Psyc2965 -- Wk10

Eye Movements, Visual Attention, and Visual Search

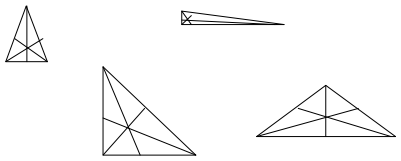
Types of Eye Movements

- **Saccades**
  - used to bring images of chosen objects to the fovea, the central region of the retina where resolution of fine visual detail is at its best
- **Smooth**
  - slower, continuous movements designed to track smooth motion of retinal images produced either by the motion of objects or by motion of the eye itself

Saccades

- *Saccades*
  - high-velocity eye rotations
  - A 10 degree saccade takes about 50 msec
  - Intersaccadic interval – has a minimum duration of 150 msec. 200-300 msec ISI are more common in active visual search or reading.
  - [illegible]: call this 250 msec for engineering purposes.

Saccades to Objects: Remarkably Precise



To triangle's center of gravity (intersection of the three bisectors of the three angles)

Saccades and Attention

- Eye movements are guided by selective attention
- Cannot make a saccade to one target while paying full attention to another target located somewhere else

What do the eyes tell us about cognition?

- **Saccades**
- **Blinks**
- **Pupil Dilation**

Inferring mental states from saccades

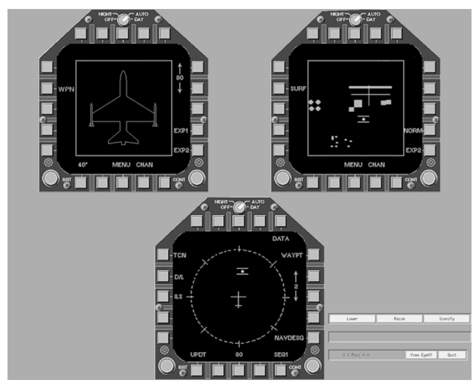
- Sequences of movement interpreted as providing clues about underlying cognitive strategy
- Ballard task example
  - Use of the display as external memory: a diectic strategy

Eye Blinks

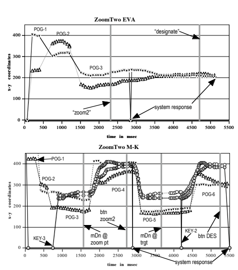
- **John Stern says that eye blinks “are the punctuation marks of cognition.”**
  - **(who is John Stern & why would he say such a thing?)**
  - **Examples from CogWorks Lab tasks**
  - **My conclusion -- correlational not causal. Treat with caution (until the CogWorks Lab Tech. Rpt. tells you otherwise.**

Pupil Dilation

- **Pupil dilation is thought to reflect cognitive effort**
- **Several problems with PD as a measure**
  - **Very noisy**
  - **Changes over time**
  - **Causality -- why should pupil dilations have anything to do with cognition?**
- **My conclusion -- a skeptical stance is justified -- (I’m from Missouri)**



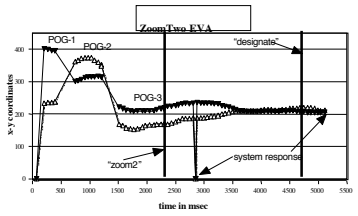
Cognitive workload: A measure of busyness?



CPM-GOMS Estimates of EVA vs M-K Cognitive Workload

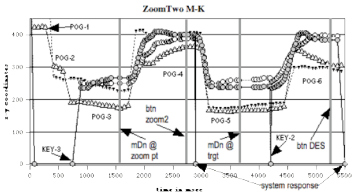
	M-K	Eye/Talk
Cognitive	31	18
Perceptual	14	8
Motor-mouse or key dn only	6	0
saccades	6	3
TOTALS	57	29

Lingering POG?



Rensselaer | Cognitive Science

CPM-GOMS & EVA



Rensselaer | Cognitive Science

Demos

- **Eye track data from**
  - **The button study**
  - **Argus Prime**

Rensselaer | Cognitive Science

Eye Movements & Visual Attention

- Salvucci, D. D. (2001). An integrated model of eye movements and visual encoding. *Cognitive Systems Research, 1*(4), 201-220.
- **Models often make two fundamental assumptions either explicitly or implicitly**
  - **Assume a direct correspondence between unobservable attention shifts and observable eye movements — that is, where people focus their attention is the same as where they look**
  - **Assume that the encoding of all visual objects requires the same amount of processing time — that is, what people encode does not affect how long they need to encode it**
- **Researchers agree that these assumptions, while they may hold in some cases, do not hold in general**

Rensselaer | Cognitive Science

EMMA

- **Salvucci's *Eye Movement and Movement of Attention* model**
- **Minimalist approach towards describing relationship between eye movements and visual encoding**
- **Eye movements**
  - **EMMA describes whether or not eye movements occur, when they occur, and where they land with respect to their targets**
- **Visual Encoding**
  - **EMMA describes how peripheral viewing and object frequency affect the time needed to encode a visual object into an internal representation**

Rensselaer | Cognitive Science

EMMA

- **Not intended to capture all known eye movement phenomena**
- **Is intended to demonstrate how a minimal description of these processes can significantly facilitate the modeling of cognitive and visual processing for common domains**
- **In addition, because it produces quantitative predictions about when and where the eyes move, EMMA serves as a useful tool for generating behavior at a fine-grained level and for comparing predicted behavior to observable eye movement data**

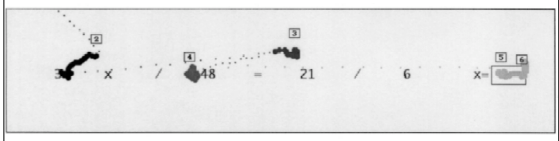
Rensselaer | Cognitive Science

EMMA

- Describes the interface between eye movements, visual attention, and a central cognitive process
- The interface is quite minimal:
  - cognition requests an encoding of some visual object (and thus a shift of visual attention)
  - EMMA handles the encoding process and resulting eye movements
  - provides the visual object to cognition when encoding is complete
- This minimal interface makes it easy to integrate EMMA with ACT-R or with any cognitive model or architecture that predicts shifts of visual attention from one visual object to another

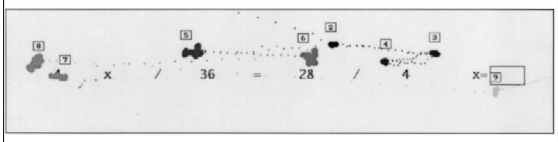
Eye movement ≠ to Visual Attention

- Fig. 1(a) illustrates how students sometimes encode the outermost values in their peripheral vision, and thus eye-movement rewide cords show no apparent fixations on these values.



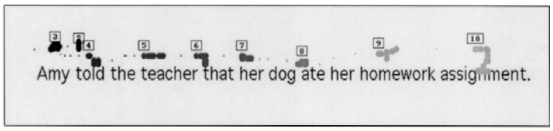
Eye movement ≠ to Visual Attention

- Fig. 1(b) illustrates how students sometimes produce multiple fixations on a single value (e.g., fixations 2–3–4 and 7–8) after undershooting or overshooting the value with an eye movement.



Eye movement ≠ to Visual Attention

- Fig. 1(c) illustrates how readers need not fixate every word as they read, even as they maintain almost perfect comprehension of the sentence (e.g., Schilling, Rayner & Chumbley, 1998).



Encoding time for visual objects is not constant

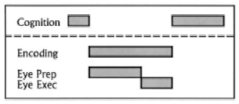
- Higher the frequency of encoding -- the faster the encoding
- The more eccentric the object, the slower the encoding (eccentric = distance from current POG)

EMMA

- Introduces focuses on the effects of
  - object frequency and
  - foveal eccentricity
- on the interaction between voluntary eye movements, visual encoding, and cognitive processes

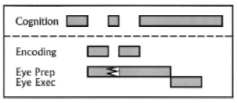
Control Flow in EMMA

- Control Flow = the interaction of the cognitive processor (Cognition), visual encoding (Vision), eye-movement preparation (Eye-Prep), and eye-movement execution (Eye-Exec)
- Simplest case
  - encoding requires the same amount of time as an eye movement
  - (the cognitive processor cedes control to visual encoding and receives control back when encoding is complete)



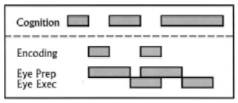
Control Flow in EMMA

- Case where encoding completes and cognition requests a subsequent shift of attention before the eye movement has completed
- Example 2b -- eye-movement canceled, new eye-movement begun



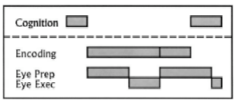
Control Flow in EMMA

- Example 2c -- Attention shift occurs during eye-movement execution
  - Execution runs to completion even while a new eye movement is begun



Control Flow in EMMA

- Example 2d -- eye-movement completes before encoding completes
  - Encoding continues even as a new eye movement is being prepared
  - (But speed of encoding increases as visual object is nearer to the fovea)



Control Flow in EMMA -- Summary

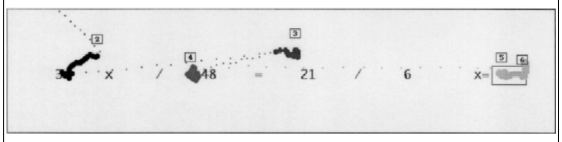
- EMMA incorporates indirect link between encoding and eye movements that decouples unobservable attention shifts and observable eye movements
  - attention shifts occur at the initiation of encoding
  - the actual eye movement only occurs after programming completes at some later time
  - Thus, temporal lag between unobservable attention shifts and observable eye movements

Control Flow in EMMA -- Summary

- EMMA encoding and cognition proceed normally during a saccadic eye movement
  - Some evidence that encoding stops during a saccade
  - But data are contradictory
  - EMMA opts for the simpler model and allows encoding and cognition to proceed during an eye movement

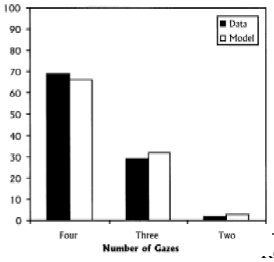
EMMA Models versus Data

- Equation solving



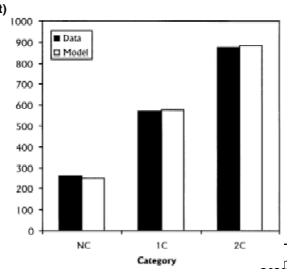
Equation solving

- Fig. 3. Percentage of trials with four, three, and two gazes in the equation-solving task



Equation Solving

- Fig. 4. Gaze durations by computation in the equation-solving task. NC gazes involve no computation, 1C gazes involve one computation (i.e., an intermediate value), and 2C gazes involve two computations (i.e., an intermediate value and the final result)



EMMA -- Summary

- Equation solving data provide a good demonstration of the interaction between oculomotor and cognitive processes
- The equation solving model successfully fits lower-level behavior in terms of gaze durations and fixation landing points
- The fixation duration measures are clearly influenced by cognitive processing — namely, the computation of intermediate results during problem solving
  - This aspect of the model helps to explain why some gazes are significantly longer than others (approximately 200–300 ms for gazes during which no computation occurs, versus 500–900 ms for gazes during which computation occurs).

Reading

Table 4
Skip, one-fixation, and two-fixation probabilities across frequency classes for data (Reichle et al., 1998) and model

Class (per million words)	Mean frequency	Skip probability		One-fixation probability		Two-fixation probability	
		Data	Model	Data	Model	Data	Model
1	3	0.10	0.09	0.68	0.84	0.20	0.07
2	45	0.13	0.19	0.70	0.77	0.16	0.04
3	347	0.22	0.30	0.68	0.68	0.10	0.02
4	4889	0.55	0.55	0.44	0.44	0.02	0.01
5	40,700	0.67	0.78	0.32	0.22	0.01	0.01
R	–	0.99		0.97		0.96	

EMMA -- Summary

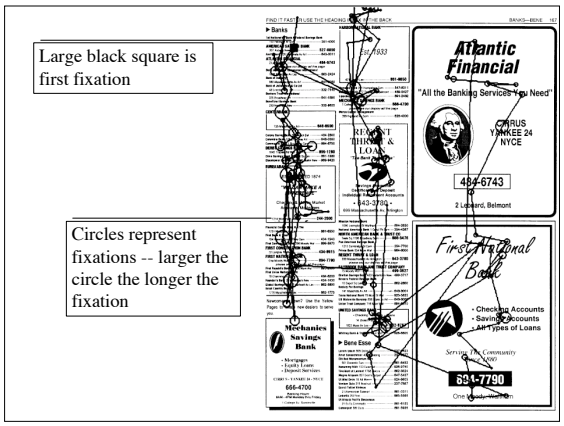
- Reading model also shows the interaction between oculomotor factors (such as eccentricity) and more cognitive factors (such as frequency of reading a word)

Lohse -- Yellow Pages

- Yellow Pages are big business (still)
- Business pay by the size and color and graphics of an ad
- (Probably same with web pages)
- Would be nice to have some hard data rather than opinion data

Hypothesis Investigated

- P1a: color ads noticed before any other type of ad
- P1b: large ads before small ads
- P1c: graphics before ads w/o graphics
- P2: ads near beginning of heading more likely to be noticed (serial position effect)
- P3: more time spend on ads for businesses that are chosen than time spent on businesses not chosen.



Dependent Variables (DVs)

- How to turn eye data into interpretable data
- Attention to ads
  - Noticed ads defined as having at least one eye fixation
  - Minimum fixation duration was 100 msec (6 samples at 16.67 m per sample)
- Search Patterns
  - Fixations numbered from 1 to n. Mean value of fixation number indicates the relative order in which people viewed an ad.
  - Serial position of a business refers to the alphabetic ordering of each listing on a page.
- Viewing Time
  - Total time (in sec) that a subject viewed an ad

DVs

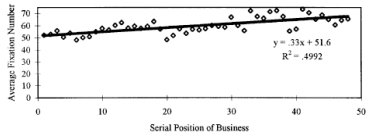
- Definition of three DVs (attention, search, and viewing time) raise causal construct validity issues -- (as per Gray & Salzman, 1998)
- Do fixations = attention?
- Does fixation order = search order?
- Does viewing time = processing time?
- Lohse's assumptions make minimal demands on theories of cognition (measurements are almost *intuitive*)

Attention to Ads

- Large ads noticed more than small ads
- Color ads noticed more than non-color
- graphics had no effect (but this may be a ceiling effect)

Search Patterns

- **Serial position important**

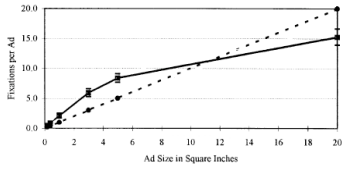


Search Patterns

- For display ads only (1/4 page and 1/8 page)
  - color ads noticed before non-color
  - large before small
  - graphics not an issue
  - ads with more information noticed before those with less information

Viewing Time

- More time per ad size, though this function peaked at 5 sq inches and declined for largest ad
- More fixations per size -- but fixations per sq inch are at a maximum for ads of 5-sq inches



Conclusions

- **Eye movement are a type of behavior**
- **Governed by both oculomotor and cognitive processes**
- **Approximate modeling techniques such as EMMA hold promise for integrating accounts of eye movement behavior with accounts of higher level behavior (as per Anderson's 7 Orders of Magnitude paper)**
- **With a minimum of theoretical assumptions (as per Lohse) can use eye data to do some important practical work**