ABSTRACT

An augmented vision device for patients with severely reduced peripheral visual field (tunnel vision) was proposed, combining a see-through head-mounted display (HMD) and video rate minified contour (edge) detection.

We integrated and then compared 6(displays) $\times$ 2(cameras) systems using off-the-shelf (OTS) components for both the edge detection and the display components.

INTRODUCTION

Peripheral visual field loss (tunnel vision) affects patients suffering from Glaucoma and Retinitis Pigmentosa (RP). Tunnel vision limits patient mobility because of reduced ability to spot obstacles and difficulties in navigation. Current optical aids for patients with restricted peripheral field are largely ineffective.

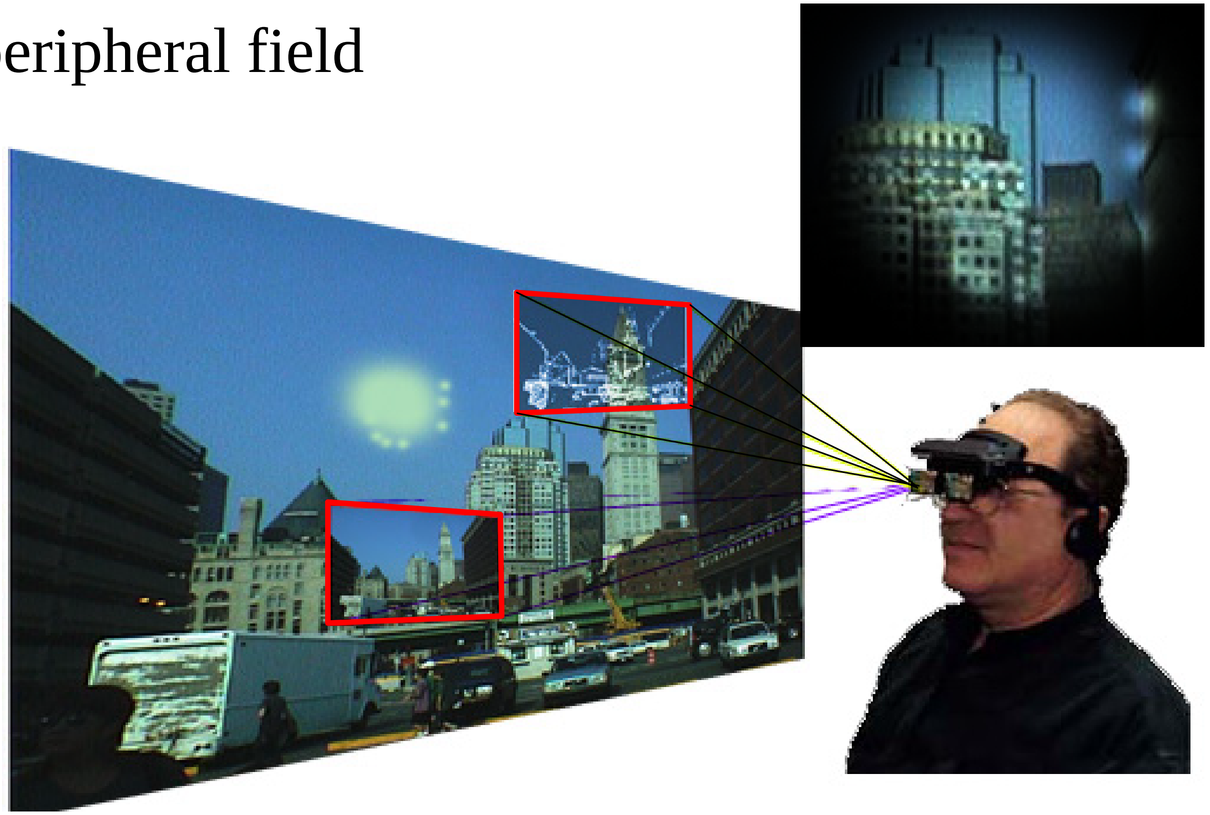
Miniaturized video cameras, rapid image processing, and HMDs provide the configuration, flexibility, and portability needed for the development of more effective aids. Use of OTS design is preferred due to the small size of the market.

CURRENT MOBILITY AIDS:

- **Visual**:
    - Tunnel Vision: Reversed telescopes, centered or in bioptic position
    - Night Blindness: Photomultiplier night visors, wearable flash lights, high sensitivity video HMD
- **Non Visual**: long canes, laser canes, audible sonar scanners, tactile displays, guide dogs

REQUIREMENTS FOR A TUNNEL VISION VISUAL AID:

- Provide information about objects in the peripheral field
- Compatible with the remaining visual capabilities (resolution and visual field)
- Compatible with natural eye movements
- Can function in both light and dark
- Permit use of refractive correction
- Portable, low weight, and long lasting operation



TWO NEW STRATEGIES:

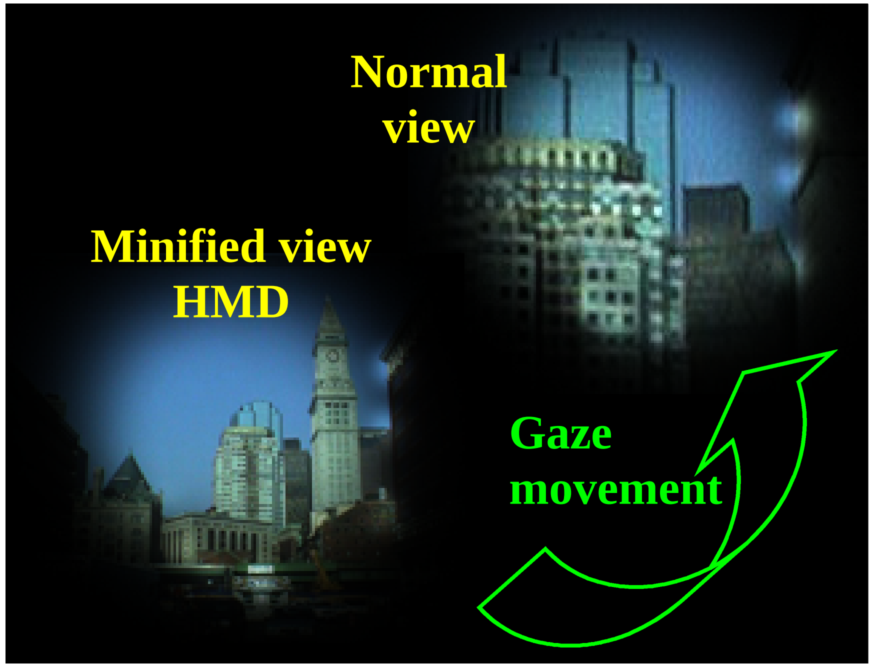
In both strategies, display on an HMD a minified image (3-5 times) of a wide-angle field (Approx. 75°), from a head-mounted camera.

1) **<u>Bioptic Minified Preview</u>** (using an opaque HMD)

- The minified field displayed is placed away from the primary position of gaze.
- The user can scan the display and get a quick preview of the scene. Once an object of interest is chosen, it can be observed with natural sight (full resolution).
- The correspondence between displayed and actual object position requires training. (Similar to the use of rear-view mirrors)

<u>Advantages</u>:

- ✓ Easy image interpretation and object search
- ✓ Short delay
- ✓ Inexpensive – no processing needed
- ✓ Color can be used



2) **Augmented Vision** (using a see-through HMD)

- The display is superimposed on the see-through view.
- The image display contains only the edges of the minified field as bright lines over a transparent background.
- This strategy allows the user to obtain information from a wide visual field at the same time as using his/her normal central vision (spatial multiplexing).
- The minified-field image is perceived as distinct because of its shape, brightness, and motion.

Advantages:

✓ High resolution vision through the HMD is maintained
✓ Instantaneous information from peripheral hazards
✓ Lower retinal illumination (for night blindness)
✓ Lower display resolution sufficient

IMPLEMENTED COMPONENTS

CAMERAS [*]

Mitsubishi Artificial Retina

128×128 pixels, B/W
58° and 78° (Horiz.)
In-chip edge detection
5 frames per second (fps)

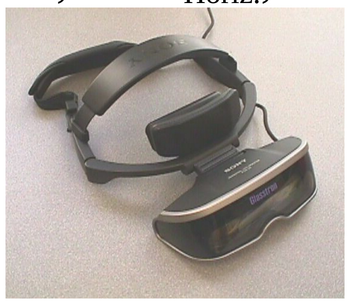
MicroOptical USB ClipOn camera

- 640×480 pixels, Color
- High Sensitivity, Auto-Gain
- 59°, 72°, and 97° (Horiz.)
- Software based processing
- 5-22 fps

(*) Numbers describe values used in the study

DISPLAYS (*)

- **SONY Glasstron PLM-50** (binocular)
  NTSC , $22.3^{\circ}_{\text{Horiz.}}$, selectable see-through density



- **IO Virtual Stereo HMD**
  NTSC , $22.3^{\circ}_{\text{Horiz.}}$, see-through

- **Olympus monocular Eye Trek**
  VESA, 320 x 240, $20.67^{\circ}_{\text{Horiz}}$, see-through

- **MicroOptical EyeGlass** (monocular)
  QVGA, 320 x 240, $17^{\circ}_{\text{Horiz..}}$, see-through

- **MicroOptical ClipOn** (monocular)
  NTSC or QVGA, 320×240, $7.4^{\circ}_{\text{Horiz.}}$, opaque

- **MicroOptical VGA ClipOn** (monocular)
  VGA 640×480, 16°Horiz., opaque

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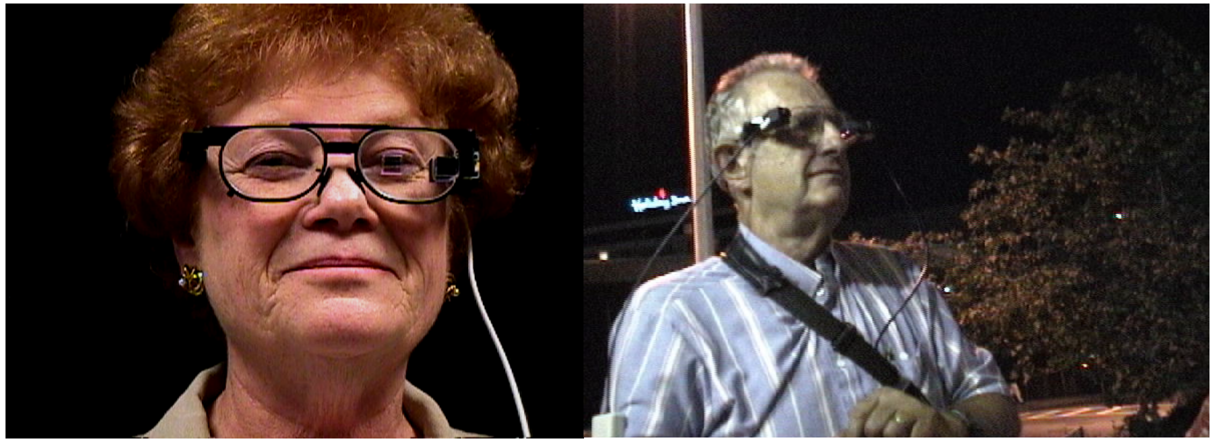
EVALUATION BY PATIENTS

- LAB: All configurations were evaluated
- OUTDOOR (Selected configurations)
  - Walking on the street
  - Day & Night



SUBJECTS' RESPONSES

- **Adaptive brightness required**
  - High brightness needed in sunlight
  - Reduced brightness needed in dim illumination. Patients with night blindness require more display brightness in the dark
  - Manual control of display brightness in dim illumination is desirable
- Avoid need for **focusing**
  - Auto-focus system or large depth-of-field
  - Edge detection requires well focused images
- Increase both **transparency** and **contrast** for see-through HMDs
- **Color** display may help with the correspondence between the displayed and the real world (for Scene Preview)

- **Binocular** displays preferred, even though **monocular** HMDs have advantages (field, transparency, weight, cost)
- Preferred using own **spectacle correction**
- Need to improve **ergonomic function**

PRELIMINARY CONCLUSIONS

HMD FEATURES:

- **Active Display Size**: Close to the remaining visual field (5 to 15 deg diameter) in the scene preview. (No need to scan the display)
- **HMD Frame Size**: Avoid limiting the fixation field that subjects actually use
  - Scene Preview: Built-in-glass display, transparent frame or open peripheral design
  - Augmented Vision: larger than fixation field
- Resolution (camera & HMD): High resolution for subjects with normal central vision

CAMERA FEATURES

- **Increase sensitivity:**
  - IR illumination to provide or supplement signal in darkness
  - Needed for edge detection performance
- **Run at video rate:** both display and acquisition

EYE MOVEMENTS WHILE WALKING

<u>Purpose</u>: Subjects with tunnel vision use both eye and head movements to scan the space looking for obstacles and moving objects. Some patients report using mostly head movements. To estimate the required size of displays for augmented vision, we recorded the eye movements (referenced to the head) while walking. (We assume that the size of display should be ~ 2 $\times$ standard deviation of movement in degree)

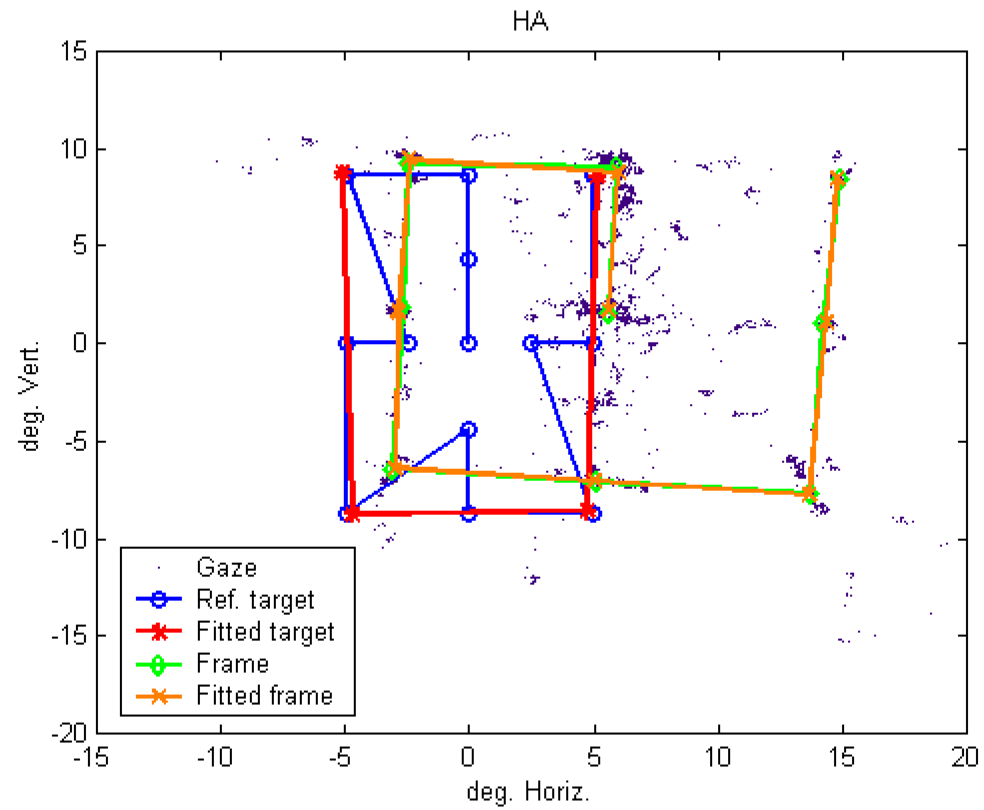
<u>Methods</u>: A head mounted ISCAN eye-tracking device was modified to be portable. It records scanning eye movements with reference to the head. A video camera mounted on the head provides a video image of the pupil. The signal is stored on a digital camcorder with analog inputs (Cannon ZR10). The stored signal is later processed by the ISCAN system at 60Hz.

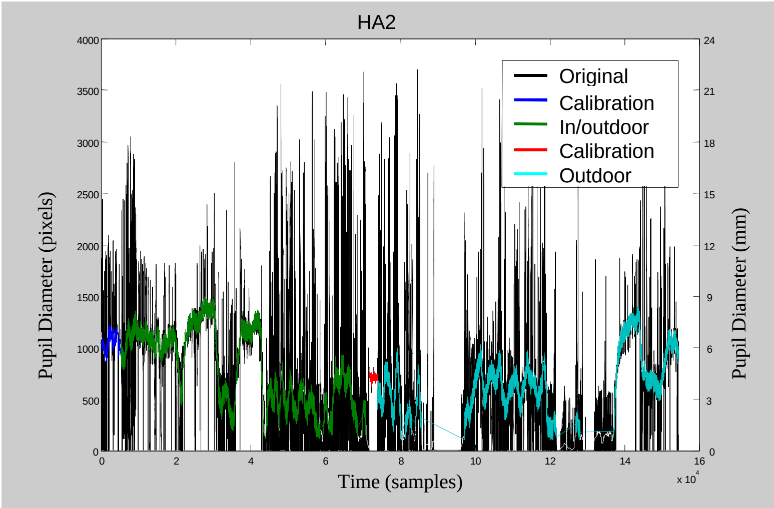
Subjects were walking on the street and indoors as they do normally (using long canes).

Calibration: The pupil position data were converted to field angle data through a 2-D 2nd order Taylor expansion.

Coefficients were fitted from the pupil positions obtained when looking at a 9-point reference frame. The equivalence in degrees was derived from a simultaneous image of the frame and a calibrated background target.

This frame is mounted on a bite-bar that allows stability and enables outdoor calibration re-checks.





Eye Movement Data Rejection: Values excluded when pupil diameter outside of a reasonable range due to:

- Blinks
- Fast illumination changes

Subjects:

2 RP (10° & 5° in better eye, respectively) using long cane

1 Normally sighted

Males, 50-60 y/o, Right eye recorded

Eye Movements Standard Deviation (degree)

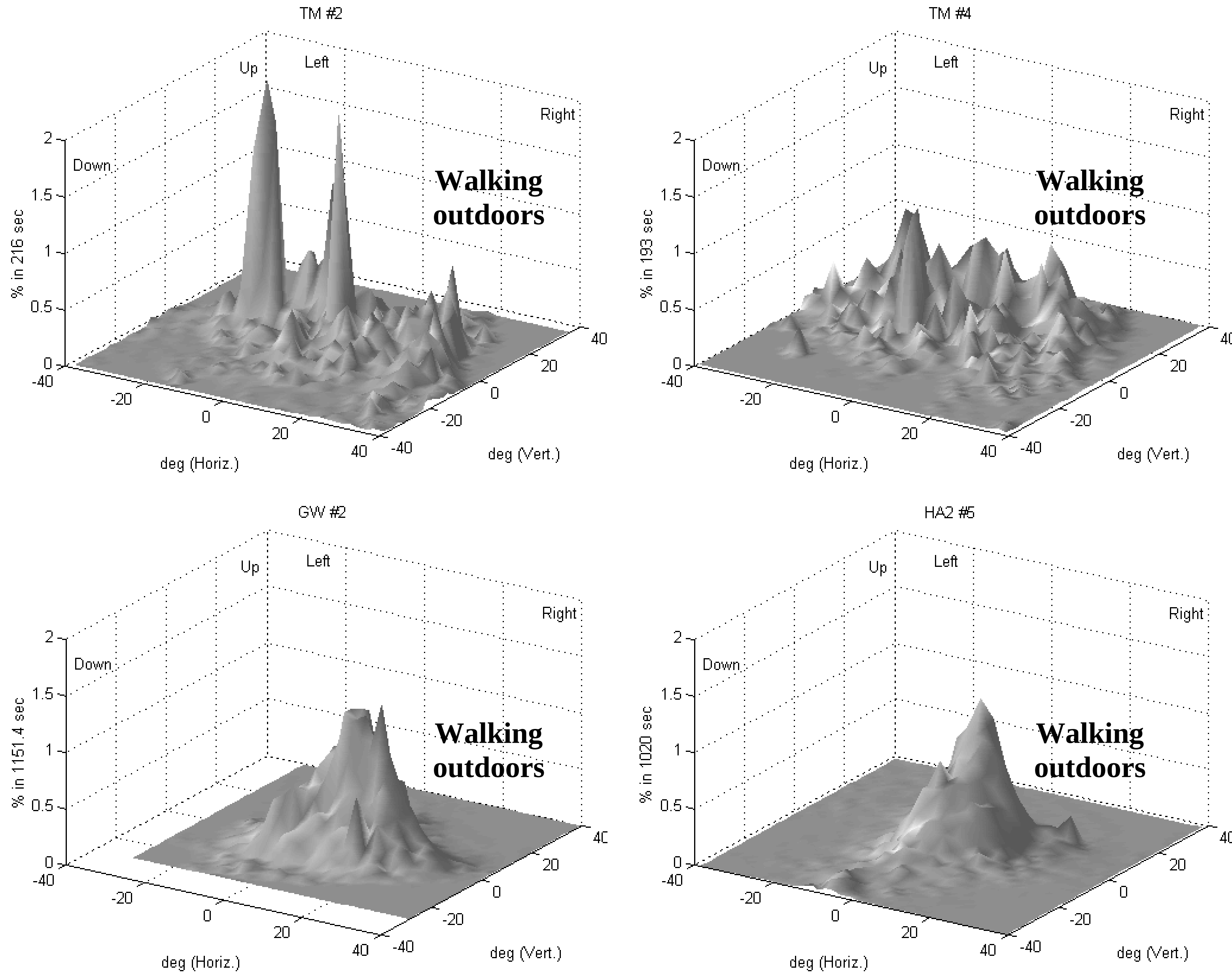
	Subject	$S_{Horizontal}$	$S_{Vertical}$	Context	code
CONTROL	TM	18.6 16.5	11.7 11.1	Outdoor/Indoor Outdoor	#2 #4
RP pacients	GW (5 deg)	9.5	7.1	Outdoor/Indoor	#2
RP pacients	HA2 (10 deg)	9.0	11.5	Outdoor/Indoor	#5
RP pacients	HA (10deg)	4.9 8.7 8.2	7.0 9.8 5.8	Reading (PAL) Outdoor Indoor -incl. steps	#2 #3 #4

Preliminary Results:

- The tested tunnel vision patients moved their eyes less than the control normal subject, possibly due to:
  - Scanning head movement
  - Tactile aids (long cane)

Normally sighted observer

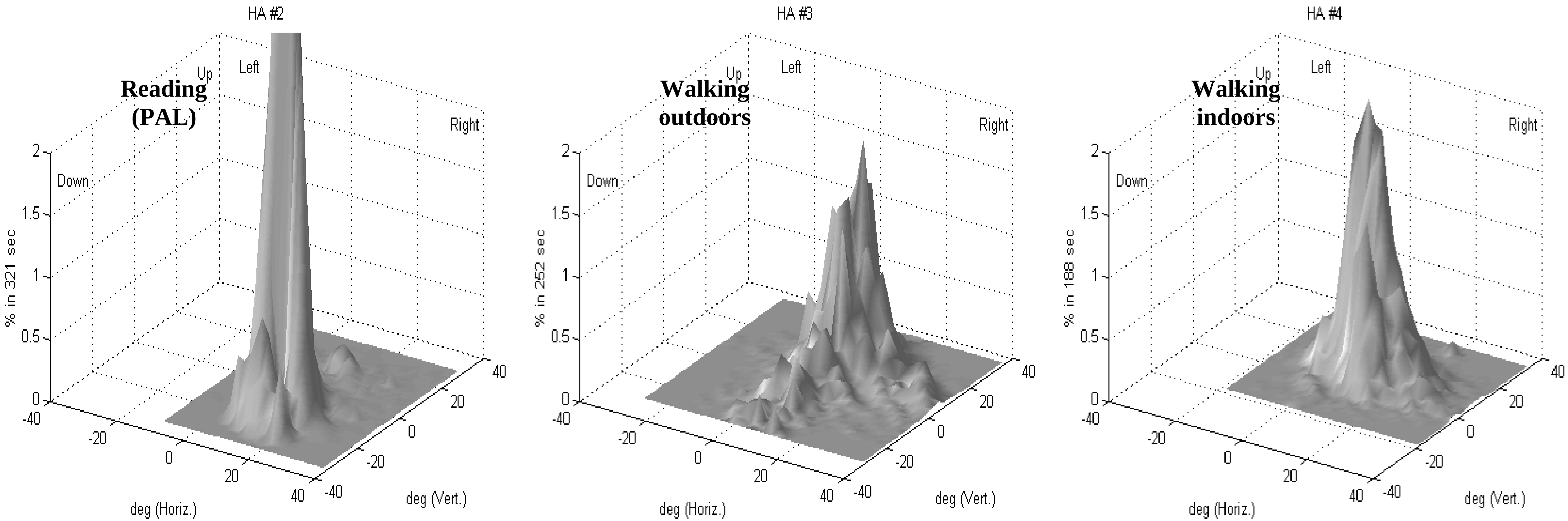
Advanced RP patients



- The **scanning strategy** changes with the environment and individual
  - <u>Horizontal scanning</u>: Indoor, flat floor, or known path
  - <u>Vertical scanning</u>: Uneven floor or unknown path (outdoor)

RP subject

(10 deg. visual field)



FUTURE DEVELOPMENTS:

- Higher sensitivity camera (IR)
- Automatic/Manual override brightness adjustment
- Temporal based algorithm for edge detection
- Improve control by head (temporal multiplexing)
- Developing a portable and compact device for users

    - Ergonomic
    - Long lasting
    - Build-in processing unit
    - Test in larger population

MORE PATIENTS for eye recording experiment, and simultaneous record scene image.

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Comments:

Augmented vision for tunnel vision: off-the-shelf implementation

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