Eye tracking for people who don't care about vision or how to get more dependent measures

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Why monitor eye movements?

- People can only get detailed info about a small area at a time, so they move their eyes
  - *fovea* provides detail for about 2º of visual angle
  - parafoveal & peripheral vision fuzzy; provide info for deciding where to foveate next
- Fixation location highly correlated with attention
  - tend to move eyes to what is attended
- Fixation duration correlated with cognitive processing difficulty
  - e.g., word frequency & contextual constraint in reading
- Eye tracking provides a non-intrusive, on-line measure of allocation of visual attention.
- Eye movement data may be informative about processing in a wide variety of tasks.

Properties of eye movements

- Eye position is stable for 200-300 ms (*fixation*) before rapidly moving (*saccade*) to a new location.
- Even when stable, there is jitter (*nystagmus*)
- During saccades, no new visual information acquired (*saccadic suppression*).
- Mean fixation duration and saccade distance vary with task & stimulus.
- Attention moves to a location in space before eyes do.
- Time to plan a saccade is 150-175 ms (*saccade latency*)
  - longer for bigger distances & more precise destination
- For study of information processing, usually ignore other types of eye movements
  - pursuit, vergence, vestibular

Some applications

- Moment-by-moment effects in reading
- Implicit memory for people & scenes
- Scope of planning in typing, music-reading, & speech production
- Options considered in decision making

Some dependent measures

- Fixation duration; # fixations; (often least useful for higher-level cognition studies)
- # gazes
  - Gaze composed of sequential fixations within experimenter-defined region
- p(fixating object); First pass gaze duration; Total gaze duration; also frequency of

particular sequences of gazes; mean saccade distance; saccade latency given a change in the display or a cue

Issues in data analysis

- How is data recorded?
  on video or as coordinates in a computer file?
- How is point of regard determined?
  hand-coded from video or automatically relating coordinates to 3D objects or 2D picture content?
- How are fixations, saccades, & blinks defined?
  variability in algorithms may lead to different fixation durations
- How are gazes defined?
  Do intermediate saccades count?

Data analysis

- Often the data must undergo a number of transformations to yield measures for analysis.
- Samples → fixations & saccades → gazes
- Even once gazes extracted, might need to consider timing of other processes.
  Onset of observers speech
  Onset of word in speech observer is listening to
  Onset of response

Video based tracking

- Infrared light (invisible) reflects off eye
- Infrared image recorded by video camera with filter
- Image processing software calculates locations of pupil and reflection off the cornea.
  Relative positions change with eye position
  Calibration procedure relates relative positions to fixating particular points in space
  Various methods for extrapolating to intermediate positions

(we'll ignore the more intrusive & difficult to use methods of eye tracking here, as well as those that don't provide point of regard)

Head-mounted eye trackers

- Pros
  Allow free movement of observer
  No programming necessary if use video output to record data
  Cheap ~$15-20,000
  Made by multiple companies who haggle (ASL, ISCAN, SMI)
- Cons
  Less temporal resolution (60 Hz; 1 sample every 16 ms)
  Large variability in quality of software
  Without head-tracker (~$4000) or reducing movement (chin rest), cannot output coordinates (X,Y) for point of regard

Sample use for head-mounted trackers

- Interactions with objects; movement
  Because not limited to showing flat stimuli
- Social interactions
  Because can face another person or 3D display
- Monitoring kids' eye movements
  Because fidgeting is OK

Remote eye trackers

- Pros
  Easy to get point of regard in (X,Y) coordinates
  Variety of temporal resolutions (60, 120, 240 Hz; samples every 16, 8, or 4 ms)
  No contact with observer
  Cheap ~$15-20,000
  Made by multiple companies who will haggle (ASL, ISCAN, SMI)
- Cons
  Only permits limited head-movements
  Often have trade-off between spatial & temporal resolution
  Only good for use with 2D displays (or other with stable distance from observer)
  Large variability in quality of software
  Limited field of view

Sample uses for remote tracker

· Ensure observers maintaining fixation in attention tasks
· Visual search & scene memory experiments
· Language production in younger & older adults
· Labeling effects in face perception
· Infant gaze direction

Very accurate: EyeLink from SMI

- Pros
  High temporal resolution (240 Hz; 1 sample every 4 ms)
  High spatial resolution (Gaze-position accuracy: 0.5° - 1.0° average error)
  Includes head tracker, so observer can move a bit
  Outputs (X, Y) point of regard
  Very good software generally
- Cons
  High price ~$45,000
  Some temporal precision lost in Windows version

Super accurate: Dual Purkinje Image trackers

- Pros
  - >1 Minute of Arc accuracy
  - Response time < 1 ms
- Cons
  - Requires a bite bar so your observer won't move around much.
  - Very expensive, about $70,000
  - Need custom software? Use ancient software from UMass?
- Uses
  - Oculomotor studies; those with gaze-dependent display changes; reading

Considerations in selecting a tracker

- Spatial accuracy needed
  - Reading? Sentences or paragraphs? Viewing pictures?
  - Observing big or small things? Dense or spaced?
- Temporal accuracy needed
  - Slow or fast processes studied?
  - Gaze contingent display changes?
- Conditions of use
  - Small room? Car? Multiple sites? In MRI scanner?
- Population of observers
  - Many with glasses? Bifocals? Weak necks? Fidgety children? Elaborate hair-dos?
- Observer activity
  - Viewing monitor? Moving objects? Talking? Walking?
- Form of data
  - Videotape of scene & point of regard? Coordinates on monitor/picture? On 3D scene?
- Other equipment involved
  - Stimulus display computer? Another tracker?
- Programming resources
  - Are you ready to design software for your needs?

Summary

- Eye tracking provides a non-intrusive, on-line measure of allocation of visual attention.
- Useful for studying a wide variety of questions.
- But relatively expensive to set up initially.
- Best system depends on task.
- Coping with large amounts of data or extracting most useful measure may prove challenging.

References to some basic eye movement studies & reviews

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URLs for more information

Eye tracking net http://www.eyetracking.net/

Eye movement equipment database http://ibs.derby.ac.uk/emed/

Archives of the eye movement listserv http://listserv.spc.edu/archives/eyemov-l.html