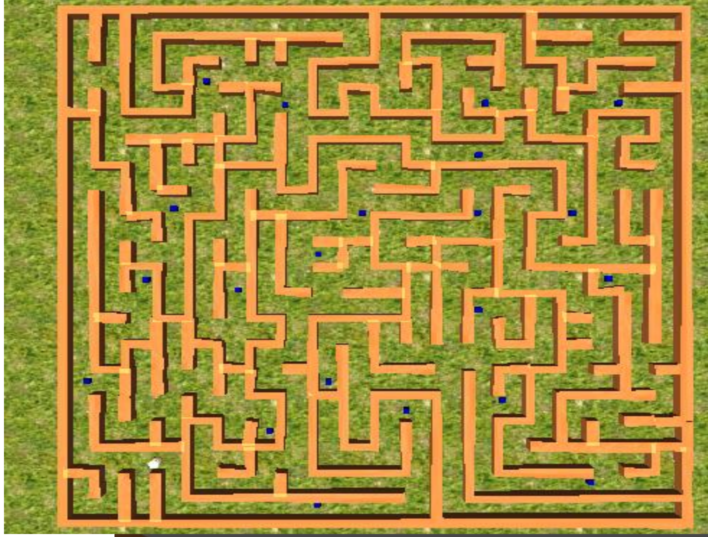
Methods:
- Bike
- Free hand

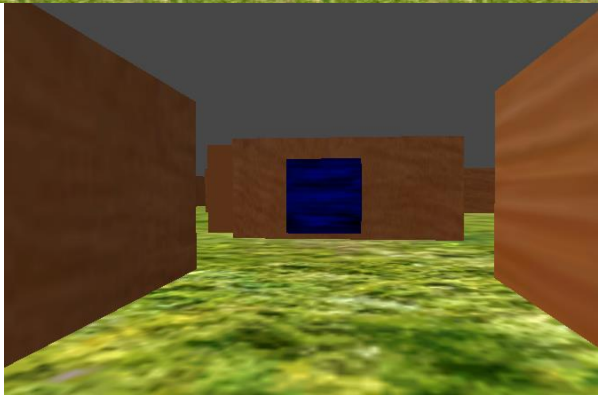
- **Null Hypothesis**: both methods are equally usable in the used conditions
- **Input variable**: navigation method (2 levels: 2 methods)
- **Output variables**: performance and opinion
- **Participants**: 17 volunteers
- **Experimental design**: within-groups (all participants used both methods)
- **Data Analysis:** Exploratory Data Analysis + parametric and non-parametric tests

Bike method

Freehand method

Experimental protocol

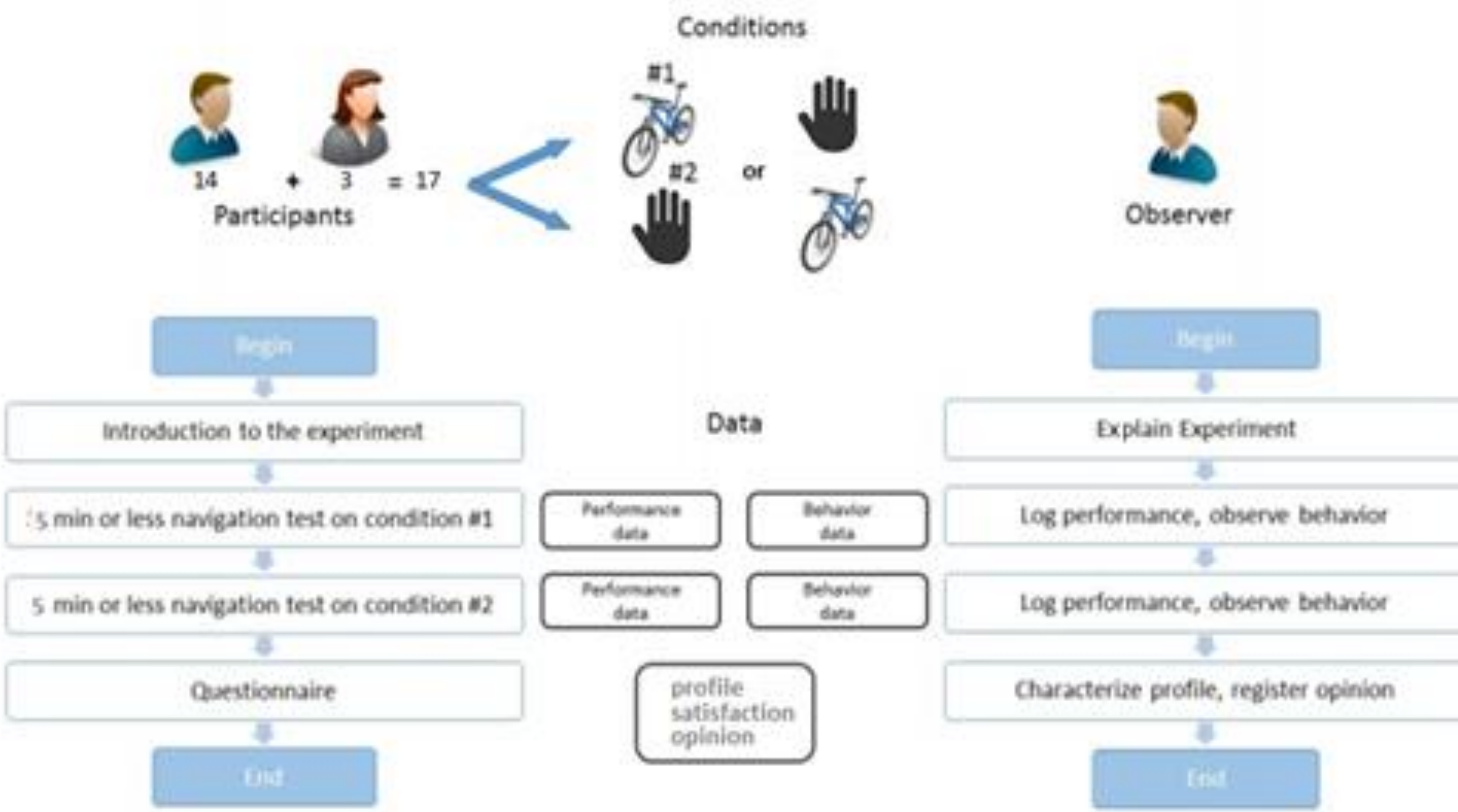




- Brief explanation of the methods
- Training cycle before each method
- Performance measures logged by the system:
  - Number of collisions with the walls
  - Distance
  - Velocity
  - Number of objects caught
- Users' satisfaction and opinion obtained through questionnaire
- Half of the participants started by each method

(to counterbalence for possible learning effects)

Experimental protocol

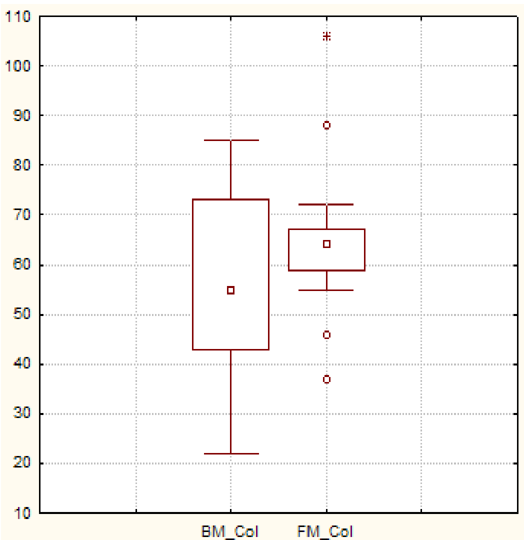


Results: performance variables

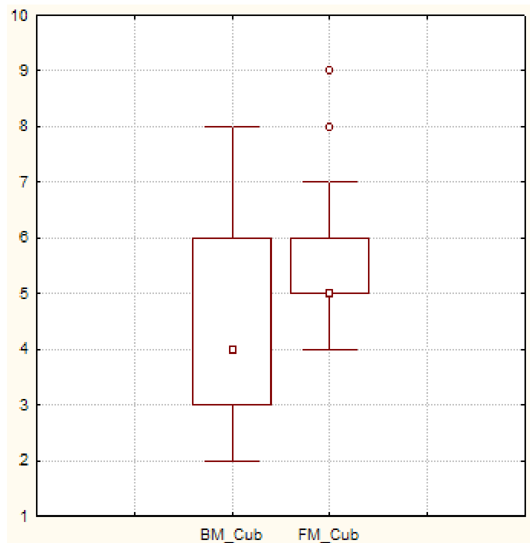
	Bike	Freehand
Speed (average)	1,13	1,49
Distance (average)	337,6	447,3
Collisions (median)	55	64
Boxes (median)	4	4

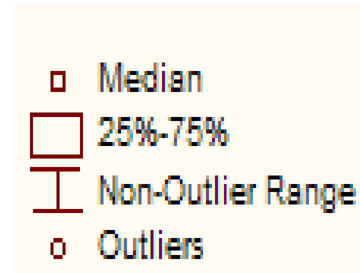
Boxplots of the performance variables

Number of collisions

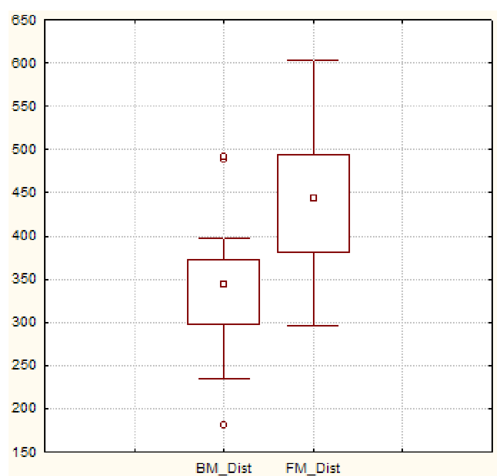


Number of objects caught

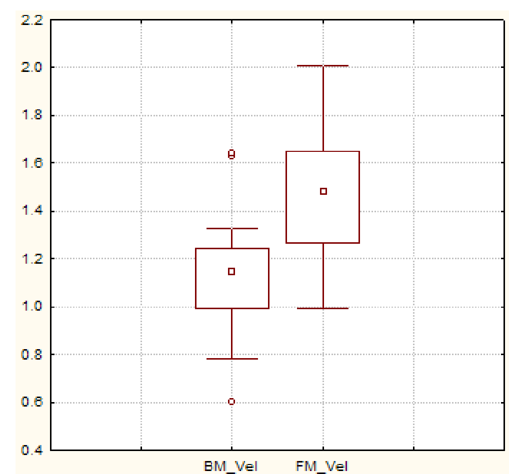




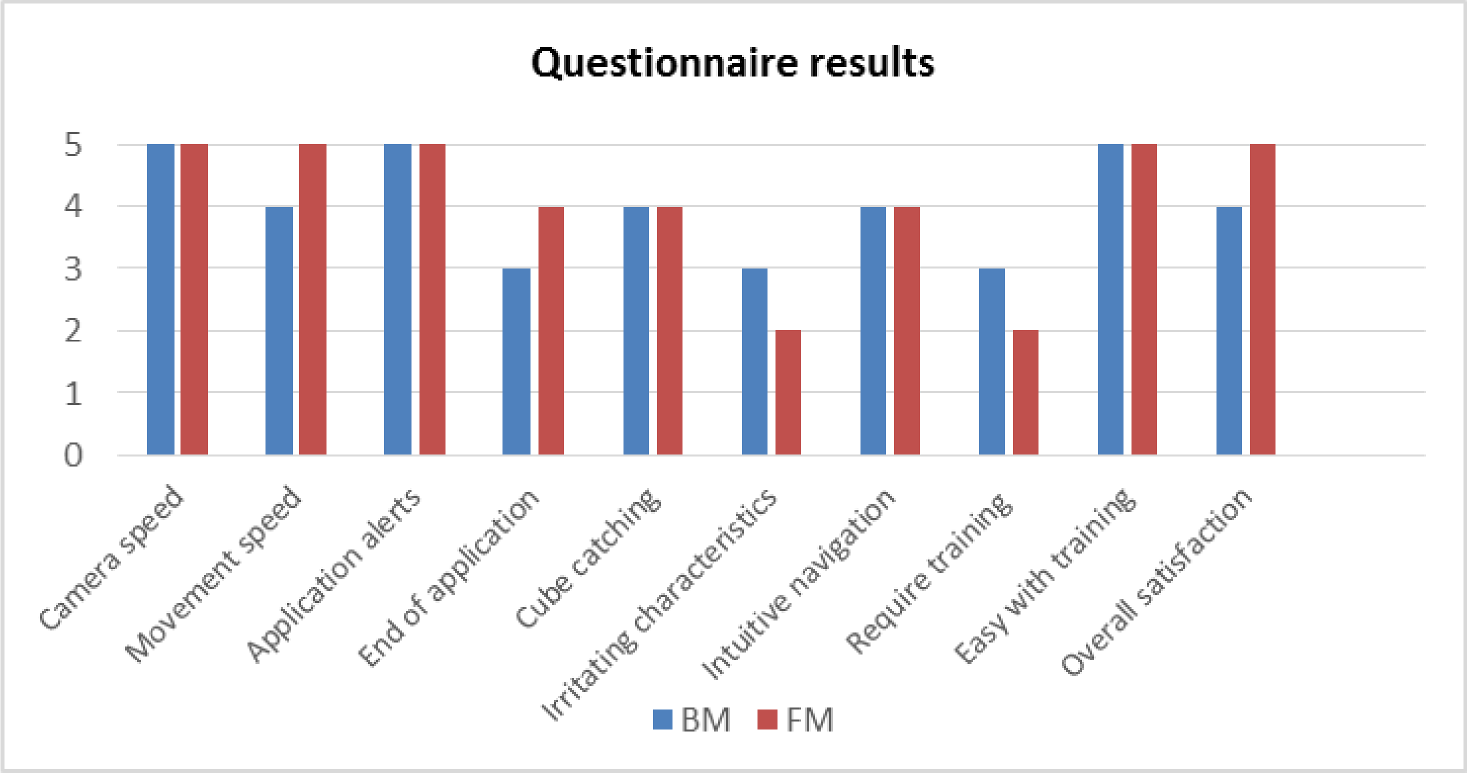
Distance



Velocty



The equallity of all variables, except n. of collisions, was statistically rejected suggesting that **users have a better performance while using Free Hand** than Bike



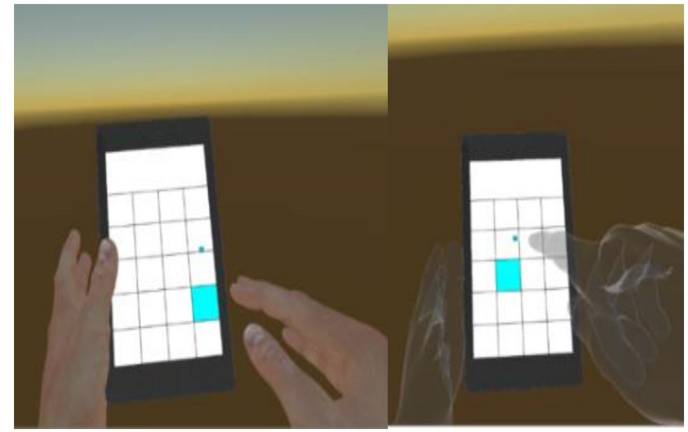
- Results suggest that the Free Hand mode was preferred by in many characteristics

- Tests confirm that some characteristics of both methods are significantly different: “Free Hand” is better than “Bike” in those characteristics

Paulo Dias, João Parracho, João Cardoso, Beatriz Quintino Ferreira, Beatriz Sousa Santos, “Developing and evaluating gestural virtual environment navigation methods for large displays”. *Distributed, Ambient, and Pervasive Interactions, N. Streitz and P. Markopoulos (Eds.), DAPI 2015*,LNCS 9189, pp. 141– 151
http://link.springer.com/chapter/10.1007%2F978-3-319-20804-6_13

Studying the effect of hand-avatars in a immersive VE using a tablet as input device for a selection task

(latest experiment)



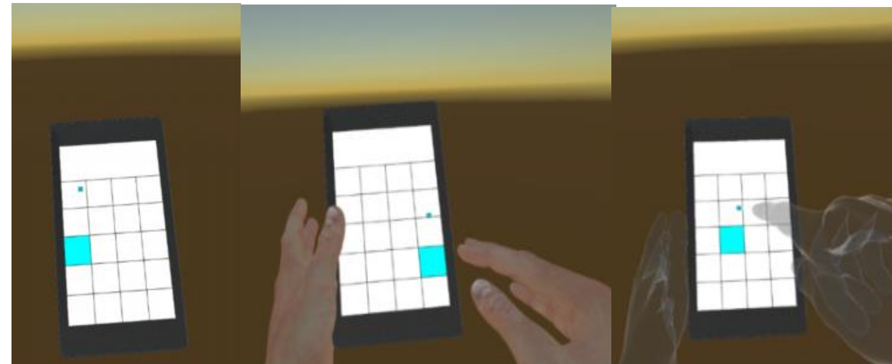
Motivation

- Mobile devices have already been used as input to perform interactions in VEs
- Literature suggest their usage as input devices is viable and presents benefits
- The effect of using avatars in this situation is still an open issue

Studying the effect of hand-avatars in a immersive VE using a tablet as input device for a selection task

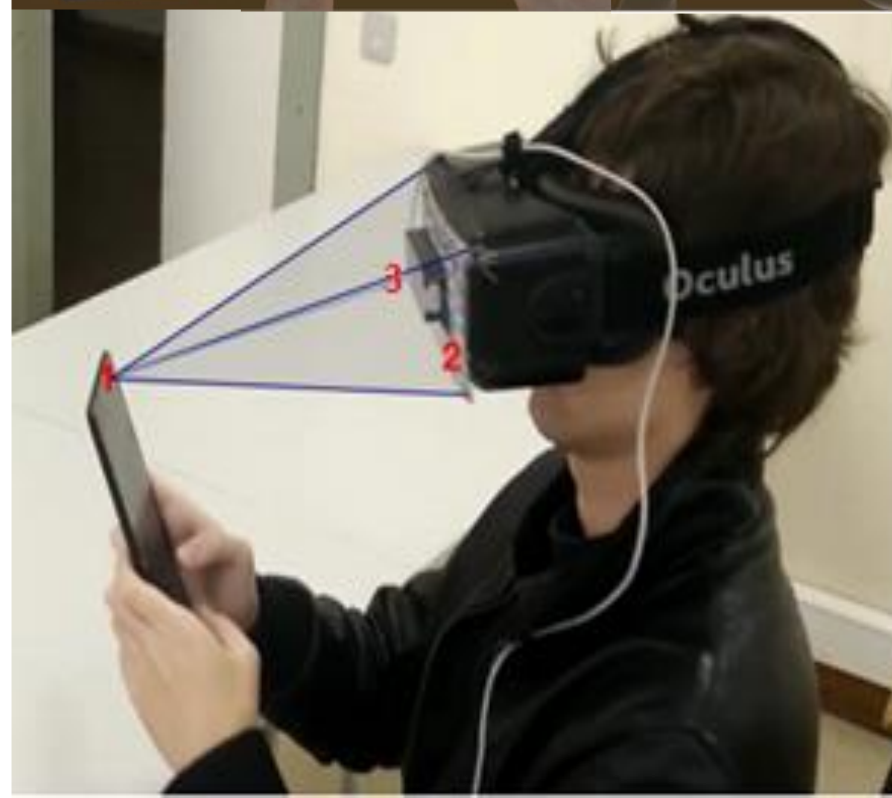
- **Task:**

- Selecting as fast as possible a highlighted button from a group of 25 buttons on the virtual tablet screen



- **Experimental Setup:**

- Oculus + Tablet + Leap Motion
- Unity + Vuforia
- Tablet front camera (1) tracking
- AR marker on the Oculus (2)
- Leap Motion (3) mounted on Oculus
  providing hands tracking



- **Hypothesis:**

- All conditions concerning hand avatar have similar usability (performance and opinion)

- **Independent variable (3 experimental conditions):**

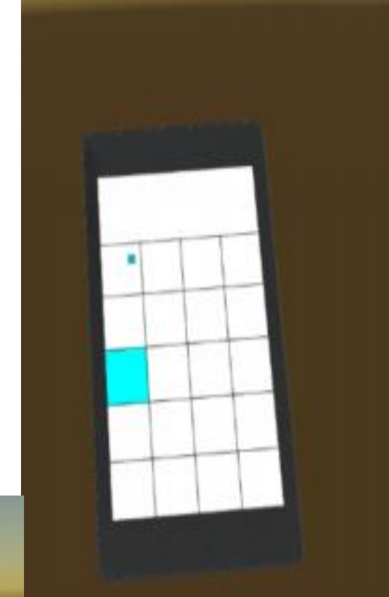
- No hand avatar
- Realistic hand avatar
- Translucent hand avatar

- **Dependent variables (performance and opinion):**

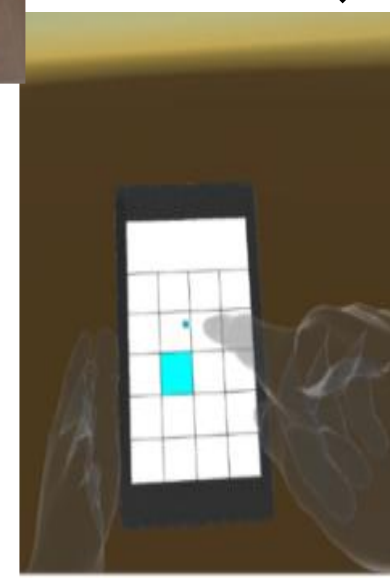
- Task completion time (seconds)
- Selection errors: number of incorrect buttons pressed

- **Experimental design: within-groups**

(all participants used the three experimental conditions in different order to compensate for learning)



No avatar ⇧
⇦ Realistic
Translucent ⇩



- **Experimental procedure:**

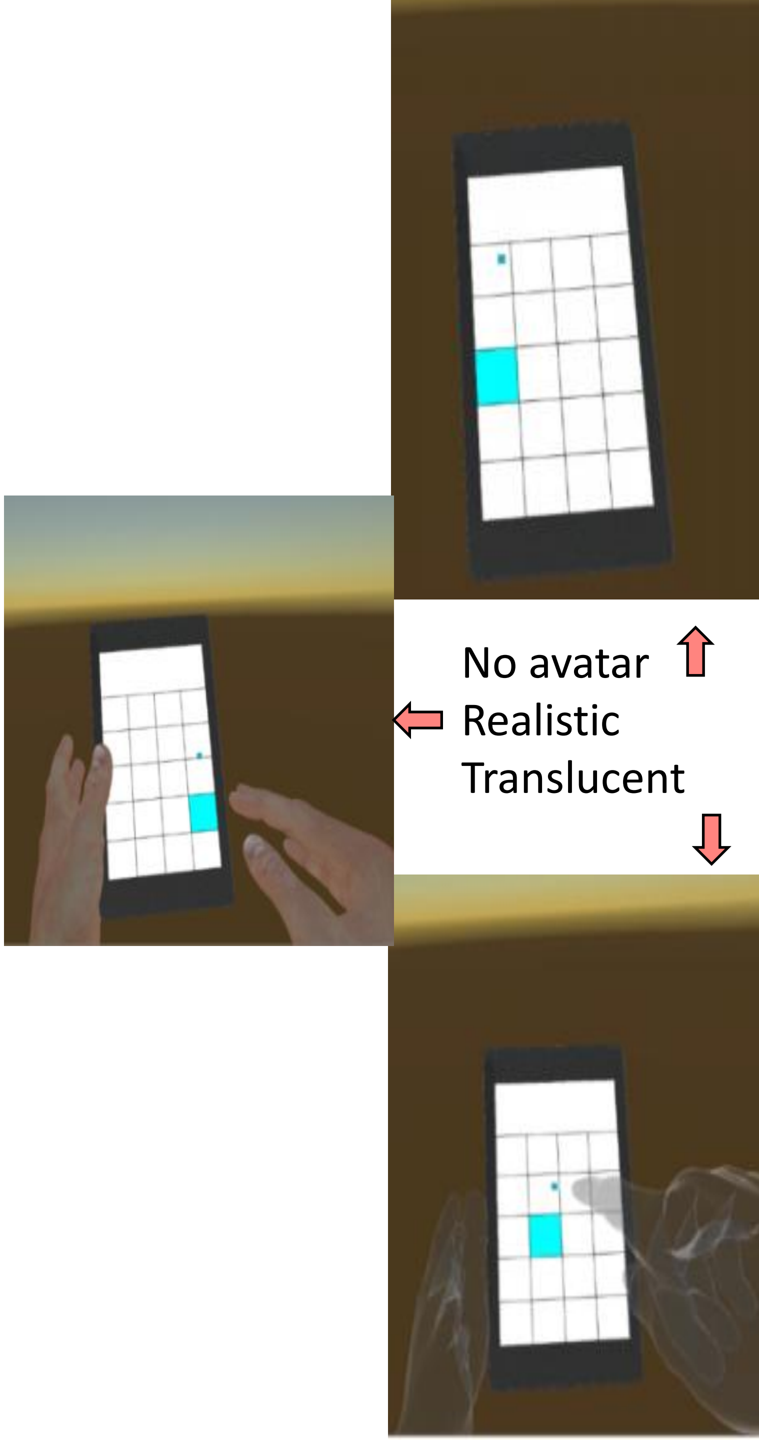
- Briefing about the experiment
- Familiarization with the setup
- Selecting 25 buttons
- Using three experimental conditions
- Questionnaire

- **Participants:**

- 55 students performed the tasks
- 52 answered the questionnaire
  (4 females; aged 19 to 28 years)
  (30 had never used VR before)

- **Statistical analysis:**

- Non parametric tests (Friedman) due to:
  - non normality of time and error data
  - ordinal nature of questionnaire data



Questionnaire

Hand representation experiment questionnaire

1. **User ID:** ____________
2. **What is your age?** ______
3. **What is your gender?** ☐ Female ☐ Male
4. **Have you used Virtual Reality before?**
   - ☐ Yes
   - ☐ No
5. **Dominant hand:**
   - ☐ Right
   - ☐ Left
6. **How often do you use smartphone/tablet devices:**

   Never ☐—☐—☐—☐—☐ Regularly
7. **Please rank the three modes by preference:**

   No Hands (1) ______

   Realistic Hands (2) ______

   Transparent Hands (3) ______
8. **Explain why the mode [1/2/3] was your favorite:**

   ____

   ____

   ____

   ____
9. **How much physical fatigue did you experience in your arms while interacting with the environment?**

   None ☐—☐—☐—☐—☐ Extreme

No Hand Representation

10. **The task was (1 difficult, 5 easy) to perform.**

    Difficult ☐—☐—☐—☐—☐ Easy
11. **I felt like I was able to interact with the tablet the way I wanted to.**

    Strongly Disagree ☐—☐—☐—☐—☐ Strongly Agree

Realistic Hand Representation

12. **The task was (1 difficult, 5 easy) to perform.**

    Difficult ☐—☐—☐—☐—☐ Easy
13. **I felt like I was able to interact with the tablet the way I wanted to.**

    Strongly Disagree ☐—☐—☐—☐—☐ Strongly Agree
14. **I felt as if the virtual representation of the hand moved just like I wanted it to.**

    Strongly Disagree ☐—☐—☐—☐—☐ Strongly Agree

Transparent Hand Representation

15. **The task was (1 difficult, 5 easy) to perform.**

    Difficult ☐—☐—☐—☐—☐ Easy
16. **I felt like I was able to interact with the tablet the way I wanted to.**

    Strongly Disagree ☐—☐—☐—☐—☐ Strongly Agree
17. **I felt as if the virtual representation of the hand moved just like I wanted it to.**

    Strongly Disagree ☐—☐—☐—☐—☐ Strongly Agree

18. **Comments and/or suggestions about the equipment or the environment:**

    ____

    ____

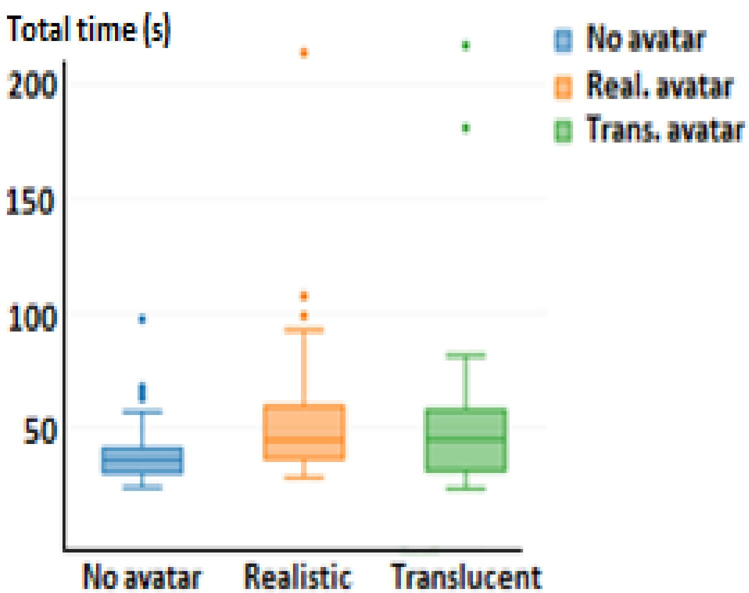
    ____

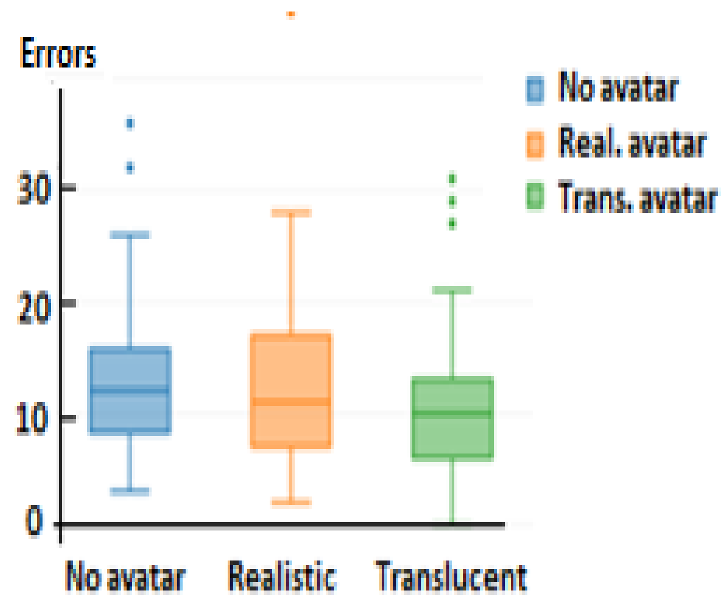
    ____

Main results concerning performance

Total task time and errors:

- Participants were faster but made more errors when there was no avatar
- Translucent avatar was the condition with less errors
- Friedman tests rejected the equality hypothesis -> differences are significant





Main results concerning preference and opinion:
(ordinal data -> median values)

Question (scale)	No avatar	Real. avatar	Trans. avatar
(number of 1st) **Q1**- Preference (number of 2nd) (number of 3rd)	18 16 18	9 25 18	25 18 9
Q2- The task was (1 difficult … 5 easy) to perform	3.5	3	4
Q3-I felt like I was able to interact with the tablet the way I wanted to (1 Strongly Disagree… 5 Strongly Agree)	3	3	3
Q4- I felt as if the hand avatar moved just like I wanted it to (1 Strongly Disagree … 5 Strongly Agree)	NA	3	3.5

All differences were statistically significant (ordinal data -> Friedman test)

Conclusions of the study

The results of our study suggest that:

- An avatar may increase usability
- It does not need to be very realistic
  (in line with previous work regarding avatars in immersive VEs)
- The hands-representation provides feedback; however:
  - it may occlude the virtual screen,
  - and become distracting as a consequence of tracking inaccuracies
- The translucent avatar provides feedback not occluding
- Accurate tracking is crucial

Future work

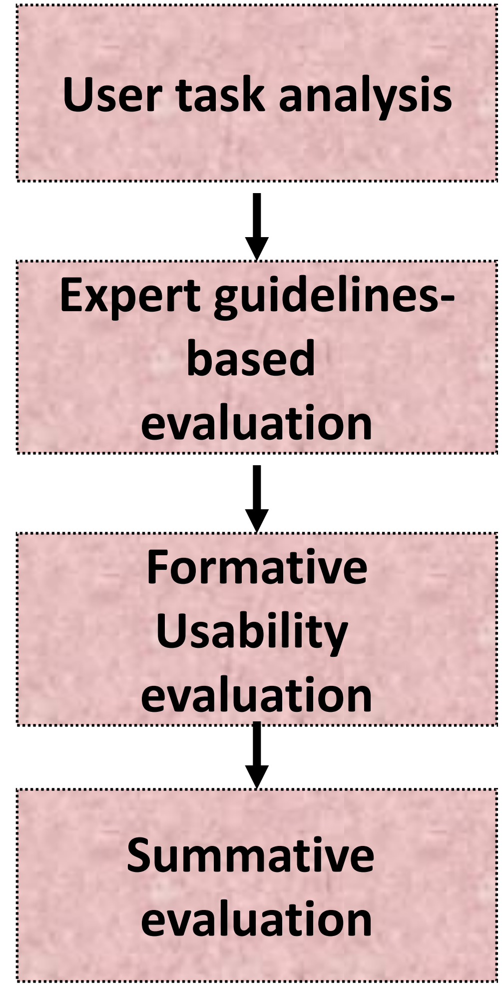
- Improve tracking
- Continue to explore the influence of the hands avatar, e.g.:
  - with other types of mobile devices,
  - to perform different tasks in VEs,
  - using other non-realistic (e.g. robot or cartoon-like) avatars

Usability Engineering

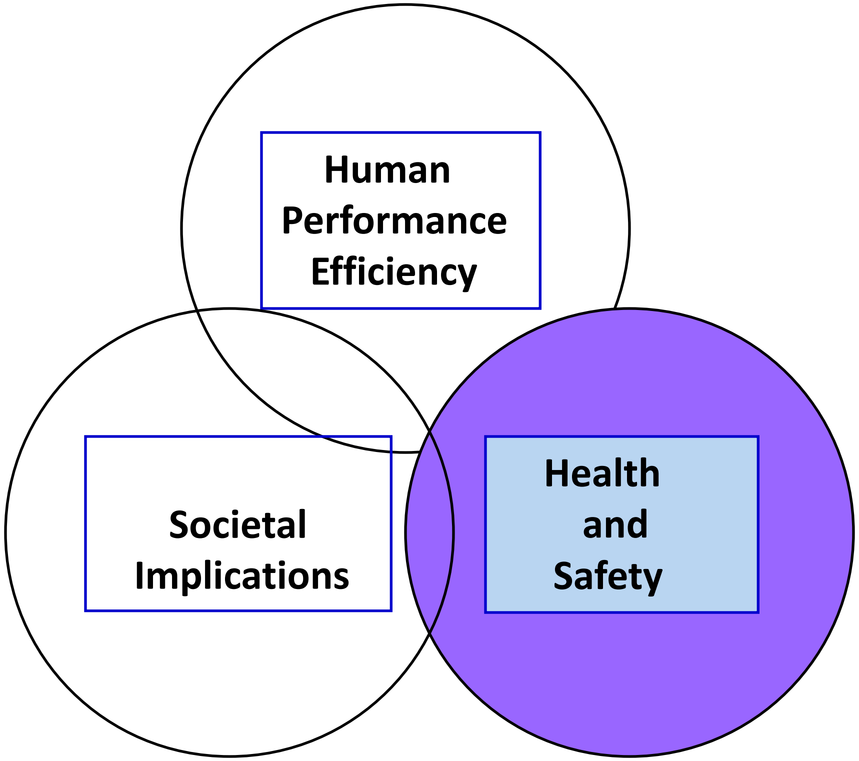
“engineering approach”:

Aimed at detecting problems and fixing them

The methodology consists of four stages



(Burdea, Coiffet, 2003)



(Stanney et al., 1998)

Effects of VR on users

Direct effects - involve energy transfer at the tissue level and are potentially hazardous

Indirect effects - are neurological, psychological, sociological, or cyber sickness and affect the user at a higher functional level

Direct Effects of VR Simulations on Users

Affect mainly the user's visual system, but also the auditory, skin and musculoskeletal systems

Effects on the skin and muscles are due to haptic feedback at too high a level

(Burdea, 2005)

Direct Effects of VR on Users

- Possible adverse effects on the visual system:

  - when the user is subjected to high-intensity lights directed at his/her eyes

  - an "absence" state due to pulsing lights at low frequency (1-10 Hz);

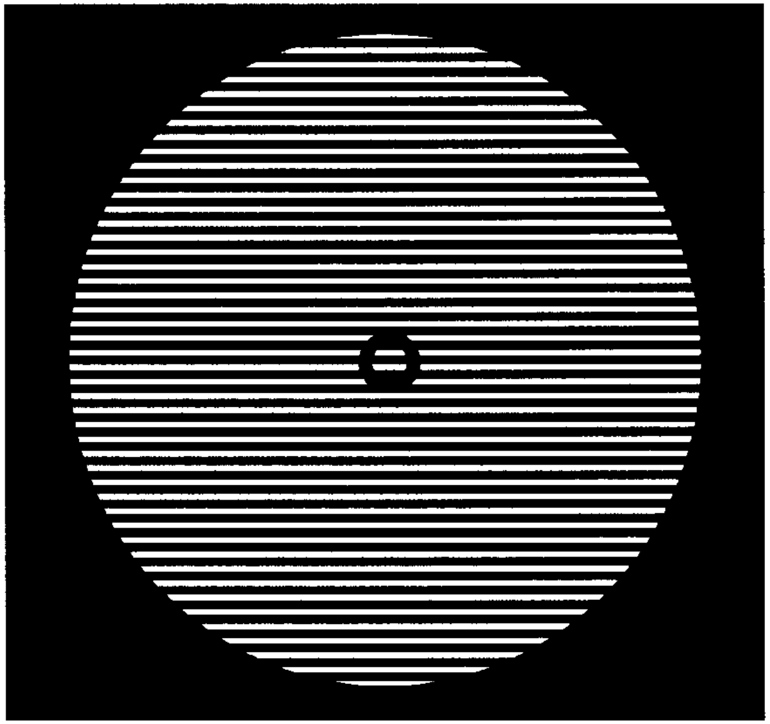
  - bright lights coupled with loud pulsing sounds can induce migraines

- Direct effects on the auditory system are due to noise that has too high a level (115 dB after more than 15 minutes);

- Specific spatial and temporal patterns produce visual stress and may cause epileptic seizures in predisposed individuals

- The most powerful combinations are striped patterns:
  - ~3 cycles per degree
  - ~20Hz

Warning! This pattern can cause seizures in some individuals. If it causes you to feel ill effects, avoid looking at it.



(Ware, 2012)

Cyber sickness

- User safety concerns relate primarily to cyber sickness, but also to body harm when haptic feedback is provided;
- Cyber sickness is a form of motion sickness present when users interact with virtual environments
- Cyber sickness has three forms:
  - Nausea and (in severe cases) vomiting
  - Eye strain (oculomotor disturbances);
  - Disorientation, postural instability (ataxia) and vertigo.
- Flight simulators have an incidence of up to 60% of users experiencing simulation sickness (military pilots – elite group)
- Studies suggest regular VR users are effected more (up to 95%)

Oculus and cyber sickness

Oculus "… seems worried that bad experiences with competing products could sour the entire market on virtual reality"

Oculus "… currently seeking an exceptional researcher to perform cutting-edge research into perception, visual and/or vestibular mechanisms, and human factors"

http://arstechnica.com/gaming/2014/11/oculus-to-competitors-dont-release-bad-vr-headsets/

System characteristics influencing cyber sickness

- When VR technology has problems, it can induce simulation sickness:
  - **System lag** that produces large time delays between user motion and simulation (graphics) response
  - Lag is influenced by tracking sampling speed, computer power, communication speed, and software optimization
  - **Tracker errors** induce a miss-match between user motion and avatar motion in VR
  - **Poor resolution** and small **FOV** are not acceptable. Large FOVs can also be problematic

Influence of user’s characteristics on cyber sickness

The **user characteristics** can play an important role in cyber sickness:

- Age that induce a miss-match between user motion and avatar motion in VR

- Sick users, including those on medication are more prone to cyber sickness

- Female users who are pregnant are more prone to simulation sickness

- Some people are more prone to motion sickness than others. Pilots are screened for such

Neural Conflict

Occurs when simulation and body sensorial feedbacks **conflict**:

Type I: two simultaneous conflicting signals (A and B):

e.g. Information from a moving platform does not coincide with the motion of waves seen on an HMD

Type II: Signal A is present and B is not:

e.g. looking at a roller coaster simulation, without a motion platform;

Type III: Signal B is present and signal A is not:

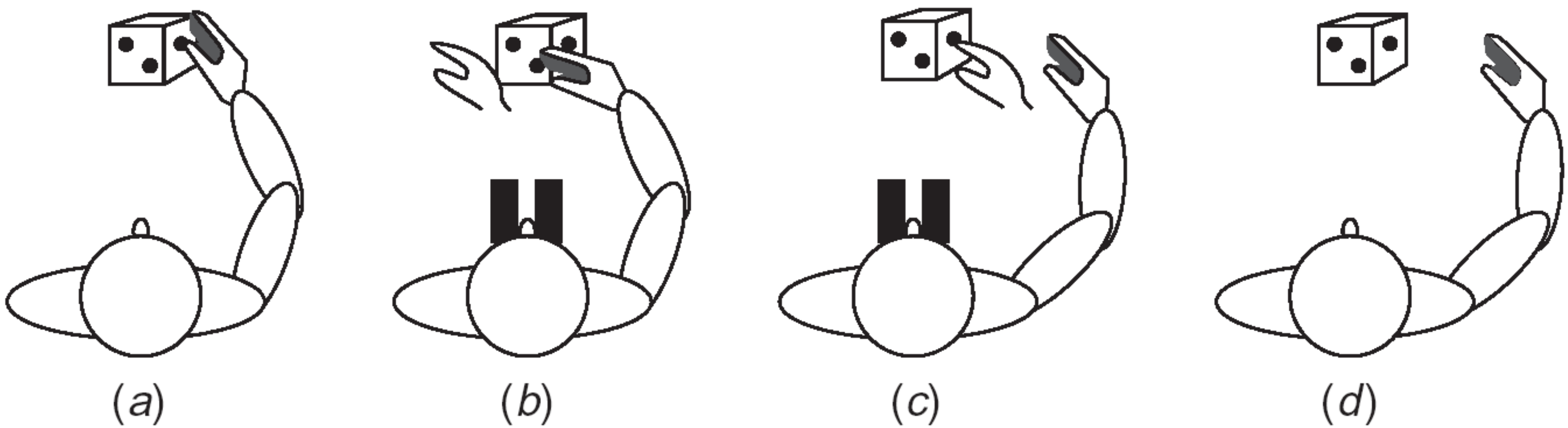
e.g. motion platform moves, but visual feedback is unchanged

Neural conflict induced cyber sickness **grows with the duration of immersion**

Adaptation

"Adaptation to sensory rearrangement is a semi-permanent change of perception and/or perceptual-motor coordination that serves to reduce or eliminate a registered discrepancy between, or within, sensory modalities, or the errors in behavior induced by this discrepancy." (Burdea and Coiffet., 2003)

Adaptation



Hand-eye coordination adaptation:
a) before VR exposure
b) initial mapping through artificial offset
c) adapted grasping
d) aftereffects

(Burdea and Coiffet., 2003)

Aftereffects

- Induced through adaptation to neural conflicts
- Occur after the simulation session ended and can last for hours or days
- While adaptation is good, aftereffects may be bad. Forms of aftereffects are:

  - Flashbacks
  - Sensation of “self motion”
  - Headache and head spinning
  - Diminished (remapped) hand-eye coordination
  - Vestibular disturbances

Guidelines for Proper VR Usage

Meant to minimize the onset and severity of cyber sickness; largely qualitative

During system development

- Minimize latencies and make them stable;
- Avoid pulsating light sources of low frequency;
- Reduce spatial frequency content in large displays;
- Assure HMDs have properly aligned optics and sufficient resolution;
- Reduce intensity and duration of loud 3-D sound sources;
- Use accurate trackers and remove sources of interference;
- Assure consistency in multimodal displays.

Before Immersion

- Screen users whenever possible for susceptibility to cybersickness;
- Place warning labels and educate users of potential adverse effects from VR exposure;
- Limit exposure to users that are free from drugs and alcohol consumption;
- Encourage users to be well rested before exposure;
- Discourage VR usage by those with cold, flu, binocular anomalies, susceptibility to migraines or photic seizures.

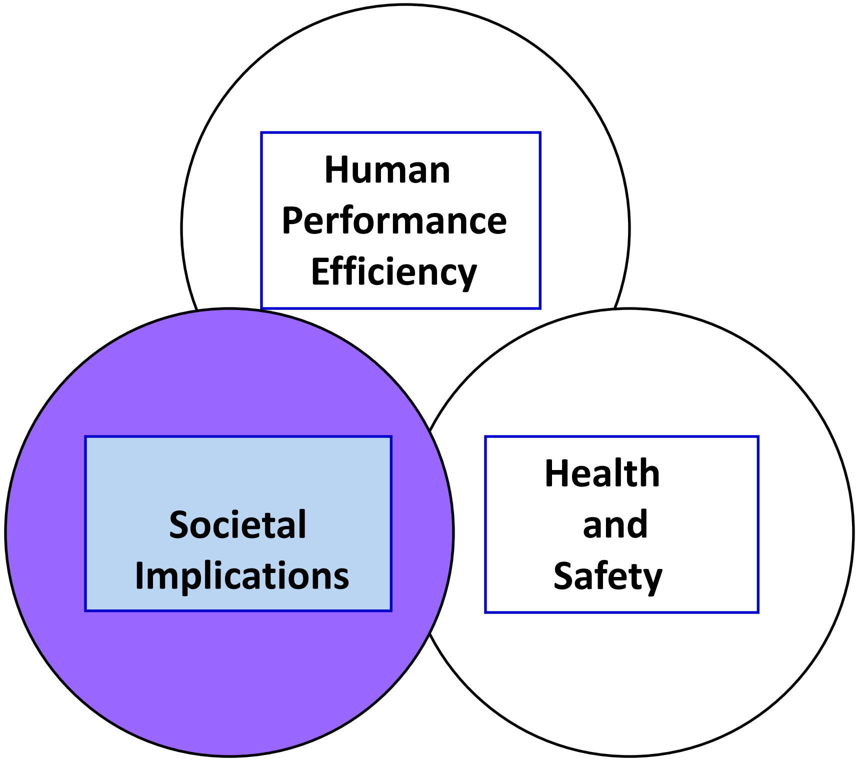
Guidelines for Proper VR Usage

During Immersion

- Provide proper airflow and comfortable air temperature (preferably below 70° F);
- Ensure equipment fits users comfortably through necessary adjustments;
- Minimize initial exposure time for strong stimuli (10 minutes or less);
- Monitor users for signs of cybersickness;
- Inform users they can/should discontinue the simulation if they so wish.

After Immersion

- Measure user hand-eye coordination and postural stability;
- Introduce a time period immediately after VR exposure in which users are not allowed to perform high-risk activities (driving, piloting, biking, etc.);
- Possibly re-immerse users in a re-adaptation simulation;
- If necessary, follow up with users to monitor prolonged aftereffects;
- Introduce intersession periods of three to five days.



(Stanney et al., 1998)

Social implications of VR

Negative potential after-effects of VR:

Violence of VR games: additive response could result

desensitization to real-world violence

Increased individual isolation

Reduction in health-care and education quality

Recent example:

Particpants in a Pokémon Go crawl in San Francisco on July 20, 2016. LAURA MORTON

https://www.wired.com/2016/08/ethics-ar-pokemon-go/

Main bibliography

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The author of these slides is greteful to:

- Burdea and Coiffet for making available the slides supporting their book
- All colleagues and students that have contributed in any way