Simulations in Vision Rehabilitation
The Good the Bad and the Ugly
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Simulations in vision rehabilitation
• Illustrations of impaired vision
• Simulations as an evaluation tool
  – Evaluate impact of loss on performance
  – Evaluate impact of rehab on performance
  – Demonstrate effect of device
• Verification of Simulations’ validity

Simulation of Impaired Vision
• Improve understanding of the visual effect of vision impairments for:
  – Education and training of professionals
  – Education of patients and family
  – Gain insights for treatment modalities
  – Preliminary evaluation of treatments

Types of simulations of Impaired vision
– Images and videos processing
– Optical simulations
– Electronic simulations
• Virtual reality/ HMD

Simulations on the Lions Club web site
Diabetic Retinopathy  RP  Ring scotoma  L Hemianopia

NEI web site simulations
They are all wrong and misleading
Properly represent Photoshop™ disease
Simulation-using software developed by Bill Geisler

Typical Static Simulation

Visual scene for simulations

Arrow shows direction of Gaze

Recent Video Simulations

- Street Lab – a company
  – Affiliated with Paris Institute of Vision
  
  http://www.streetlabvision.com/en/our_platforms/simulators/urban_simulator/

- Vision loss videos
  - AMD
  - Color vision defect
  - Tunnel vision
- Same problems as others
- Just using video is not sufficient

Really Bad Simulation of BiTemporal Hemianopia-Perception

Left Eye field

Right Eye field
BiTemporal Hemianopia-Vision

From Wikipedia

Is that consistent with previous diagram?

It is not consistent!

BiTemporal Hemianopia-Vision

That’s what Wikipedia should show

Many more Bad or Ugly examples

• The problem is not Photoshop use
  —Lack of understanding of the situation
  • Everyone is entitled to make errors
  • Testing and verification is needed
  • To catch errors and improve understanding
    —Unfortunately this is rarely done

Simulating Vision with Retinal Prosthetic

• A number of simulations conducted
  —Illustrate potential vision
  —Determine implant parameters needed
    • Resolution, number of electrodes
    • Dynamic range (grey levels)
• Most not reasonable
  —Main deficit no consideration of eye movements
    • Most designs have camera on the head and implant in eye
  —No evidence that looking with good fovea at pattern is
    the same as getting that pattern on the retina
• Best work from Gislin Dagnelie at John Hopkins U.

Optical Simulations

Simulating reduced acuity

"not intended to represent any particular eye condition"
Optical Simulation of Cataract
Vaseline applied to the camera’s lens


Make Your Own Vision Impairment Simulators by Dona Sauerburger, COMS
http://www.sauerburger.org/dona/simulators.htm

For Training
Works for reduced acuity, i.e., cataracts
Does not work for field loss of any sort:
Attached to head not to eyes
Easy to look around Central scotoma
Difficult to create a small enough central residual


Simulating Effect of Tunnel Vision


It is really difficult to simulate field loss optically

• Head bound simulations
  – Misses the effects of eye movements
  – Difficult to use in functional evaluation
  – Not useful in device evaluation

• Contact lens simulations
  – Ineffective
  – Too close to the eye’s entrance pupil
    • Control light level but not image formation
    • E.g., pupil constriction does not restrict peripheral field

• Working on a possible solution

Simulations as an evaluation tool

Evaluate patient performance

– Determining the impact of impairment
  • Driving simulators
  • Walking simulators
  • Obstacle courses for pedestrian mobility
  • Evaluate performance on manual tasks
Our Driving simulator

FAAC Inc. DE-1500 --Originally developed for training of:
- Police officers in crashes
- Emergency vehicle drivers
- Military personnel

Realistic Driving Environments

- Residential

Realistic Driving Environments

- Urban

Realistic Driving Environments

- Downtown

Normal Vision view

Central monitor of simulator

Assuming gaze in center

Simulated left hem

Normal view

Gaze moves farther left

Simulated left hem
Age affects **blind** side detection rate

![Graph showing the relationship between age and percent detected with a trend line and equation: \( r = -0.71, p = 0.001 \)]

Everyone “cut” the curves

Hemi’s stay away from blind side

![Diagram showing error bars and Lateral lane offset - LLO (m)]

Published Driving Simulator Studies


Hemianopes Frequently Fail to Scan

![Images of hemianopic conditions](image1)

At T intersections

![Graph showing different conditions and corresponding effects](image2)

Headlight Glare Simulator

Bright LED light is superimposed onto the central monitor image and projected to subject/driver’s eyes

![Diagram of headlight glare simulator](image3)

To study the impact of headlight glare on patients and on ophthalmic devices, i.e., Multifocal IOLs

Commercial Low Vision Simulations

- Street Lab – a private French company
  - Artificial street
  - In-door platform simulating urban environment
• 1. The platform is to be used for applied research
   – behavior studies, design of new equipments
   – On mobility of visually impaired pedestrians
   – On perception of the urban objects
     • detection, legibility, contrasts
   – On needs in terms of accessibility and comfort

• 2. This platform is an evaluation tool for ergonomics, usability and comfort
   – Visual simulations: lightings, projections of images
   – Sound simulations: atmospheres, nuisances
   – Tactile simulations: ground cover, objects, obstacles

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**Treadmill & Display**

Woodway Desmo Treadmill:
• 22 x 68 in. walking surface
• Low friction
• Modifications:
  – Tachometer
  – Speed input
  – Feedback Control

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**Subject Position Tracking**

Normally sighted subjects fail to detect obstacles with decreasing field size, but make accurate judgments when obstacles are detected.

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**Our Walking Simulator**

Walking inside a virtual shopping mall

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**Simulated tunnel vision**

In Virtual Mall with head and eye tracking.

Simulations as a tool to evaluate the effect of treatments or devices

- Demonstrate effect of device
- Compare with and without, before and after
  - Driving simulators
  - Walking simulators
  - Obstacle courses for pedestrian mobility

Simulating the effect of a device: Augmented-vision System for tunnel vision

Image simulating the view of a patient with 5 deg residual field (1/9X)

Video Simulation of Augmented View
Looking at a table in a conference room with tunnel vision

Spatial Multiplexing

Evaluating Performance with the Augmented vision HMD device in the walking simulator

Subjects determined collision risk using minified contour

IOVS, 50: 4509-4515
Spatial multiplexing in aviation: HUD

Simulating Spatial Multiplexing
• Can the brain handle it?
  – Inattention Blindness
    • Cognitive ability to use the device

    Inattentional blindness and augmented-vision displays: Effects of
cartoon-like filtering and attended scene.
    OPO 28: 204-217
    Inattentional blindness with same scene at different scales.
    OPO 30: 124-131

Neisser & Becklen experiment

Unexpected events
We staged the videos filtered and superimposed

Juggler Lost ball Umbrella woman
Choose-up Handshake Ball toss

Real-world experiments
for device evaluation
• Walking course in shopping mall
• Subjects scored by mobility instructor

Real world test environment

• **Urban experimental area**
  - set up by the City of Paris in collaboration with "Institut de la Vision"
  - carry out experimentations, on products or devices aiming to improve daily life of visually impaired
  
  —Not really Simulations

Obstacle Courses

• **Simulated test environments**

Robotic Walking Simulator in Corridors

Simulating the simulator

One unit built and operated manually to illustrate the effect

State of the Art French Simulations

• **Home Lab**
  - 400 sf apartment
    - reproducing a real living environment
    - initiate research and development programs
    - to improve living environment of visually impaired and elderly

Image Processing

Simulations for central and peripheral vision

• Peli E (1990) *Contrast in complex images.* JOSA A 7(10), 2032-2040
**Verification of Simulations**

- Is the simulation valid?
  - Face validity
    - I implemented what I know is true!!
    - Easy but not reasonable
  - Testing of simulations
    - Complicated
    - Implementation may be erroneous
      - Unless enough power to accept
    - Most people avoid

**Verification of Simulations of central vision**

- E. Peli (1996)
  Test of a model of foveal vision by using simulations.
  JOSA A 13(6), 1131-1138

- E. Peli (2001)
  Contrast sensitivity function and image discrimination.
  JOSA A 18(2), 283-293

**Simulating effect of image enhancement**

Image spans 4°, CSF equal for both patients

**Simulated view at various distances**

Span 1°
Span 2°
Span 4°
Original

**Changing Image size and image contrast**
Simulations fail at extreme contrast levels

Now the simulation predict viewing distance for all contrast levels

Unverified -linear filtering simulations

Verification of Simulations of peripheral vision

• E. Peli and G. A. Geri (2001) Discrimination of wide-field images as a test of a peripheral-vision model. JOSA A 18(2), 294-301
Testing of peripheral vision simulations
Max eccentricity tested 32 deg.

(a) (b)

Central fixation. Which side is processed?

Effect of different (measured) CSFs Used in the simulations

Contrast=0.1

Contrast=0.3

Contrast=1.0

Fundamental Eccentricity Constant

Recent Paper on Simulating Vision

Applied to Simulating Vision with LHON

Verification of Simulations Vision with Multifocal IOL

Verification considered but rejected:
"Subject …hard to find"
"...hard to decide which, between two…..images"

Dichoptic Presentation

• Both eyes views are perceived simultaneously
  – Side by side
• Multifocal IOL eye always sees the original image
• Right eye view can be on the Right or Left of the screen
• Monofocal IOL eye sees versions of the simulations
Verification of headlight glare simulation

With Headlight Glare simulator

Real-world photography of simulated condition

Simulation accuracy of light level

- Brightness difference between simulation and real headlight <2X:
- Within the real-world variation of headlight brightness among cars
- Just detectable difference by human observer

Main Considerations for Any Simulator

- What is the purpose of the simulator
  — What do you want to do with it?
- What fidelity is needed for the simulator
  — To achieve the purpose
- How can you evaluate the simulator?
  — Depends on what you want to do with it
  — But you have to evaluate/validate it!

Thank You!