Eye- and head-Tracking

Motivation for eye tracking

- Determine fundamental mechanisms of eye movement
  - Fixations
  - Saccades
  - Smooth Pursuit
  - Microsaccades?
  - Nystagmus, tremors, disorders

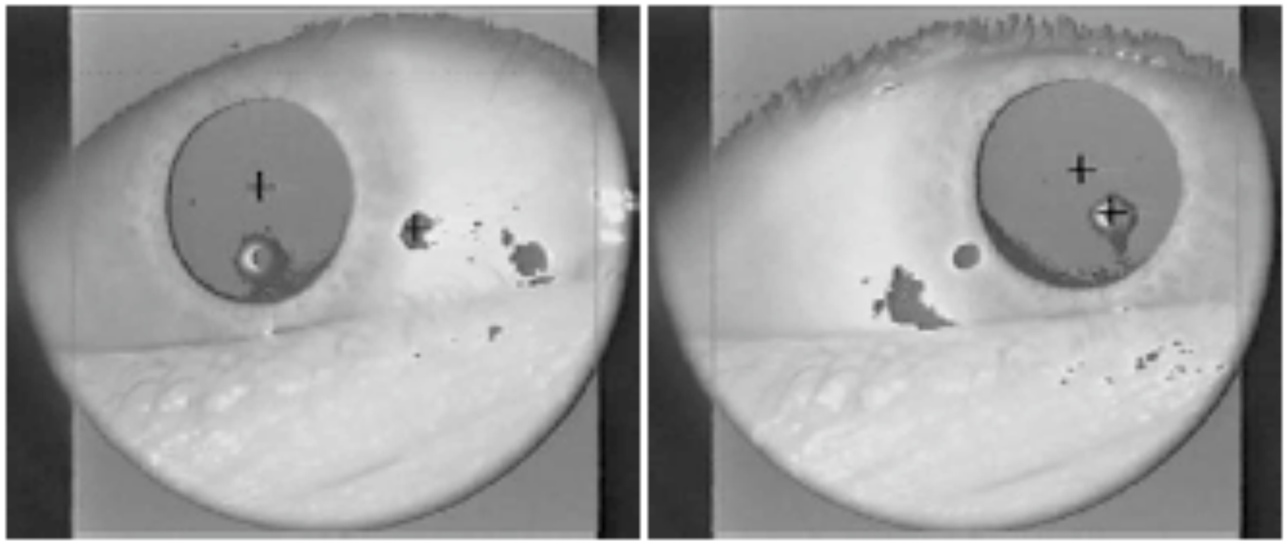
Motivation for eye tracking

- Determine strategies for human performance
  - Where do subjects look?
  - How long do they look there?
    - Final fixation duration is correlated with successful trials, skilled performers, difficult tasks

How to track point of gaze

- Eye tracking system alone just calculates line of gaze
- 2 Cameras
- Infrared light shining on eye
- 2 primary reflections: pupil and cornea
- Vector between the reflections is related to line of gaze

Example of reflections



(a) Looking to upper-left. (b) Looking to upper-right.

From Duchowski, Andrew (2007). Eye tracking methodology: Theory and practice. Second Edition. Springer Publishing.

Example of grayscaled reflections

3 key settings:

- Illumination of IR
- Pupil reflection threshold
- Corneal reflection threshold

From Applied Science Laboratories' H6 Training Manual

Calibration of eye tracker

- Make a grid of 9 points
- Look at each of the points
- Record PR-CR vector for each
- Use a linear transformation to map PR-CR vector to point of gaze
- x and y are coordinates in plane
- u and v are measure numbers of PR-CR

$$x = \frac{c_1 u + c_2 v + c_3}{1 + c_7 u + c_8 v}$$

$$y = \frac{c_4 u + c_5 v + c_6}{1 + c_7 u + c_8 v}$$

Why use head-tracking?

- Necessary for finding point of gaze in environment

Position and orientation of eye with respect to head

+

Position and orientation of head with respect to environment

+

Positions and orientations of planes in the environment

=>

Point of gaze in the environment

How to find POG

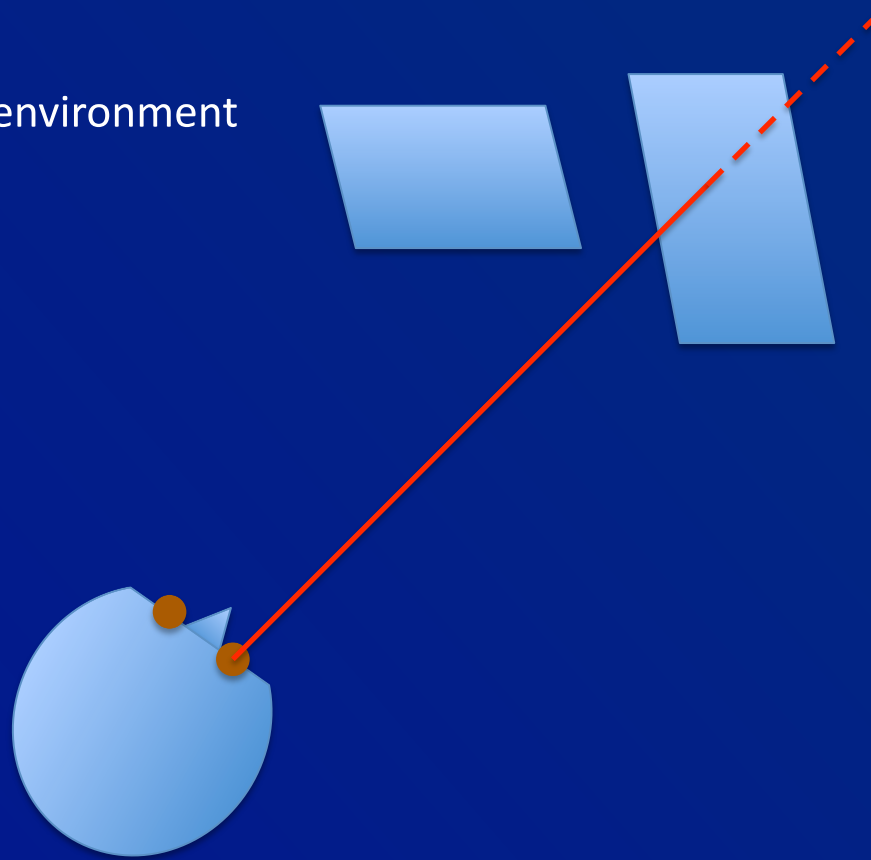
Position and orientation of eye with respect to head

+

Position and orientation of head with respect to environment

=>

Line of gaze in environment



Point of gaze is where the line of gaze intersects the bounded planes in the environment

Methods for Head-tracking

- Mechanical
- Acoustic
- Optical
- Electromagnetic

Mechanical

- Needles and paper
  - Bulky and awkward
  - Limited range of motion

Acoustic

- Ultrasonic sound waves
  - Slow
  - Need clear line of sight
  - Speed of sound varies with temperature, humidity, pressure

Optical

- Attach infrared LEDs to the head and track them with a camera
  - Need clear line of sight
  - Affected by ambient light and infrared radiation

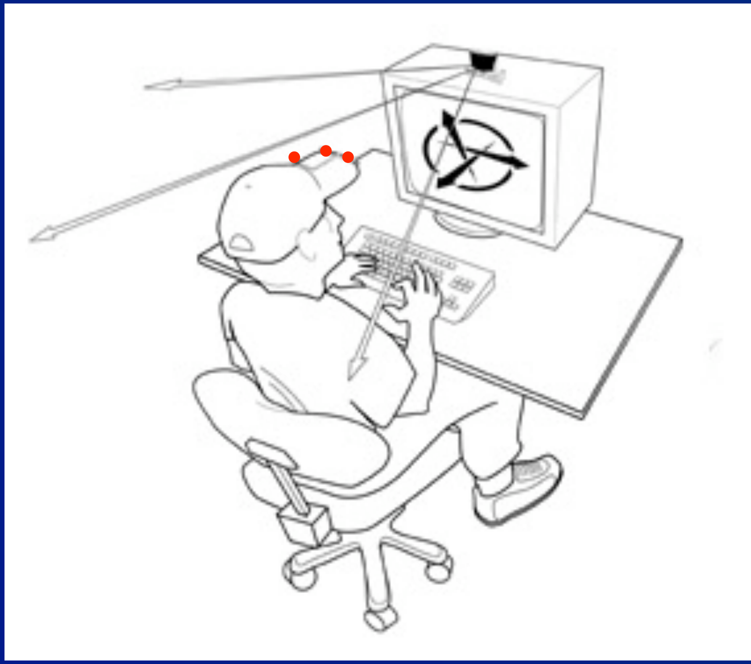
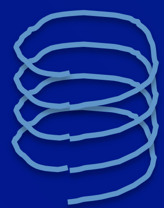
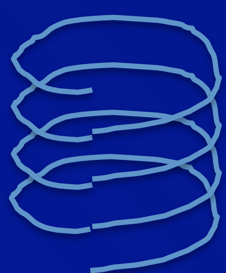


Illustration of Natural Point's TrackIR system for head tracking in video games.
Camera on monitor tracks 3 IR lights on the user's hat.

Electromagnetic - functionality

Sensor





Transmitter

1 DOF example:

- Current in active transmitter coil creates magnetic field
- Magnetic field creates current in passive sensor coil
- Current in sensor proportional to distance, and strength of transmitter

Electromagnetic - functionality

- One 6-DOF sensor is placed on the head
- Nearby transmitter sends out pulses of DC magnetic fields
- Sensor measures the magnetic field
- Computer calculates position and orientation

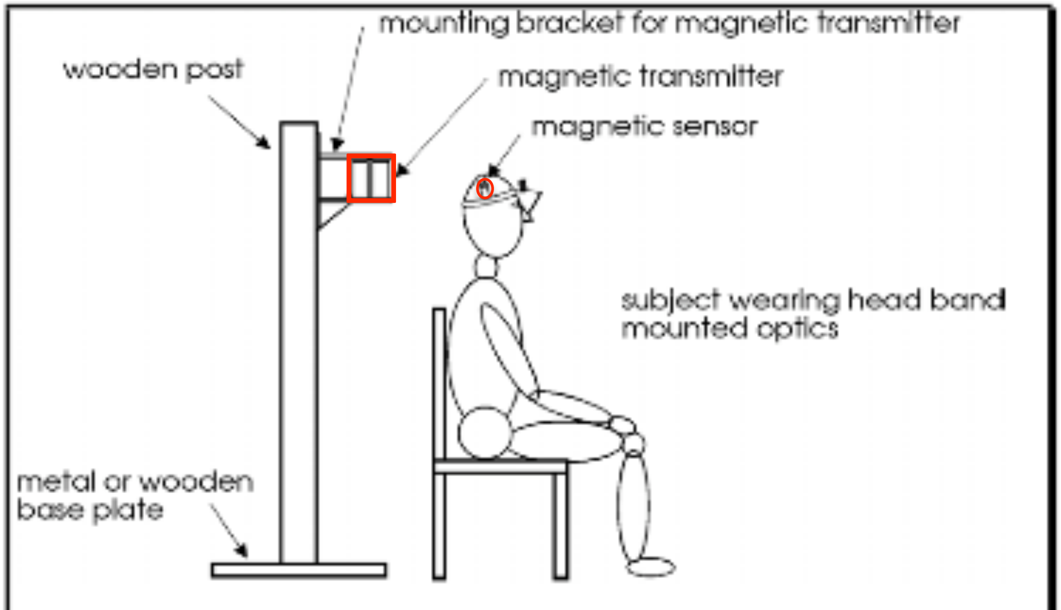


Figure 9-1. Suggested mounting arrangement for magnetic transmitter (Ascension Flock type transmitter mount is shown in sketch)

Eye-head Integration

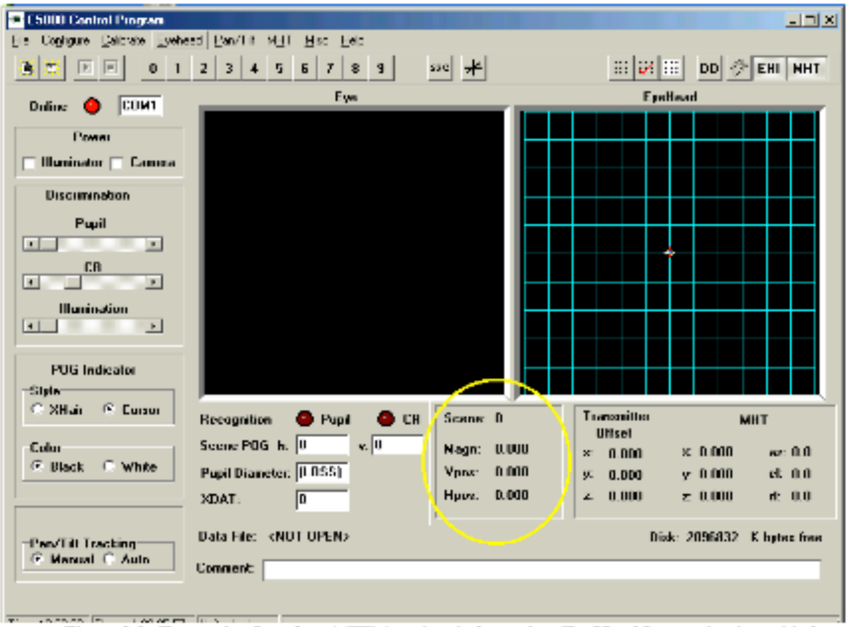


Figure 3-8. Eye tracker Interface (e5Win) main window, when EyeHead Integration is enabled.

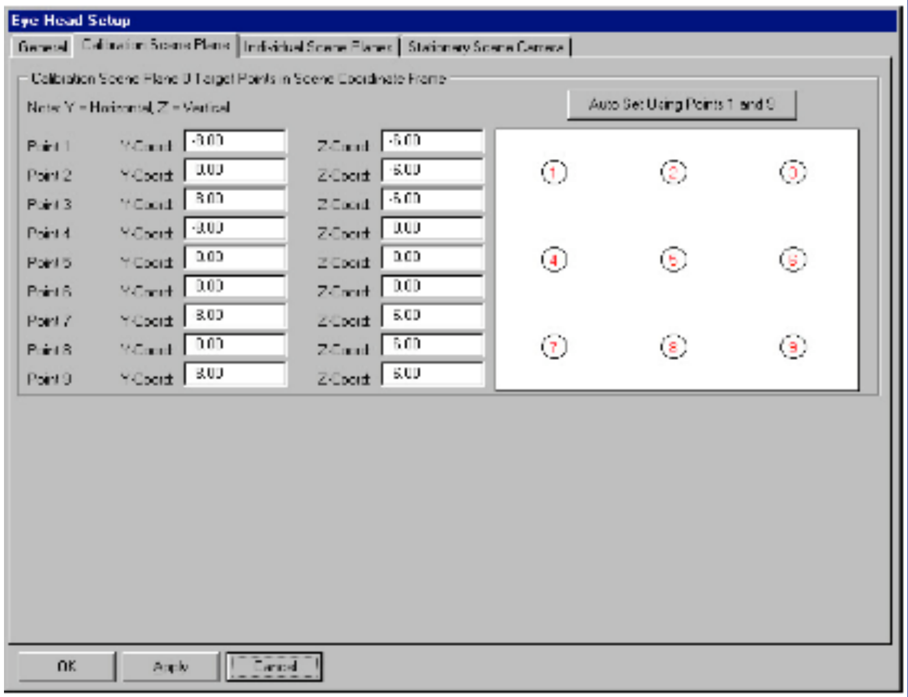


Figure 3-6. Eye Head Setup, Calibration Scene Plane dialog window

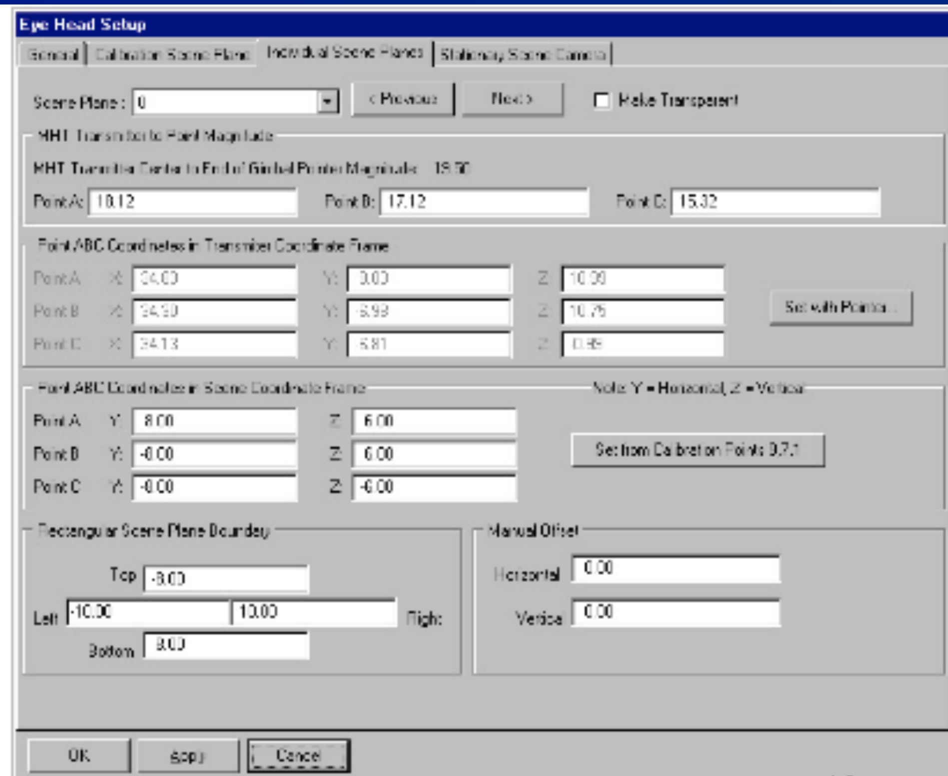


Figure 3-7. EyeHead Integration Setup, Individual Scene Planes dialog window.

Point of Aim and Eye Movement Behavior in a Rolling Task

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Introduction

- This study investigates vision's role in human motor control. More specifically, the visual fixations and the relationship between accuracy and visual target distance in bowling are examined.
- Final fixation is the last fixation that begins before the initiation of a movement, such as throwing. The consensus of previous studies is that expert performers tend to have earlier final fixation onsets. Final fixation duration is longer in successful trials as compared to misses; longer in experts than novices; and longer in more difficult tasks (Williams, Singer, & Frehlich, 2002).
- The location of point of gaze is critical. Experts typically spend more time looking at the target, as compared to other locations. In striking tasks such as putting, most of an expert's fixations are on the ball and the hole (Vickers, 1992). In throwing, performers have only one visual target (Vickers, 1996). However, bowling is a rolling task, which affords fixations on intermediate targets along the ground.
- To date there have been no studies on vision in bowling. There is only anecdotal evidence of the impact of target distance on performance. Bowlers typically use the arrows (~15 feet down the 60 foot lane) as a visual target.
- So, why are intermediate visual targets used in rolling tasks? And what is the most effective visual target distance in terms of spatial accuracy?

Methods

Participants

- 7 right-handed adult participants with normal or corrected to normal vision. All subjects were experts, as indicated by national collegiate competitive experience.

Task & Apparatus

- The task was to hit a visual target and a down-lane target with a bowling ball.
- Shots were thrown on a standard 41.5-inch wide, 60-foot long lane. Participants used their own balls and shoes.

Experimental Design & Procedures

- Four different visual target distances were used; trials were blocked by distance and the order of distances was randomized across participants. The distances were 20, 40, and 60 feet, as well as at the participant's preferred location.
- Participants performed 80 rolls (20 per target distance).
- Eye movement data was recorded using a pupil and corneal reflection system. Spatial accuracy of the ball was assessed via frame by frame video analysis.

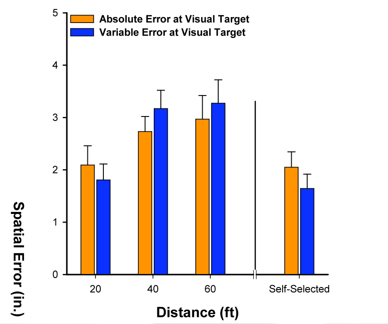
Data Analysis

- Absolute, Constant, and Variable spatial and temporal error were used as indices of performance accuracy.
- Final fixation duration was compared with the average fixation duration.
- Repeated measures ANOVAs were used to compare the mean differences between target distance conditions and paired t-tests were used to relate fixations to movement accuracy.

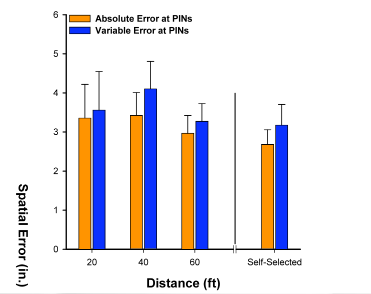
Results

Movement Accuracy

Visual target error increased as target distance increased

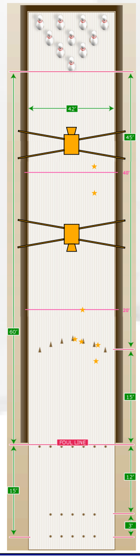


Final target error was least in self-selected and 60 feet condition



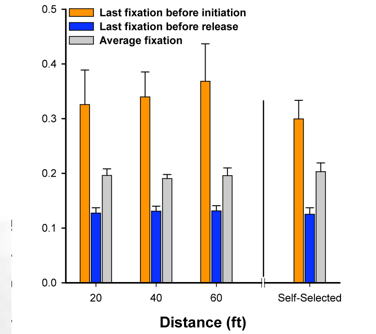
Visual Target Location

- Participants preferred aiming at spots between 12 and 42 feet down the alley. Two of the participants used a "break point" strategy aiming at the perceived point of ball break. The preferred points of aim are marked on the alley to the right with ★.

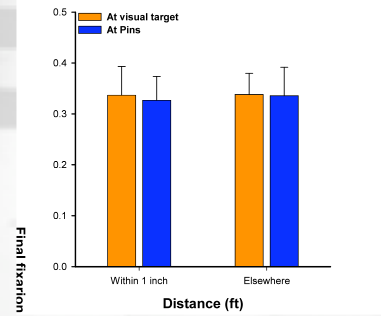


Fixation & Accuracy

Fixations were longest before movement initiation



Final fixation duration was not longer on accurate trials



Discussion

- Relative to the visual target, accuracy decreased as visual target distance increased. Relative to the pins, accuracy was greatest when aiming at the preferred distance, and second greatest when aiming at the pins (60-feet).
- Most participants preferred to look and aim at targets along the ball trajectory (intermediate targets rather than the pins). Participants were most accurate at hitting their visual target in the preferred condition.
- The final fixation time was longer than the average fixation time. Final fixation duration was not longer in accurate trials (when the ball came within +/- 1" of the target).
- The last fixation before release was not significantly longer on accurate trials.
- Accuracy in hitting a far target was improved by aiming at a closer point along the trajectory.

References

- Vickers, J. N. (1992). Gaze control in putting. *Perception, 21*, 117-132.
- Vickers, J. N. (1996). Visual control when aiming at a far target. *Journal of Experimental Psychology: Human Perception and Performance, 22*, 342-354.
- Williams, A. M., Singer, R. A., & Frehlich, S. (2002). Quiet eye duration, expertise, and task complexity in a near and far aiming task. *Journal of Motor Behavior, 34*, 197-207.

Preliminary target accuracy:

VE increased with target distance (significant)

AE increased with target distance (NOT significant)

Final target accuracy:

VE did not vary with target distance

AE lowest in preferred condition (significant)

Fixations:

The last fixation before movement initiation was longer than the average fixation duration during the approach (significant)

The average fixation duration during the approach was longer than the last fixation before release (significant)

The duration of the last fixation before initiation increased with target distance (NOT significant)

Fixation duration did not vary with preliminary target accuracy

Fixation duration did not vary with final target accuracy