Hannes
Kaufmann

Evaluations & Human Factors in VR/AR

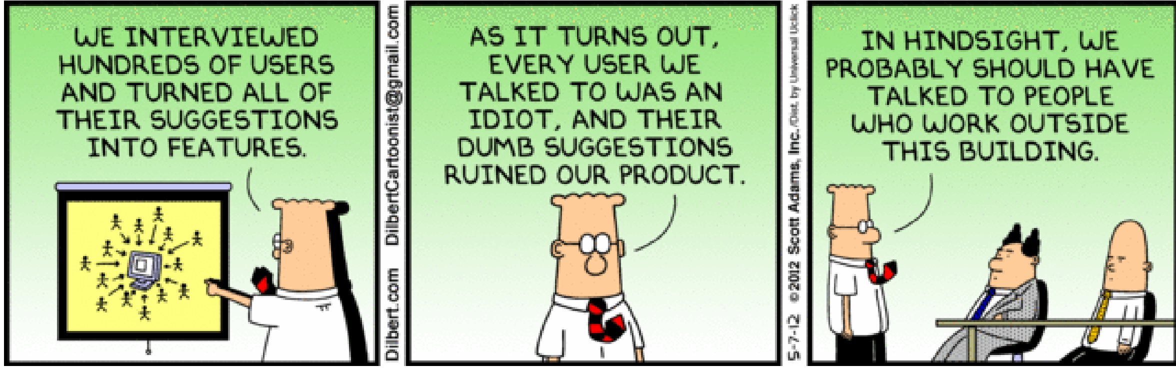
Hannes Kaufmann

Interactive Media Systems Group (IMS)

Institute of Visual Computing & Human-Centered Technology

Based on material by George Viorel Popescu, H. Rex Hartson, Deborah Hix, Skip Rizzo and Frederic Vexo

Overview



- Evaluations
  - Evaluation Techniques
  - Examples
  - Usability Engineering

Human Factors:

- Health and Safety
  - Cybersickness (Simulator Sickness)
  - Ergonomics
- Social Aspects
  - Presence

Evaluation – Why?

- Analysis, Assessment and Testing

- Identify usability problems -> change design
- Iterative process: Design <-> Evaluation
- Ideally leads to *design guidelines*
- Even better: Performance models (for UIs)
  - E.g. Fitt‘s law: How quickly can a user position a pointer over a target area, based on the distance to the target

Topics

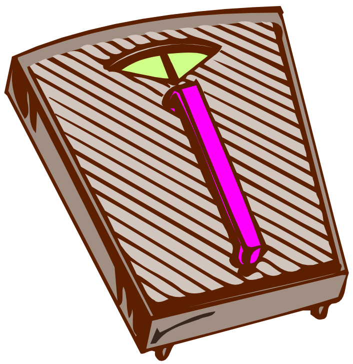
- Generating and collecting data
- Quantitative techniques
- Qualitative techniques
- Observational techniques
- Forms, variations, attitudes, tools

Generating and Collecting Data

- Preliminaries with participants
  - Explain protocol to participant, including any compensation
  - Show participant the lab and experimental set-up if they are interested
  - Have participant (or parents in case of students <18) sign informed consent form (and NDA)

Hannes
Kaufmann

Quantitative Techniques



- Collecting quantitative data (to assess usability levels)
  - – Benchmark tasks
    - Measuring time on task, number of errors, movements in space (tracking data) etc.
    - Quantitative measures such as timing can be valuable even with paper prototype, though not very precise
  - – User satisfaction scores

Hannes Kaufmann

Qualitative Techniques

- Collecting qualitative data (to identify usability problems)
  - Verbal protocol taking
    - Participants think aloud, talking while performing tasks
      - Can be intrusive, but effective
      - Some participants not good at talking
      - Evaluator/facilitator sits in room with participant to collect data
    - Can be used for both timed and un-timed tasks
      - Studies show it can be done with minimal effect on performance time
    - Answer questions about what to do with a hint, not a direct answer

Qualitative Techniques

- Collecting qualitative data (to identify usability problems)
  - Critical incident taking
    - *Critical incident*: something that happens while participant is working that has significant effect on task performance, usability or user satisfaction
    - Although participant may indicate a critical incident, it is *responsibility of evaluator* to identify and record critical incidents
    - Critical incidents are indicators of usability problems
    - Very important evaluation data!
    - Later analyze the problem and cause within the interaction design

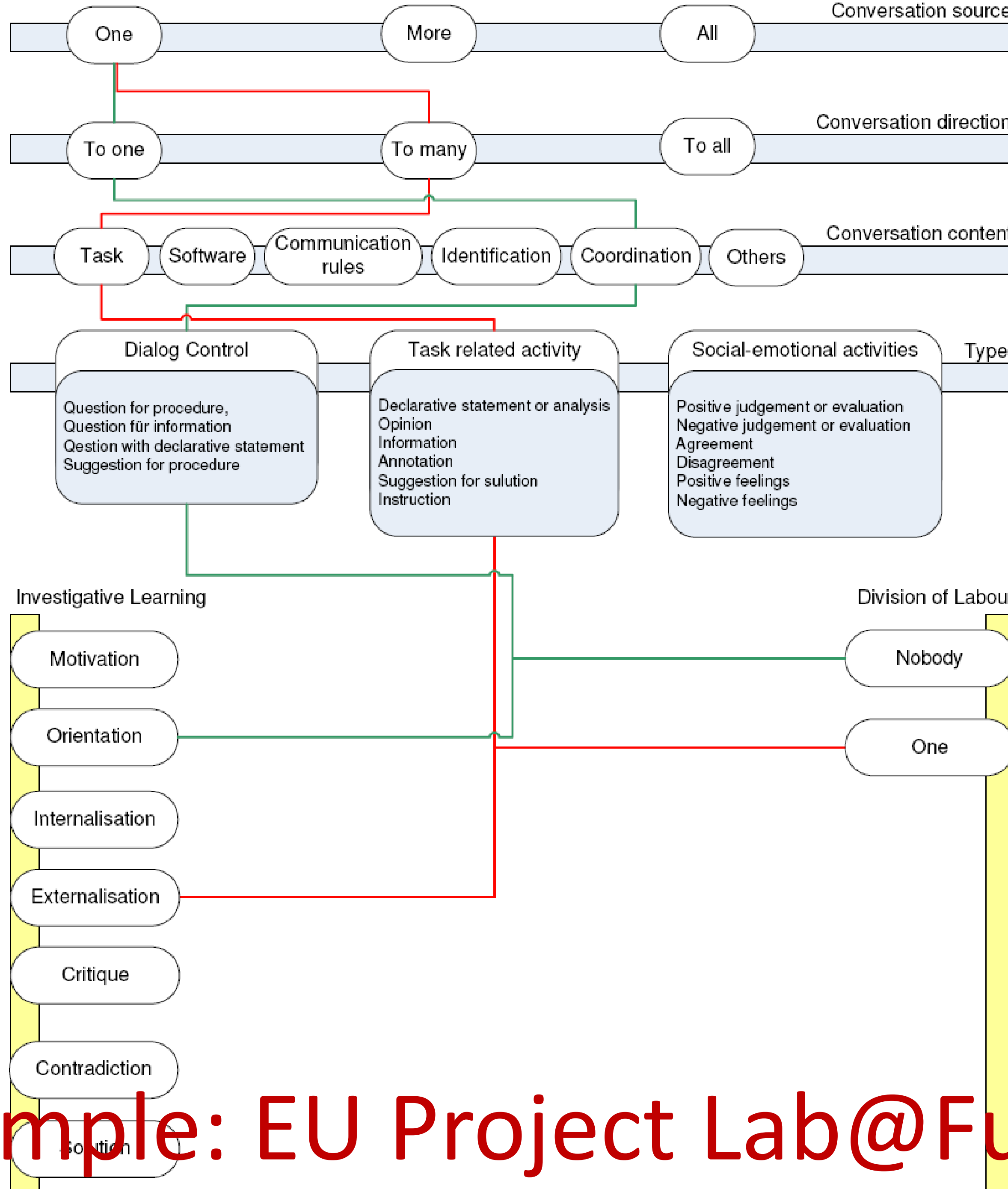
Qualitative Techniques

- Critical incident taking
  - Pay attention to detailed participant behavior – IMPORTANT!
    - It’s easy to miss them! It’s a skill; takes experience
  - Record session if possible if immediate analyzing not possible
  - Example: user doesn’t understand the menu item “Sweep” (in a CAD application)
    - multiple consequences: provide help/feedback, self-explanation
  - Example: user wasn’t sure what the alarm clock icon meant
    - Could have had to do with time of day. Solution: show it “ringing” to emphasize alarm part

Observational Techniques

- Some observational data collection techniques
  - Structured interviews
    - Post-session questioning
    - Typically obtain general information
  - Co-discovery
    - More than one participant, using system together, thinking aloud together
    - Can lead to rich verbal protocol from conversations among participants

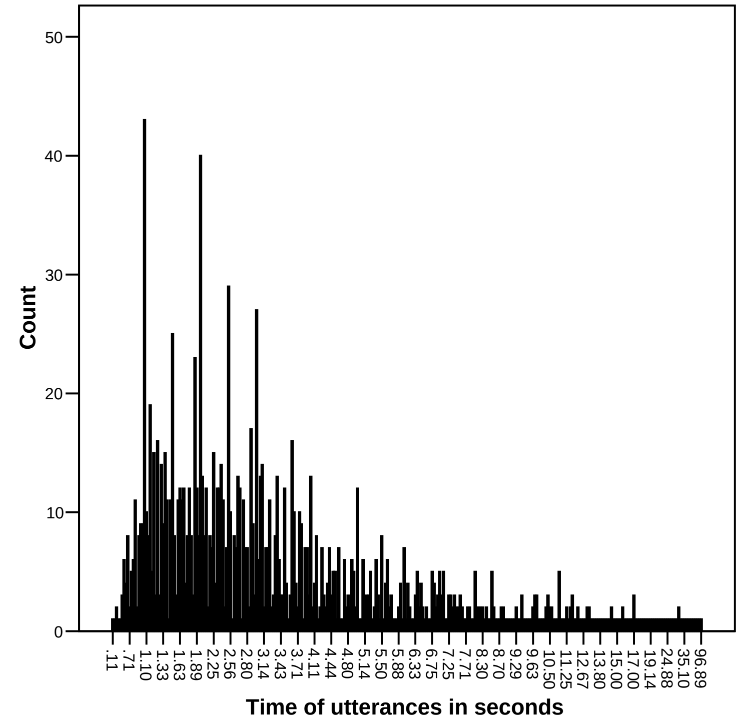
Hannes
Kaufmann

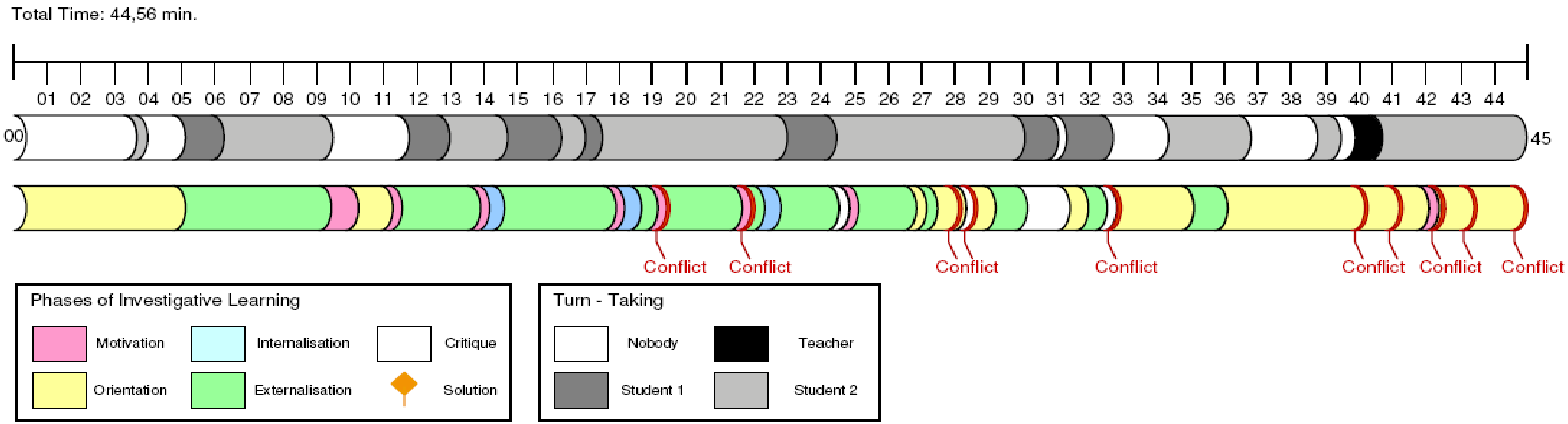


Example: EU Project Lab@Future

Group	Task 1		Task 2	
Group 1	14 min	163 utterances	7 min	94 utterances
Group 2	13 min	98 utterances	16 min	140 utterances
Group 3	>45 min	551 utterances	28 min	368 utterances

Table 58: Analysed utterances per group and tasks





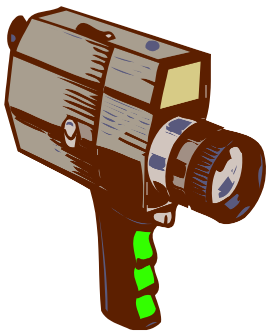
Group 3 Task 1

Observational Techniques

- Some observational data collection techniques
  - Software tools for critical incident recording (e.g., Ideal)
  - Note taking – the primary technique
    - Most important: Real-time notes (e.g., pencil and paper, on-line)
    - Nothing beats this for effective data gathering

Observational Data Collection Techniques

- Audio recording can be useful
  – Effective if used selectively for note taking, if not too distracting
  – Can be used to capture continuous dialogue with participant (more agile than video taping)



- Video taping
  – Used primarily as backup
  – Captures every detail, but tedious to analyze
  – Generally one camera on hands/keyboard/mouse/screen; if a second camera, on user's face
  – Screen action can be captured with tools like Camtasia, Fraps,…(gives high resolution)

Hannes
Kaufmann

Data Collection Forms

- Form for collecting both quantitative and qualitative data during session

DATA COLLECTION FORM

TASK NAME:	**PARTICIPANT ID:** **Date:** **No. of errors:**	**Task start time:** **Task end time:** **Time to perform task:**

Critical Incident Description	**Tape Counter**	**Evaluator's Comments**
1.		
2.		
3.		

Hannes Kaufmann

Example: Lab@Future Evaluation Methods

Levels focused by the evaluation concept	*Methods*
Organizational aspects	• (Open) interviews • Document analysis
Learning outcome	• Expert ratings • Artifact analysis • On-line questionnaire • (Tests)
Learning process	• Observation • On-line questionnaire
Usability	• On-line questionnaire • Usability interview
Technical requirements	• Observation • Workshop

Table 8: Overview of the different levels focused by the evaluation concept and the methods applied for the analysis of each level.

Adopt the Right Attitude

- Evolution of developers' attitude as they watch user evaluating a product

"Stupid user!"

"Let me at him/her!"

"It's his/her (another developer's) fault!"

"I'm mud!"

"Let's fix it!"

Variations

- Variations on the theme
  - Major point: No rules; do what works best in your situation
  - Evaluator sitting with participant (cf. in separate room)
  - Abandon verbal protocol if it doesn't work for a participant
  - Try co-discovery with two participants

Hannes
Kaufmann

Data Collection Tools

- Software tools for critical incident recording
  - Usability engineer uses to capture raw usability data
  - Quantitative: timing, error counts
  - Critical incidents: most important
    - Tags with video (Camtasia) clip for later review
    - Gathers full critical incident records in database
    - Shares database with other UE tools
    - Feeds critical incident descriptions to usability problem analysis tools

Usability Engineering

Hannes Kaufmann

- ✓ A subclass of human factors research to determine the ease (or difficulty) of use of a given product;
- ✓ Usability studies are product-oriented and part of the product development cycle.
- ✓ There are no clear standards, because this is an area of active research.

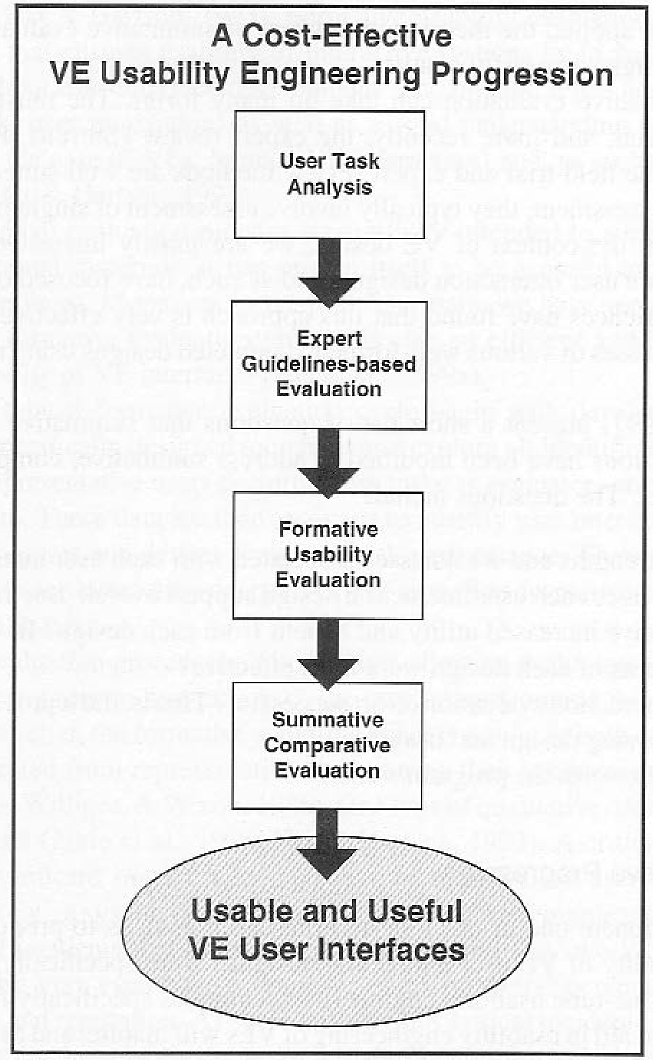


FIG. 34.1. A cost-effective progression of usability engineering methods.

Hannes
Kaufmann

Usability Engineering

✓The methodology consists of four stages:

User task analysis

↓

Expert guidelines-based evaluation

↓

Formative Usability evaluation

↓

Summative evaluation

Usability Engineering

- First stage:
  Define the task and list user's actions and system resources needed to do it!
  - Identifies interrelationships (dependencies and order sequences) and information flow during the task
- Poor task analysis is a frequent cause of bad product design.
- E.g. The task might be 3-D navigation and object (symbol) selection and manipulation.

User task analysis

↓

Expert guidelines-based evaluation

↓

Formative Usability evaluation

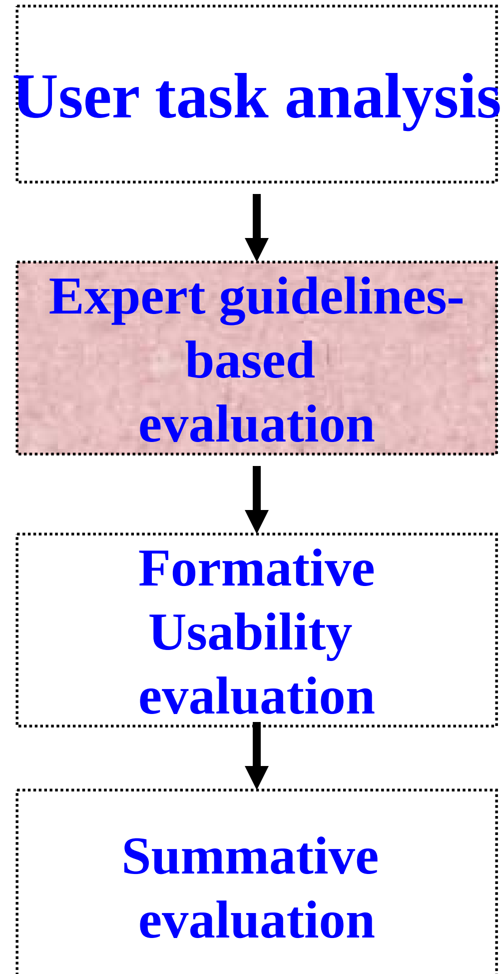
↓

Summative evaluation

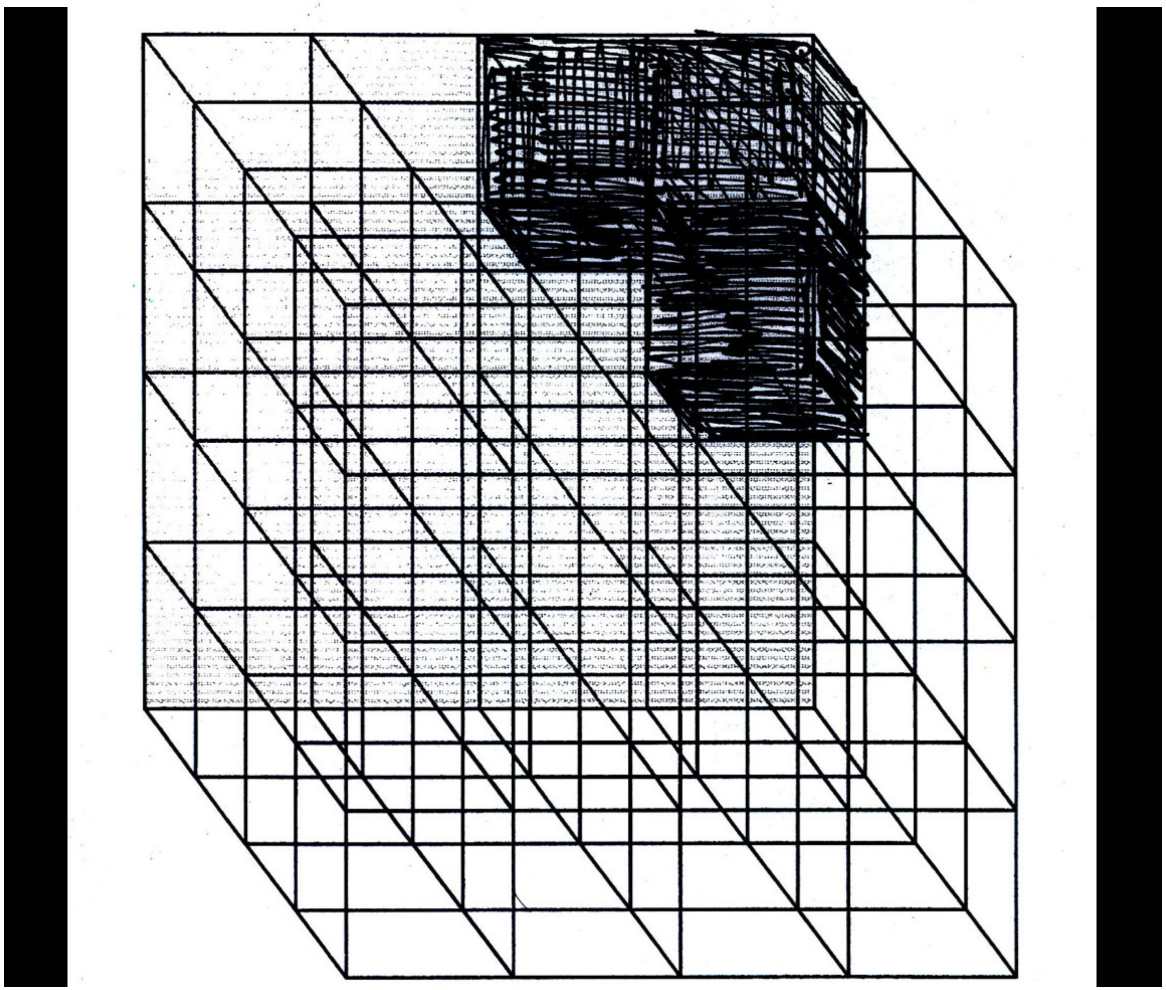
Usability Engineering

✓Second stage:
Expert guidelines-based or heuristic evaluation aims at identifying potential usability problems **early** in the design cycle.

✓ A pencil-and-paper comparison of user's actions done by experts, first alone, and then as a group (to determine consensus)



Example: AR Spatial Ability Test

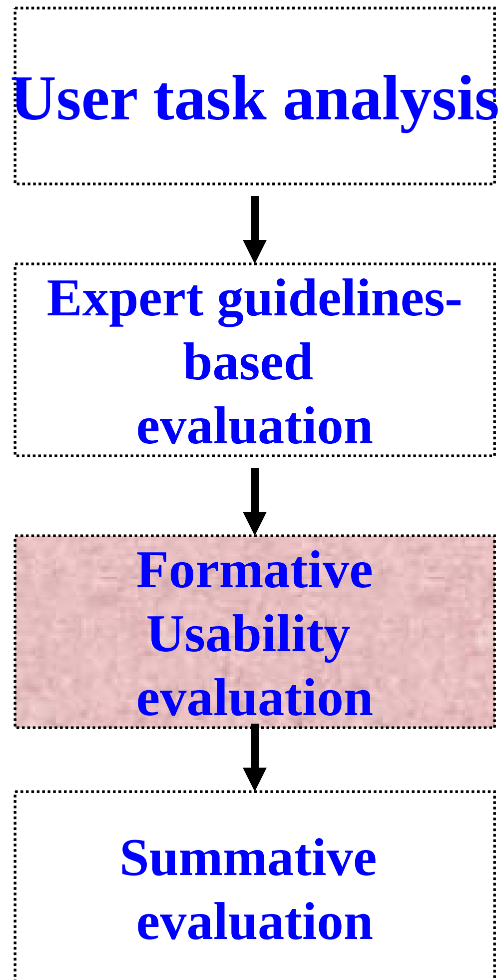


Hannes
Kaufmann

Usability Engineering

✓Third stage is an iterative process where representative users are asked to perform the task.

✓ During task performance various variables are measured, such as task completion time and error rates. These are used to do product re-design and the process is repeated.



Usability Engineering

✓Last stage:
Summative evaluation which is done at the end of product development cycle.

✓Statistically compare the new product with other (competing) products to determine which is better. The selection among several candidates is done based on field trials and expert reviews.

User task analysis

↓

Expert guidelines-based evaluation

↓

Formative Usability evaluation

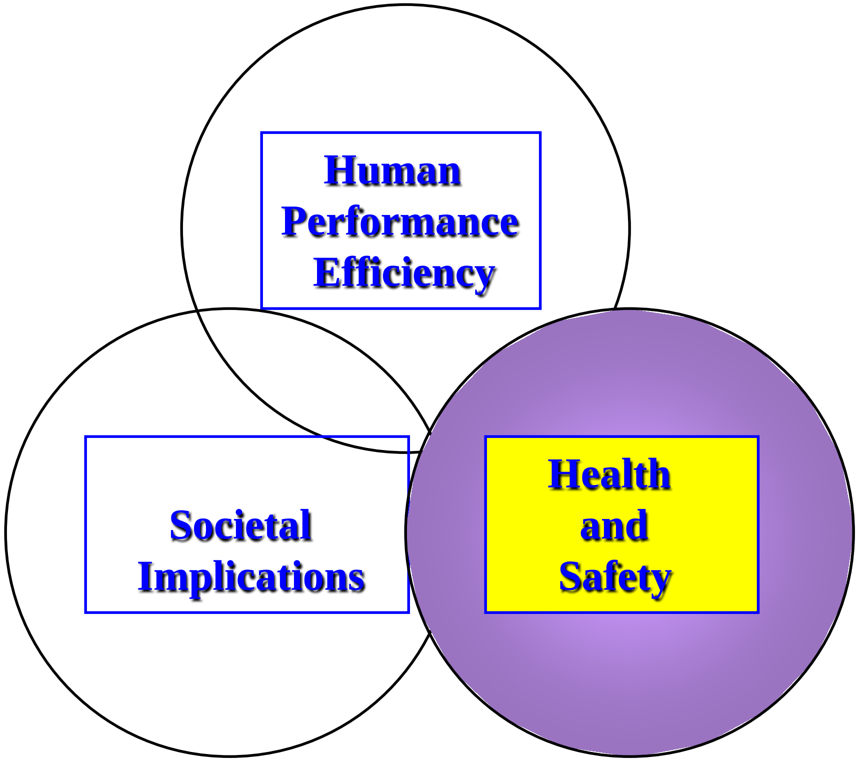
↓

Summative evaluation

Example Evaluation Design: Improving Spatial Abilities

- Pre- and posttests with 5 spatial ability tests (MRT, MCT, OPT, PSVT:R, DAT:SR)
- Strategy assessment
- Gender differences
- 5 training groups with 250 students in total
  - Construct3D group; Desktop CAD3D group
  - 2 standard school groups: Classical paper&pencil geometry, computer supported geometry educ.
  - Untrained control group

Human Factors in VR/AR



(Stanney et al., 1998)

Health & Safety Guidelines
Virtual Reality Head-Mounted Displays
GUIDANCE NOTE 1

CHECK BEFORE USE

Students reporting/showing any signs of the following should NOT take part in HMD-based trials

Conjunctivitis	Pregnancy (Heavy or 5 months+)
Corneal Ulcers	Ear infections/ear disease
Corneal Infections	Influenza
"Dry Eye"	Head Colds
Iritis	Respiratory Ailments
Cataracts or Glaucoma	"Heavy" Hangover

Students reporting/showing any signs of the following should be OBSERVED CLOSELY whilst taking part in VR trials and should be debriefed after trials to ascertain their well-being

Extreme Fatigue	Digestive Problems
Significant Sleep Loss	Emotional Stress
Mild Hangover	Anxiety

ENSURE THAT THE HEADSET IS ALIGNED STRAIGHT ON THE USER'S HEAD (SEE PICTURE ABOVE), TO AVOID ANY VISUAL DISTURBANCES CAUSED BY THE TRACKING SYSTEM RECORDING ABNORMAL ELEVATION ANGLES AT START-UP

CHECK DURING USE

OBSERVE STUDENTS AT REGULAR PERIODS DURING EACH TRIAL AND TAKE IMMEDIATE ACTION (HALT THE SIMULATION AND STAND EASY) IF THEY REPORT SYMPTOMS SUCH AS DISORIENTATION, NAUSEA, EYESTRAIN OR ANY FORM OF MALAISE

CHECK AFTER USE

- Does the student show any signs of disorientation?
- Does the student show any signs of nausea or malaise?
- Does the student show any signs of eyestrain?
- Does the student show any signs of unstable posture? If unsure, test student - walking a straight line with eyes closed and arms folded

IF THE ANSWER TO ANY OF THESE IS "YES" THEN INSTRUCT THE STUDENT TO STAND DOWN AND RELAX. DO NOT ALLOW THE STUDENT TO OPERATE MACHINERY OR DRIVE FOR 60 MINUTES

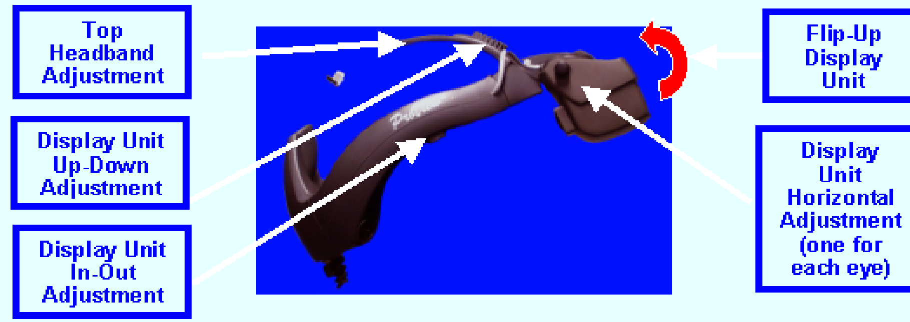
IF IN DOUBT – ASK!

Health & Safety Guidelines
Virtual Reality Head-Mounted Displays
GUIDANCE NOTE 2

BEFORE EXERCISES COMMENCE

DONNING THE HEAD-MOUNTED DISPLAY

- Before donning the headset, ensure the student is fully familiar with the adjustment mechanisms. Stress to the student that the mechanisms move freely and do not require excessive force



- Don the headset slowly, taking special care with spectacle wearers (NB. The headset is designed to accommodate spectacles)
- With the headset on the student's head, guide his/her hands towards the adjustment mechanisms
- Before commencing trials, check to see that the student is wearing the HMD comfortably and can see a clear, single ("fused") image - double images must be avoided

ENSURE THAT THE HEADSET IS ALIGNED STRAIGHT ON THE USER'S HEAD, TO AVOID ANY VISUAL DISTURBANCES CAUSED BY THE TRACKING SYSTEM RECORDING ABNORMAL ELEVATION ANGLES AT START-UP

On first using the HMD, encourage the student to look around the virtual ship superstructure and move the weapon. This familiarises them with the concept of head tracking and helps them to adapt to being "within" a virtual environment. Early familiarisation with virtual sea states 1, 3 and 6 is also recommended

AFTER THE EXERCISE HAS BEEN COMPLETED

DOFFING THE HEAD-MOUNTED DISPLAY

- Carefully loosen the headset adjustment mechanisms prior to doffing
- If necessary, raise the display housings away from the student's face or spectacles
- Slowly doff the headset
- Check for any symptoms as listed on Guidance Sheet 1 (Ref. VP/HS-1/01)
- CLEAN THE HEADSET DISPLAY HOUSINGS and STOW CAREFULLY

Effects of VR Simulations on Users

The effects VR simulations have on users can be classified as direct and indirect

Definitions:

- *Direct effects* involve energy transfer at the tissue level and are potentially hazardous;
- *Indirect effects* are neurological, psychological, sociological, or cybersickness and affect the user at a higher functional level.

Side Effects

Simulator (or Cyber) sickness

- A form of motion sickness with symptoms reported to include nausea, vomiting, eyestrain, disorientation, ataxia, and vertigo (Kennedy, Berbaum, & Drexler, 1994).
- Cybersickness is believed to be related to sensory cue incongruity.
  - occur when there is a conflict between perceptions in different sense modalities (auditory, visual, vestibular, proprioceptive)
  - or when sensory cue information in the VE environment is incongruent with what is felt by the body or with what is expected based on user’s “real world” sensorimotor experience.

Side Effects

Aftereffects

- may include such symptoms as disturbed locomotion, changes in postural control, perceptual-motor disturbances, past pointing, flashbacks, drowsiness, fatigue, and generally lowered arousal
- Aftereffects may be due to the user adapting to the sensorimotor requirements of the VE, which in most cases is an imperfect replica of the non-VE world.

Direct Effects

- ✓ Affect mainly the user’s visual system, but also the auditory, skin and musculoskeletal systems;
- ✓ Effects on visual system: e.g. user is subjected to high-intensity lights directed at his eyes (Lasers used in retinal displays (if they malfunction); IR LEDs in eye tracking systems)
- ✓ An “absence” state can be induced in a user subjected to pulsing lights at low frequency (1-10 Hz);
- ✓ Bright lights coupled with loud pulsing sounds can induce migraines (20% of women, 10% of men are prone to migraines)
- ✓ Direct effects on the auditory system are due to simulation noise that has too high a level (115 dB after more than 15 minutes);
- ✓ Effects on the skin and muscles are due to haptic feedback at too high a level.

Cybersickness

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 3 forms:

- Nausea and (in severe cases) vomiting;
- Eye strain (Oculomotor disturbances);
- Disorientation, postural instability (ataxia) and vertigo.

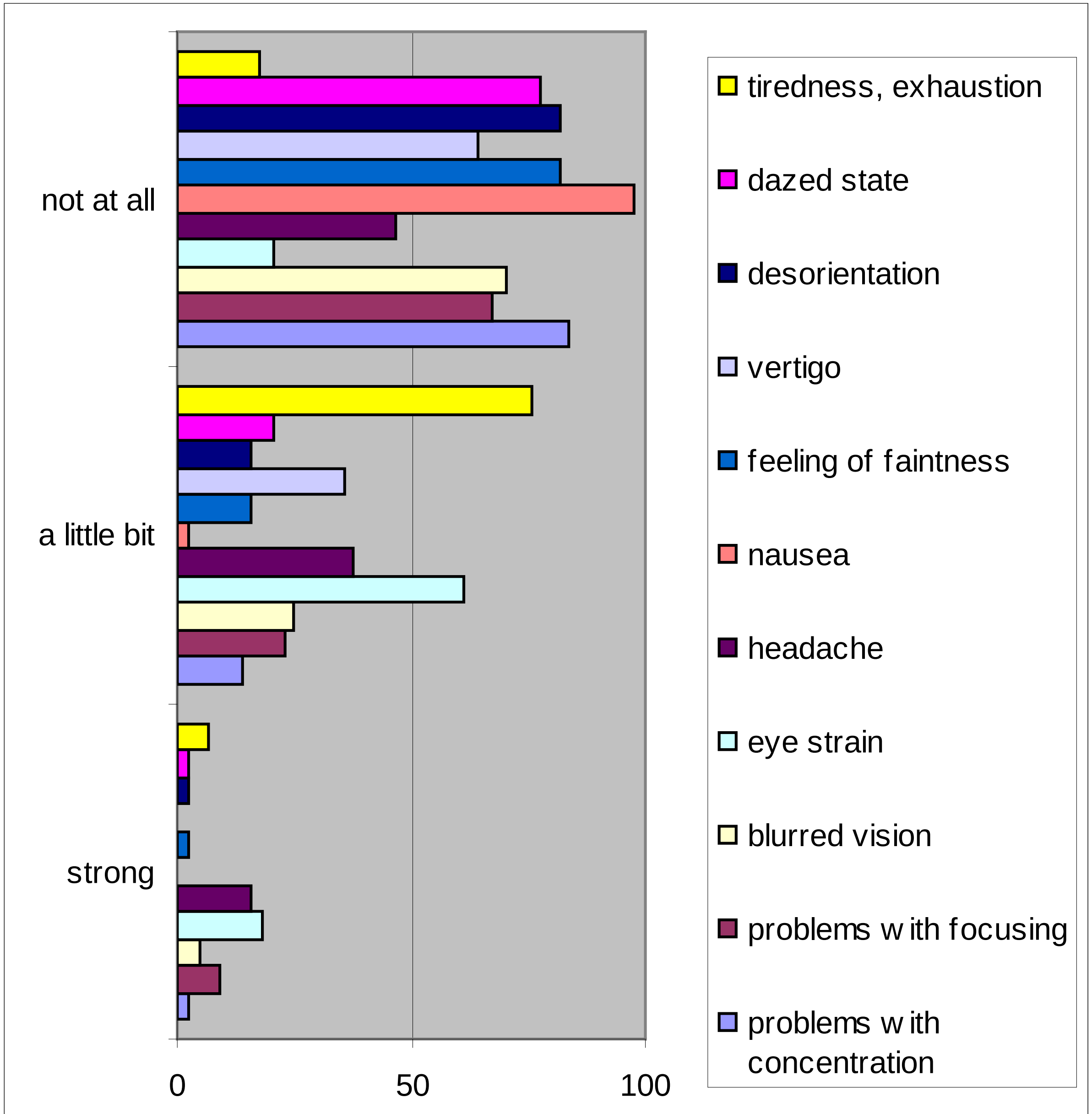
✓ Flight simulators have an incidence of up to 60% of users experiencing simulation sickness (military pilots – elite group);

✓ Studies suggest regular VR users are affected more (***up to 95%***)

(Stanney and Hash, 1998)

Hannes
Kaufmann

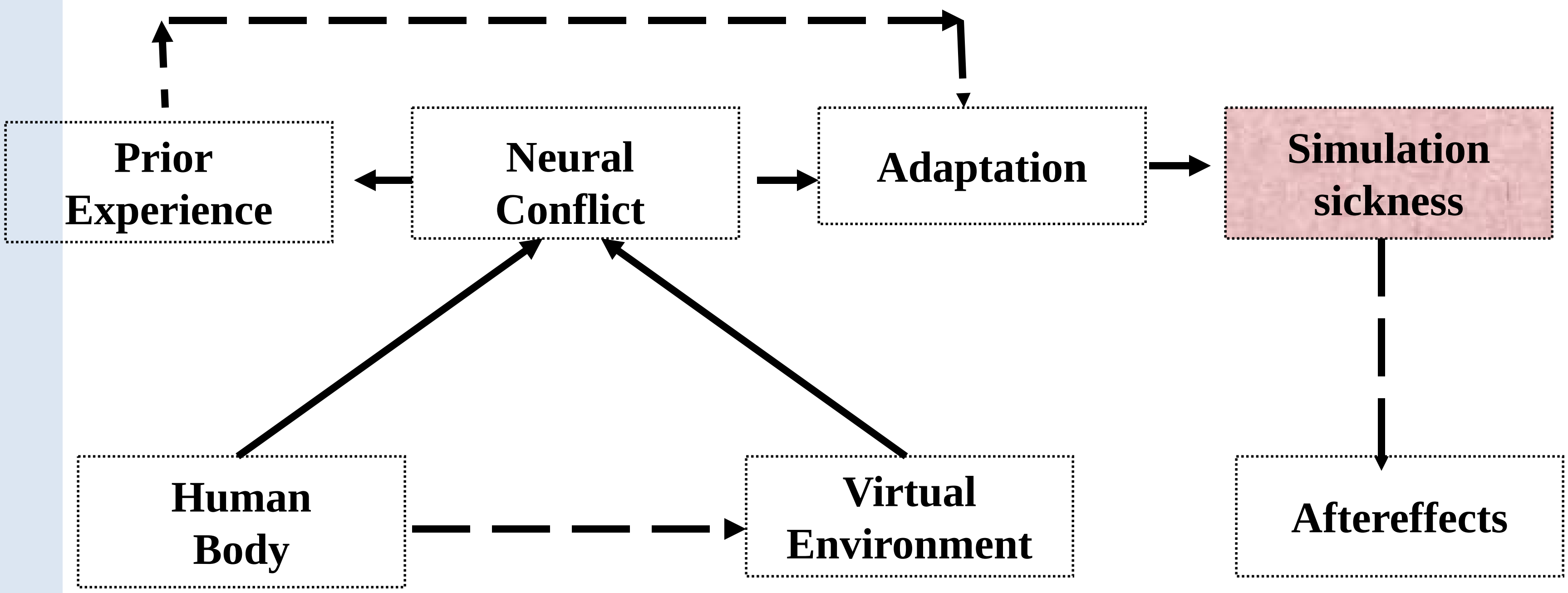
Example: Construct3D Evaluation



Hannes Kaufmann

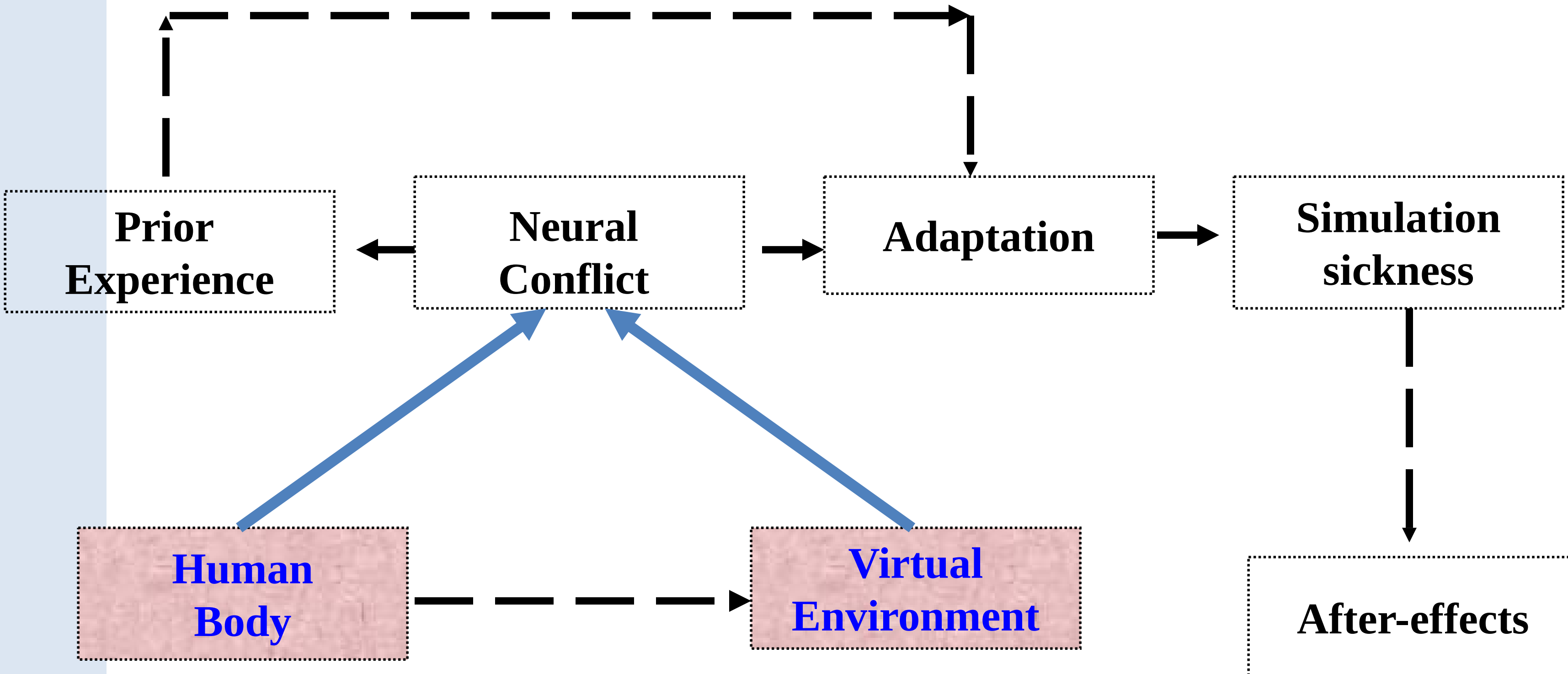
Since many users are affected, it is important to study cyber sickness, in order to reduce its effects, and allow wide-spread use of VR;

✓ Few studies exist. Based on these the following model was developed:



Cybersickness Model

The Cybersickness Model



System characteristics influencing cyber sickness

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

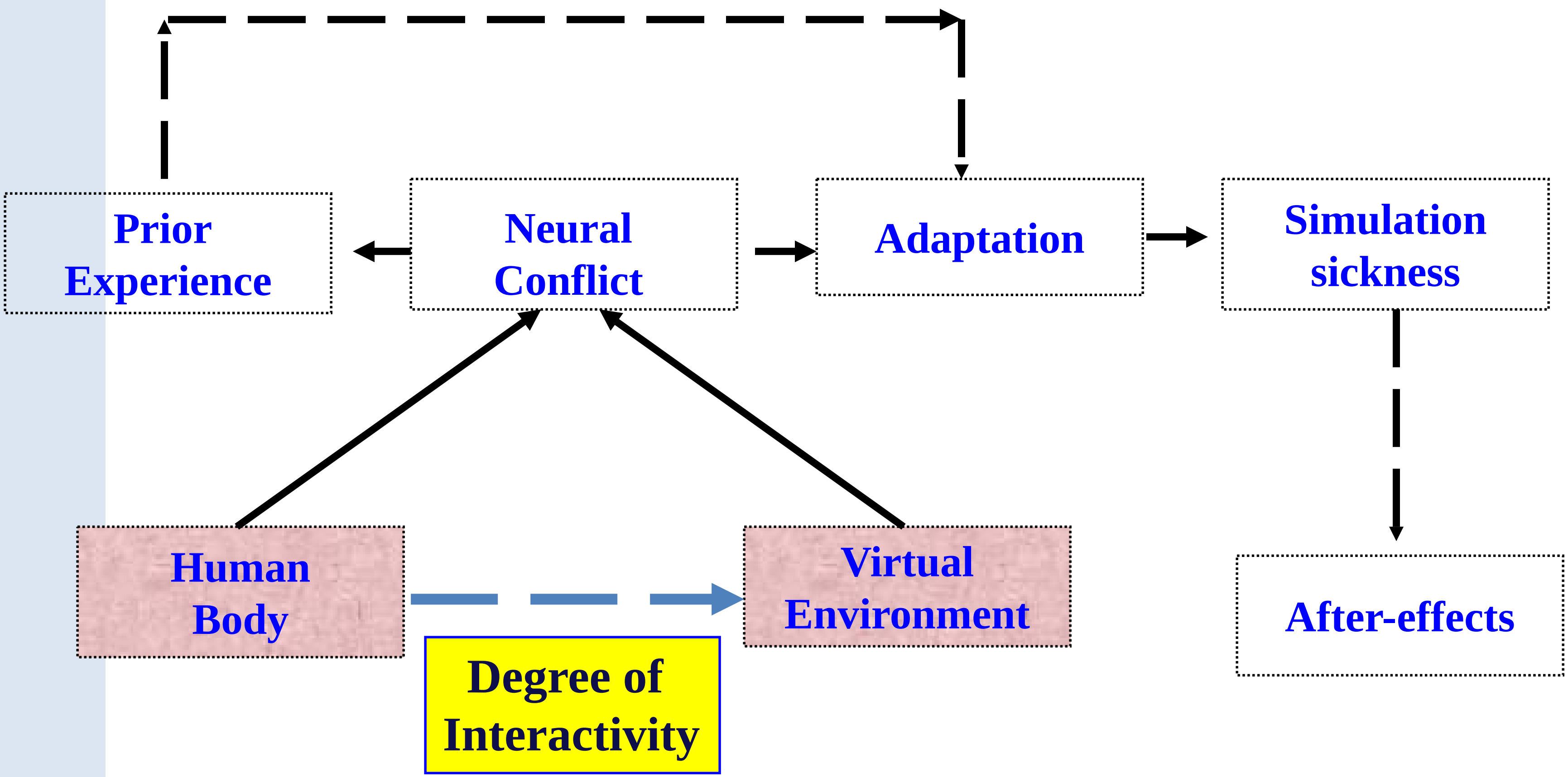
Hannes
Kaufmann

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;
- ***Health status.*** Sick users, including those that take medication or drugs are more prone to cyber sickness.
- ***Pregnancy***. Female users who are pregnant are more prone to simulation sickness.
- ***Susceptibility to motion sickness***. Some people are more prone to motion sickness than others. Pilots are screened for such.

The Cybersickness Model

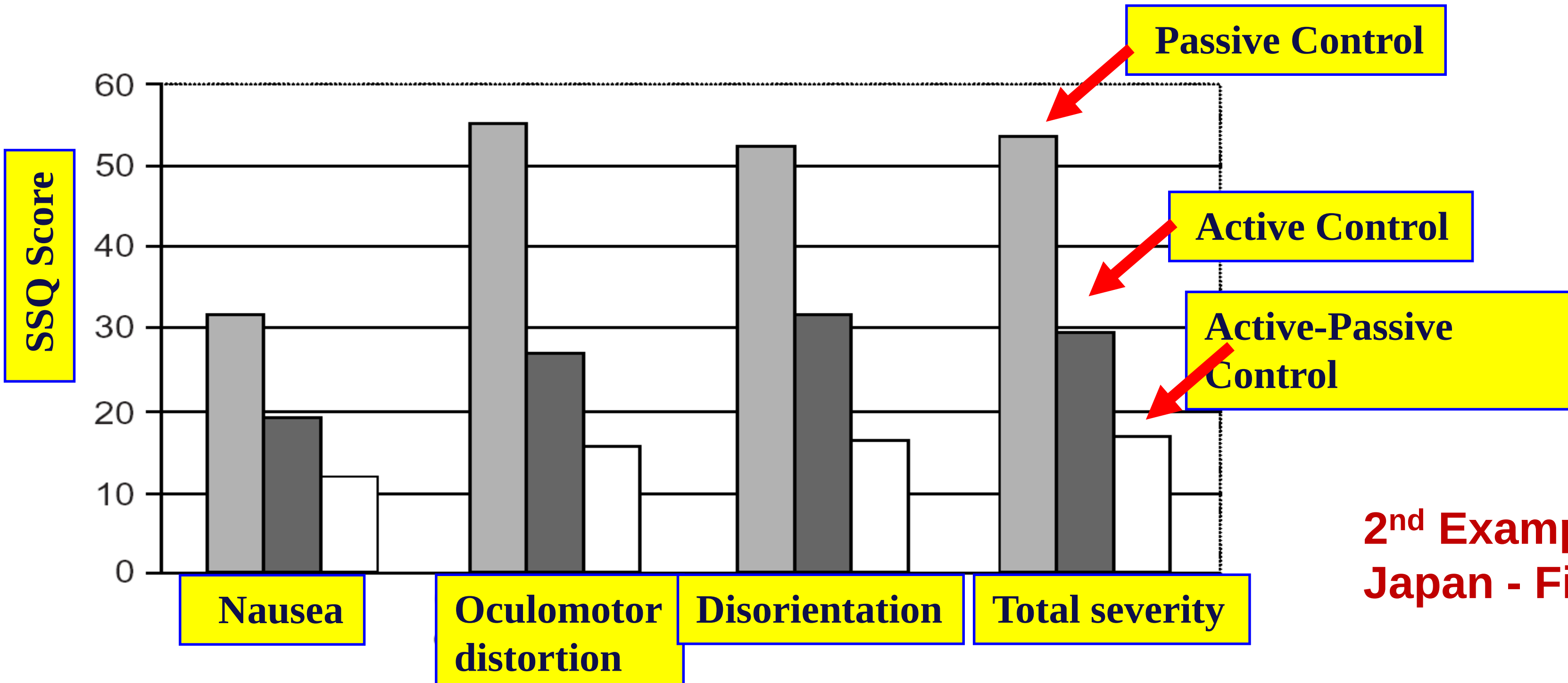


Active-passive control reduces significantly cyber sickness effects. Passive control does worse.

Influence of user's interactivity

✓ Active-passive control is better than active control, because unnecessary motions are eliminated, thus reducing the amount of neural conflicts. Both reduce adaptation time.

✓ Simulation sickness was self-reported by subjects using a Simulation Sickness Questionnaire (SSQ)

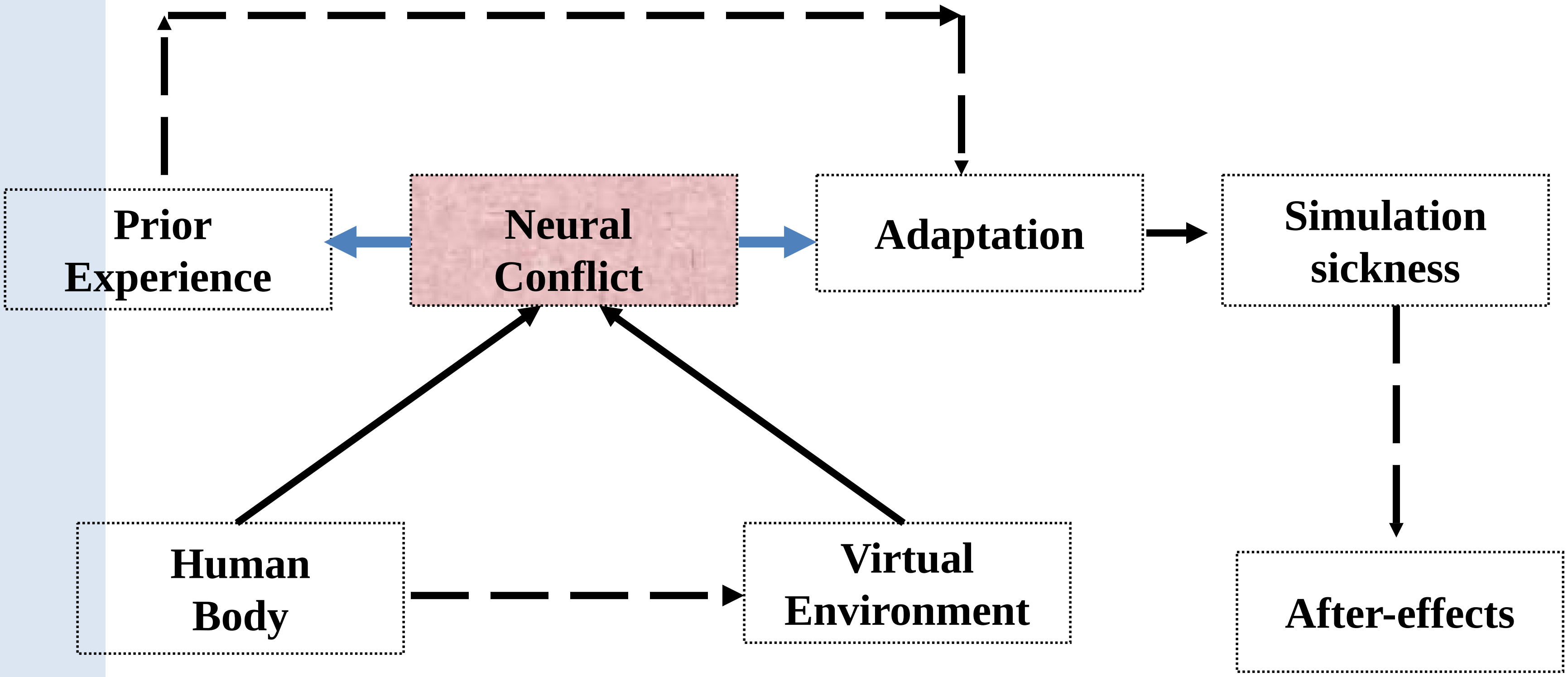


2nd Example: Japan - Film

3-D navigation statistics (Stanney and Hash, 1988)

Hannes
Kaufmann

The Cybersickness Model



Hannes
Kaufmann

Neural Conflict

- Occurs when simulation and body sensorial feedbacks conflict;

The conflict (sensorial rearrangements) can be of 3 types:

- ***Type I***: two simultaneous conflicting signals (A and B) – example 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 – example looking at a roller coaster simulation, without a motion platform;
- ***Type III***: Signal B is present and signal A is not – flight simulation in fog (instrumented flight). Motion platform moves, but visual feedback is unchanged.

✓ Since more information from the simulation results in more conflict, it is logical that neural conflict induced cyber sickness grows with the duration of immersion in the VE.

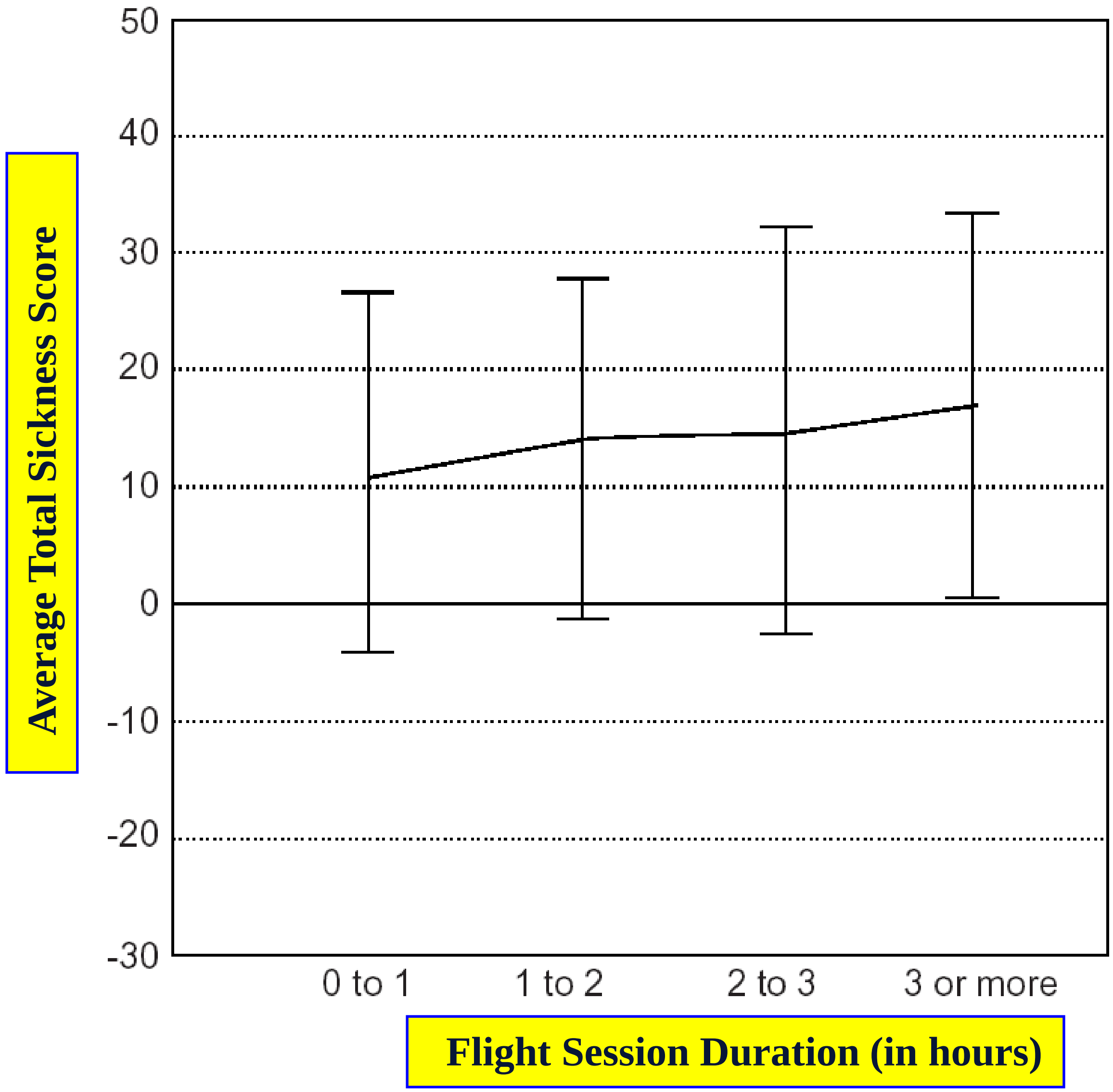
Influence of exposure duration

Studies done at University of Central Florida (Kennedy et al., 2000) to determine influence of simulation duration on cyber sickness;

- ✓ Task was flying a helicopter, and subjects were military pilots;
- ✓ The data was divided according to duration in:
  - Simulation session of 1 hour or less;
  - 1 to 2 hours;
  - 2 to 3 hours;
  - Simulation session of over three hours

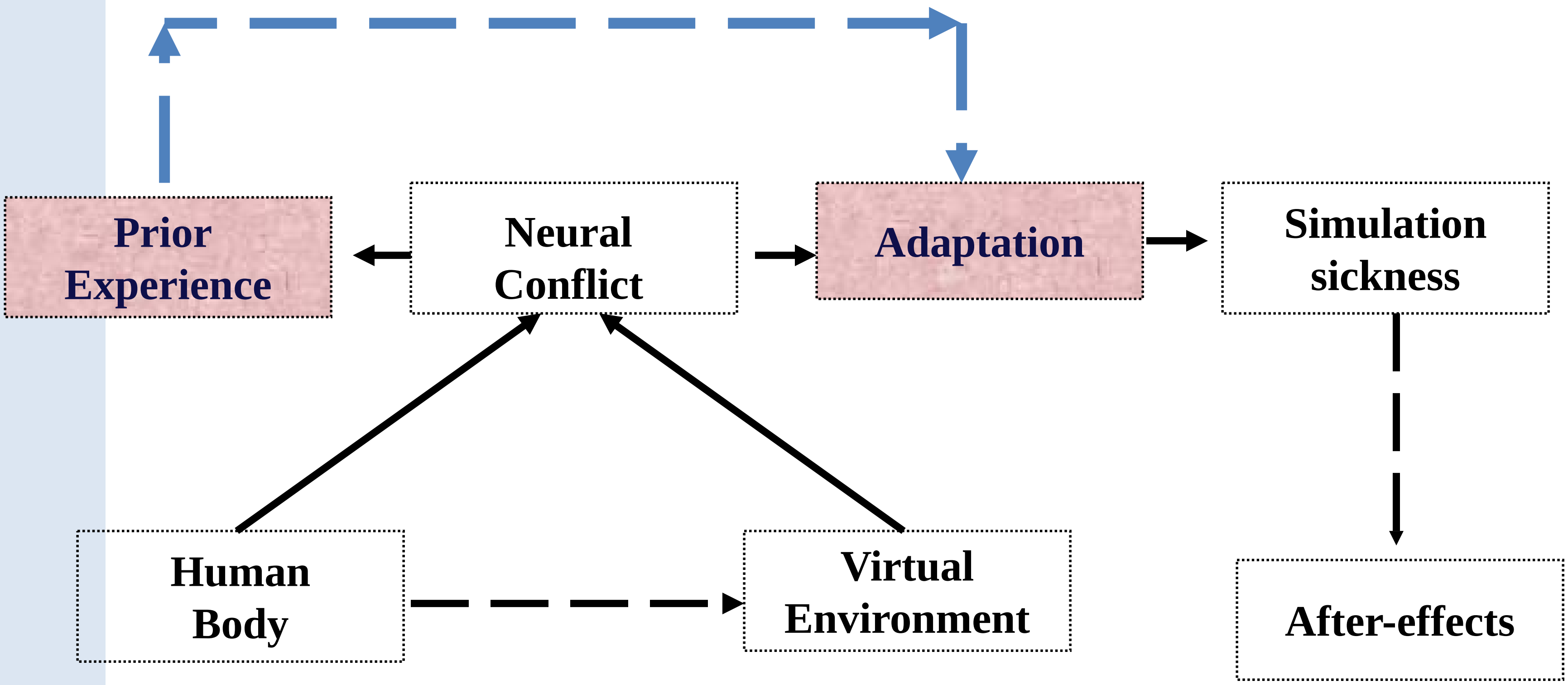
✓ It showed that there is a ***linear relationship*** between ***duration of simulation*** and ***the degree of simulation sickness***; Thus the duration of initial exposure should be limited, to minimize discomfort;

Influence of exposure duration



(Kennedy et al., 2000)

The Cybersickness Model



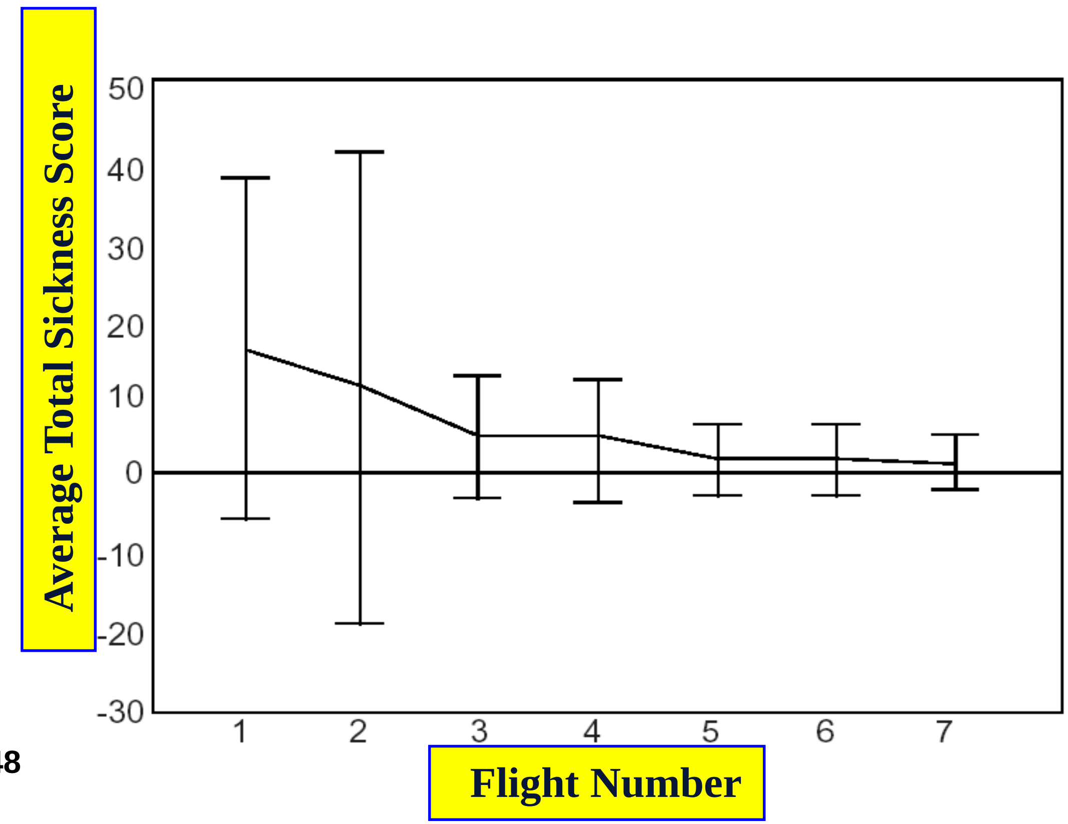
Hannes
Kaufmann

Influence of repeated exposure

- Studies done at University of Central Florida (Kennedy, 2000) to determine ***influence of user adaptation*** on cyber sickness:
- ✓ Since prior neural images play an important role in cyber sickness, can repeated exposure to VR desensitize the user?
- ✓ Study looked at military helicopter simulators. Subjects were pilots; task was prone to induce sickness (violent maneuvers).
- ✓ The study used a "Total Simulation Score" with a 35% as zero-point. Thus for military pilots 35% incidence of simulator sickness is considered acceptable. For the general public it is not.
- ✓ Results showed a ***significant reduction in TSS*** after a few flights showing that the subject had adapted to the neural mismatch. While mismatches exist, they are considered as matches due to prior experience.

Influence of repeated exposure -Results

The study did not indicate how long the subsequent exposures should be, nor over what time interval they should take place. It is believed that no more than one week should separate simulation sessions.



Cyber sickness scores vs. number of successive flights (Kennedy et al., 2000)

Hannes Kaufmann

Health & Safety Issues for VR and simulator use…

Measures

OBJECTIVE	SUBJECTIVE
Eye Tracking	SSQ
Head Tracking	MSQ
Postural Change	"Self Efficacy"
EEG, EOG, EMG	STAI
EGG	NASA TLX

Hannes Kaufmann

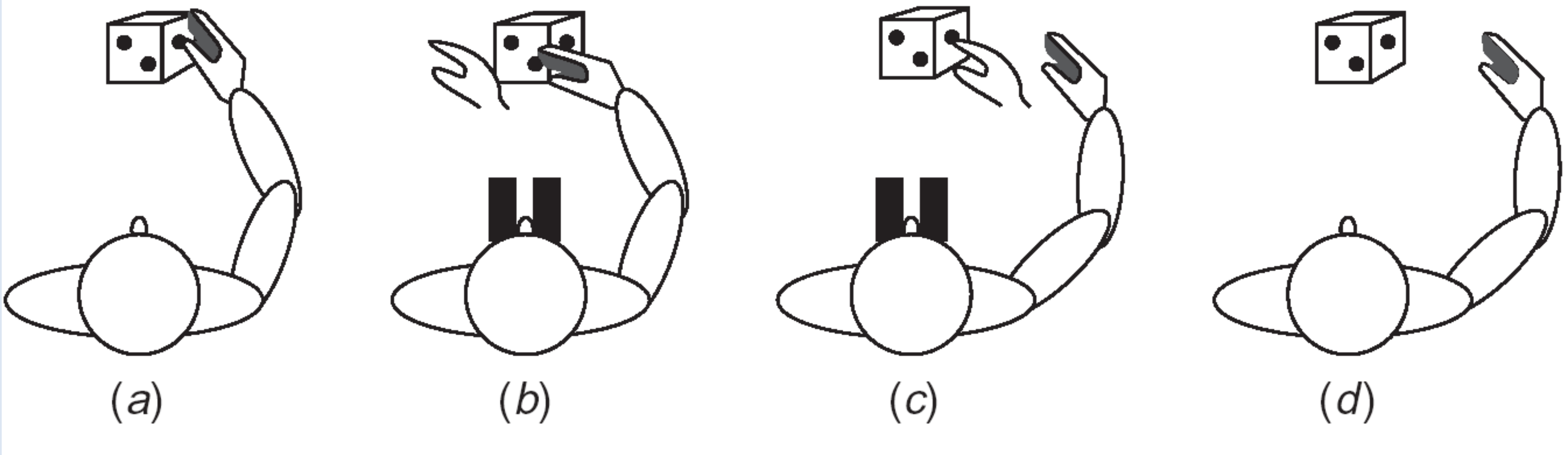
Adaptation

Definition:

“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.”

Hannes
Kaufmann

Adaptation



Hand-eye coordination adaptation:
a) before VR exposure;
b) initial mapping through artificial offset;
c) adapted grasping;
d) aftereffects.
From Groen and Werkhoven [1998].

Hannes
Kaufmann

Aftereffects

Induced through adaptation to neural conflicts.

- ✓ Occur after the simulation session ended
- ✓ 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;
- ✓ These aftereffects lead Navy and Marines to institute grounding policies after simulator flights. Other bans may be necessary (driving, biking, roof repair, etc.).

Hannes
Kaufmann

Guidelines for VR Usage

Meant to minimize the onset and severity of cybersickness.
They are 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 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.

Hannes
Kaufmann

Ergonomics in VR/AR

Classification of Physical Ergonomic Techniques

- Anthropometry: Measurement of body dimensions
- Musculoskeletal Issues: Strain muscular and skeletal systems (physically intensive work-places)
- Cardiovascular: Actions that increase stress level on the heart
- Cognitive: information over-/underload
- Psychomotor: Response to stimuli with a physical movement (lag time, low frame rate, …)

Ergonomics in Wearable Computing

TABLE 41.1
Ergonomic Commonalties in Wearable Computers and Virtual Environments

Ergonomic Category	*Wearable Computers*	*Virtual Environments*
Anthropometrics	Static and dynamic anthropometric measurements should be considered in design.	Static and dynamic anthropometric measurements should be considered in design.
Biomechanics	User mobility while wearing computer. Impact on joint and full body loading. Distribution of load.	Mobility of entire body or specific aspects of the body affected by the VE. Load mobility. Distribution of load.
Computer comfort	Design for long term wearing.	Generally, wearing time is short term.
Durability	Computer must be designed to be durable in a variety of harsh environments.	Generally, VEs do not have as harsh environments as do wearable military computers.
Cardiovascular demands	Consider weight, duration of use, task activities, and impact that these issues have on cardiovascular system.	Consider weight, duration of use, task activities, and impact that these issues have on cardiovascular system.

Head Dimensions

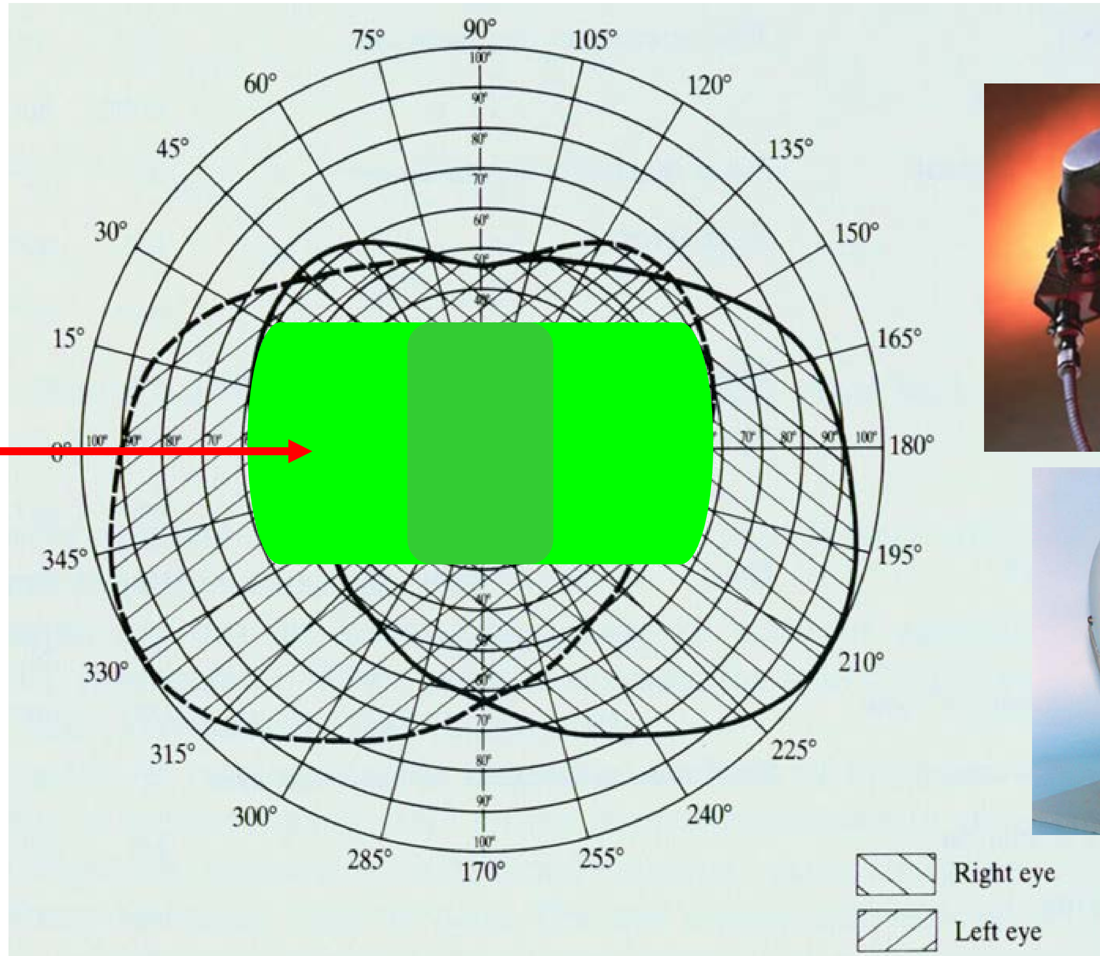
TABLE 41.2
HMD-relevant Anthropometric Dimensions for the Head (Dimensions in MM)

	Women				Men			
	5th Percentile	*50th Percentile*	*95th Percentile*	*Standard Deviation*	*5th Percentile*	*50th Percentile*	*95th Percentile*	*Standard Deviation*
Head Circumference	523	546	571	15	543	568	594	15
Head length	165	180	195	8	180	195	210	8
Head breadth	135	145	155	6	145	155	165	6
Interpupillary breadth	57	62	69	4	59	65	71	4

Source: Body Space: Anthropometry, Ergonomics and the Design of Work (2nd ed.), by Stephen Pheasant

Human Visual Field of View

Typical HMD FOV



Instantaneous Field of View (one eye): 120º(Elev) x 150º(Az)

Instantaneous Field of View (two eyes): 120ºEl x 200ºAz

Binocular Overlap: 120º El and Az

Hannes
Kaufmann

Some Relevant Human Visual Field of View Research

- Alfano & Michel (1990) - goggled subjects, path-walking task; 12° and 40° FOV resulted in significant errors compared to 90° FOV.
- Sivak & MacKenzie (1992) - grasping ability not significantly affected by narrow FOVs but reaching is (misjudged distances).
- Dolezal (1982) - narrow FOVs make objects appear closer and perceptually "shrink" the immediate environment.
- McCauley & Sharkey (1992) - wide FOVs induce vection (illusion of self-motion) and increase simulator sickness incidents

Hannes Kaufmann

Some Issues for Display Technology…

- *HMD Resolution/FOV* – Trade-Off between Viewing Needs and Cybersickness
- *Flatscreen or Projection Options* – Trade-Offs between: Cost/Immersiveness/Need for 360 Degree Stimulus Delivery

Always comes down to: *What are the needs/requirements of the application?*

Hand Measurements

TABLE 41.3
Anthropometric Dimensions of the Hands (All Dimensions in MM)

	Men				*Women*			
	5th Percentile	*50th Percentile*	*95th Percentile*	*Standard Deviation*	*5th Percentile*	*50th Percentile*	*95th Percentile*	*Standard Deviation*
Hand length	173	189	205	10	159	174	189	9
Palm length	98	107	116	6	89	97	105	5
Thumb length	44	51	58	4	40	47	53	4
Thumb thickness	19	22	24	2	15	18	20	2
Hand breadth (across thumb)	97	105	114	5	84	92	99	5
Hand breadth (minimum)	71	81	91	6	63	71	79	5
Maximum grip diameter	45	52	59	4	43	48	53	3
Maximum spread	178	206	234	17	165	190	215	15
Maximum functional reach	122	142	162	12	109	127	145	11
Minimum square access	56	66	76	6	50	58	67	5

Source: Body Space: Anthropometry, Ergonomics and the Design of Work (2nd ed.), by Stephen Pheasant

Hannes
Kaufmann

Noise Exposure

TABLE 41.6
Limits for Noise Exposure

Duration of Exposure	*dB(A)*
8 hours	90
6 hours	92
3 hours	97
90 minutes	102
30 minutes	110

Hannes
Kaufmann

Heat

TABLE 41.8
Scales for Assessing Subjective Thermal Comfort

Bedford		*ASHRAE*	
Much too warm	7	Hot	+3
Too warm	6	Warm	+2
Comfortably warm	5	Slightly warm	+1
Comfortable	4	Neutral	0
Comfortably cool	3	Slightly cool	−1
Too cool	2	Cool	−2
Much too cool	1	Cold	−3

TABLE 41.7
Safe WBGT Values*

Metabolic Rate (M) in Watts	*"Safe" WBGT (°C)* Person Acclimatized to Heat	*Person Not Acclimatized to Heat*
$M \le 117$	33	32
$117 < M \le 234$	30	29
$234 < M \le 360$	28	26
$360 < M \le 468$	No air movement: 25 With air movement: 26	No air movement: 22 With air movement: 23
$M > 468$	No air movement: 23 With air movement: 25	No air movement: 18 With air movement: 20

*Adapted from Kroemer, Kroemer, and Kroemer-Elbert (2000), from ISO 7243, 1982

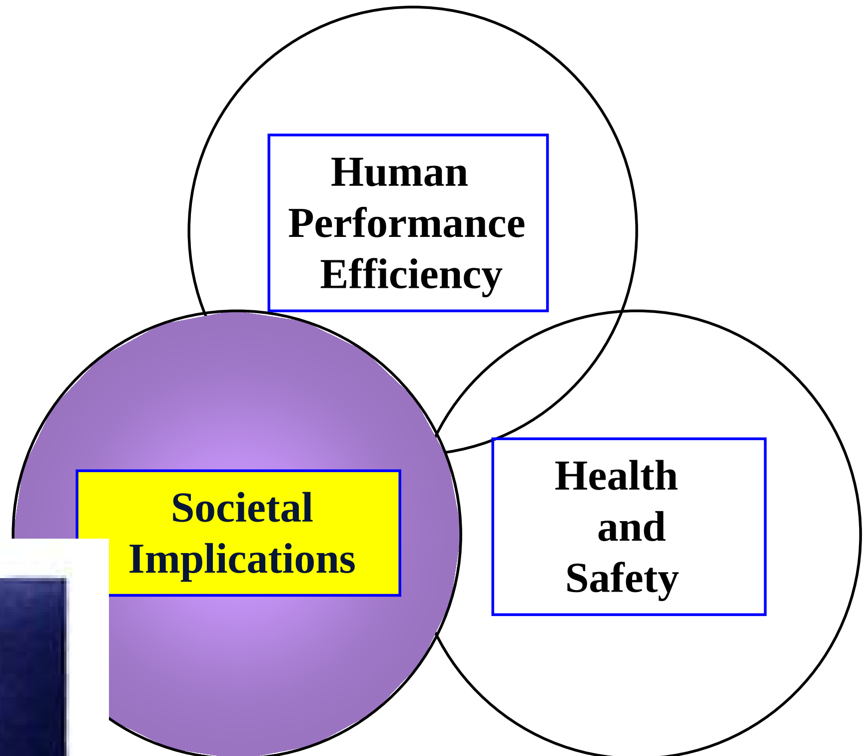
Ergonomic Checklist

TABLE 41.9
Ergonomic Checklist in VE System Design

1. Do sensors inhibit operator movement?
2. Is any limb overburdened?
3. Does task require extended latter or forward reaches beyond normal reach?
4. Do seating conditions meet ergonomic considerations for back support?
5. Are dials and controls easy to view and understand?
6. Is task more than 50% repetitive?
7. Is task performance required for more than 50% of work shift?
8. Does layout lead to efficient motions?
9. Are awkward postures required?
10. Is static loading required for task performance?
11. Is excessive force required?
12. Is twisting and lifting required?
13. Is forceful exertion required at awkward postures?
14. Is noise level within ergonomic guidelines?
15. Is sound level within ergonomic guidelines?

Hannes
Kaufmann

Human Factors in VR/AR



(Stanney et al., 1998)

Hannes
Kaufmann

Presence Definition

- Presence is a state of consciousness where the human actor has a sense of being in the location specified by the displays.
  - Presence is a central feature of VR

Hannes
Kaufmann

Meaning of Presence

- A high degree of presence should lead to the participant experiencing objects and processes in the virtual world as (temporarily) more the presenting reality than the real world in which the VE experience is actually embedded.
  - Participant should exhibit behaviours that are the same as those they would carry out in similar circumstances in everyday reality.
- VE experience should be more like visiting a place, rather than like seeing images showing a place

Hannes
Kaufmann

Presence as a Selector

- Given competing signals – Choose action based on selection amongst hypotheses
  - I am in this world
  - I am in that world
  - (I am mixed up)
- Hypotheses relating to the fundamental question:
  - Where am I?

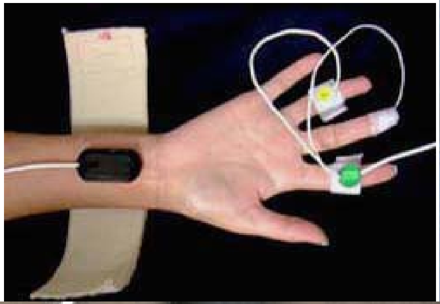
Measurement of Presence

- Questionnaires (many different ones); can be continuous – deliver conscious/voluntary responses
- Behavioural measures (Standing on top of a chair in virtual or real worlds).
- Physiological measures are in response to specific types of event (anxiety provoking): Social Phobia
- Biofeedback measures (hearth rhythm, blood pressure, skin conductivity, …)
- Deliberate introduction of conflicting signals (e.g., shadows).
  - BIPs ‘breaks in presence’ – possible to build a measure based on when these occur.

Hannes
Kaufmann

The VRMC protocol

- Non-invasive Physiological monitoring
  - Heart rate & HRV
  - Respiration rate
  - Skin conductance
  - Peripheral skin temperature



Measures

- Self-Reported Anxiety
- HR: Heart Rate
- MAP: Mean Arterial Blood Pressure
- FPA: Finger Pulse Amplitude
- FPTT: Finger Pulse Transit Time
- EPA: Ear Pulse Amplitude
- EPTT: Ear Pulse Transit Time
- TEMP: Peripheral Skin Temperature
- SCL: Skin Conductance Levels
- RR: Respiratory Rate
- TV: Tidal Volume
- ACT: Somatic Activity

Usual Results

- CAVE provides excellent results
- Few BIPs (Breaks in Presence)
- No BIPs when engaging

- How to avoid BIPs
  - No external interruptions

Ethical Challenges

- Reality Testing Issue with certain clinical populations?
- Immersive Violence? (Bushman Studies)
- VR Addiction? (e.g. SecondLife)
- Will people prefer relationships with synthetic characters over real people? (a la Star Trek Holodeck)
- Internet Delivered Diagnosis and Treatment with VR – will this be misused by "clinicians" to provide a therapeutic "Babysitter"?
- Digital Divide in access to treatment/education/etc.?
- Ethical guidelines?

Social Implications of VR

- Reduction in health-care quality may also be present – especially for mental health and at-home rehabilitation.
- Synthetic and distance learning using VR does not replace direct student-professor interaction.
- Another social impact may be increased individual isolation, through reduced societal direct interaction and involvement. Avatar-mediated interaction, may not be a substitute to direct human-human interaction.
- Violence of VR games are a concern.
  Violence may induce desensitization to real-world violence.

Hannes Kaufmann

AR Social Implications

Pokemon Go: Major Highway Accident After Man Stops In Middle Of Highway To Catch Pikachu!

Hannes
Kaufmann

The End for now….

© 1998 Randy Glasbergen. E-mail: randy@glasbergen.com www.glasbergen.com

"I have a 300 MHz computer…with 10 MHz fingers."

Hannes
Kaufmann

Exam

- Questions ?

Literature

- 3D User Interfaces – Theory and Practice
(2nd edition)
J. LaViola, Ernst Kruijff, Ryan P. McMahan, Doug Bowman, Ivan Poupyrev; Addison Wesley, 2017.
- Handbook of Virtual Environments
Design, Implementation, and Applications
Edited by Kay M. Stanney; Lawrence Erlbaum Associates,2002
- Virtual Reality Technology
Grigore Burdea and Philippe Coiffet; Second Edition with CD-ROM, Wiley, New Jersey, 2003

"A new century is at hand, and a fast-spreading technology promises to change society forever. It will let people live and work wherever they please, and create dynamic new communities linked by electronics."

- ***An article about the telephone, 1898***