EYE PATTERNS

COGAIN
Communication by Gaze Interaction

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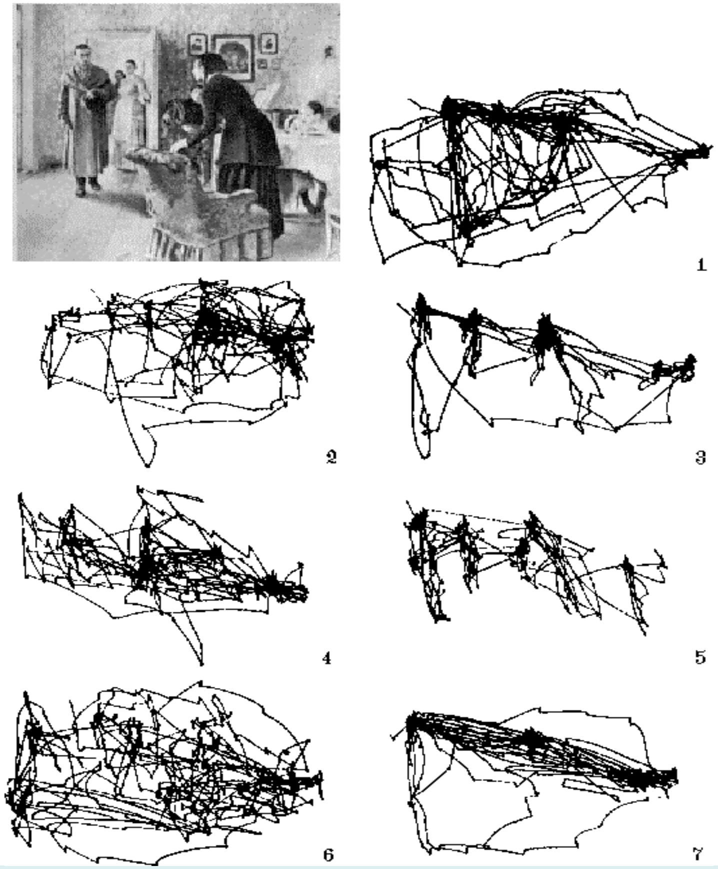
Contents

- Motivation: why eye patterns?
- Building blocks of eye patterns
  - Areas of Interest
  - Clusters of fixations
- Eye patterns as strings
- Operations on strings
- Discussion

Dynamic Replay of Gaze Paths

- How much can you remember after the replay?
- How can you compare several gaze paths?

Yarbus’s Early Scanpath Recording



1. examine at will
2. estimate wealth
3. estimate ages
4. guess previous activity
5. remember clothing
6. remember position
7. time since last visit

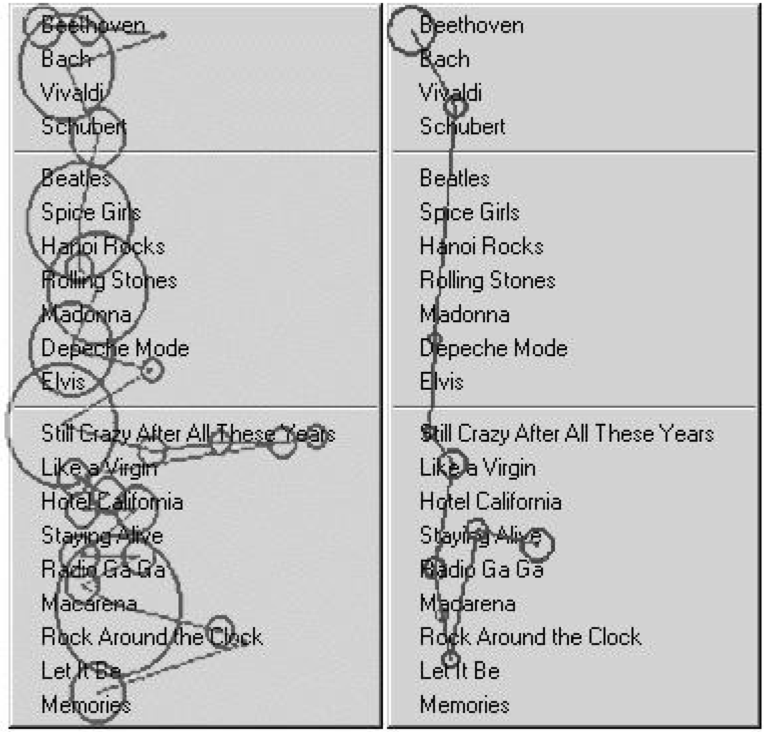
Source: Yarbus (1967), p. 174

Static Visualizations Can Tell a Lot

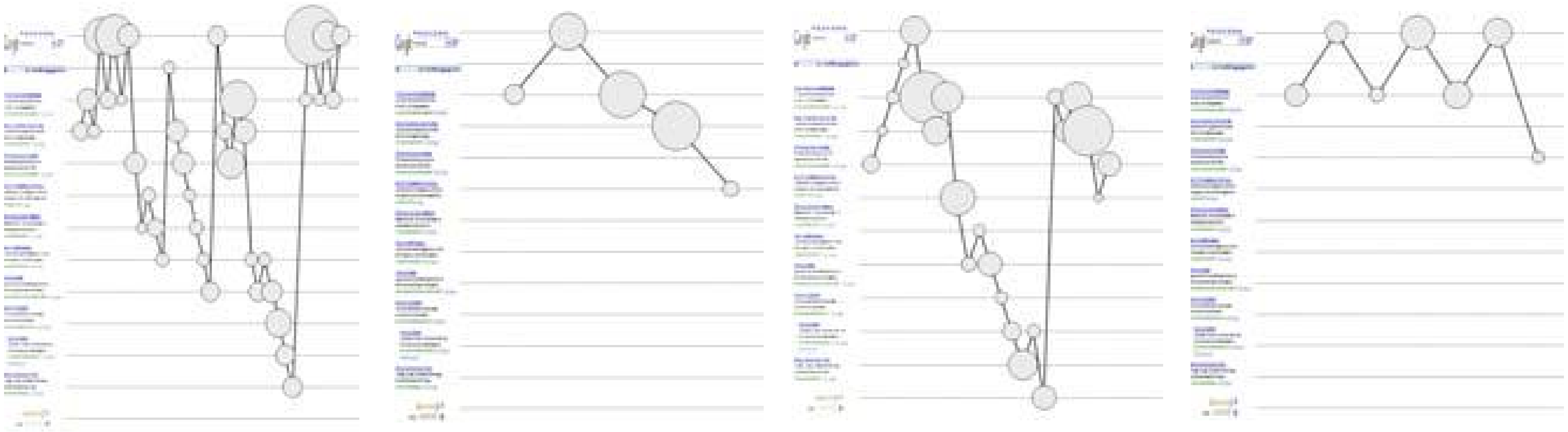
- They can be useful in characterizing typical gaze paths if the explaining variable is known (or can be guessed) in advance
- *Task* is often an important explaining variable

Typical Static Visualizations

- Fixations are represented as circles
- Radius is proportional to duration
- Saccades are represented by lines



Another Visualization



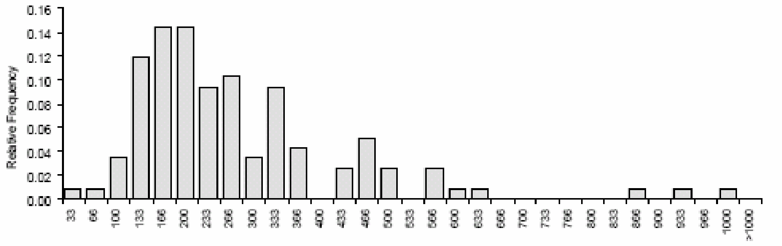
- Hypothesis: experts and novices will produce different gaze paths
- Differences could be observed visually – but expertise was *not* the explaining variable
- Comparison is still very difficult è analytical methods desirable

Source: Aula, Majaranta, & Räihä (2005)

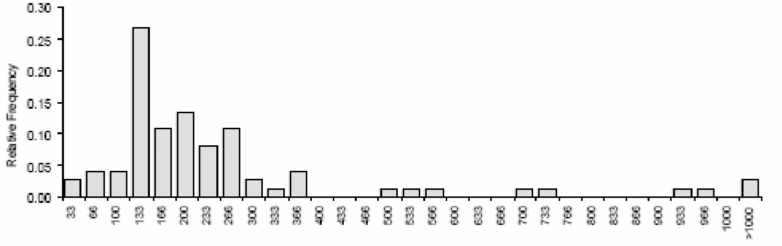
A Variety of Goals

- Dynamic vs. static
  - Dynamic playback: full information
  - Static visualization: more amenable to analysis
- Real time vs. post hoc
  - Real time: prediction in attentive interfaces
  - Post hoc: analysis of empirical data
- Goal of the analysis
  - Activity detection
  - Attention detection

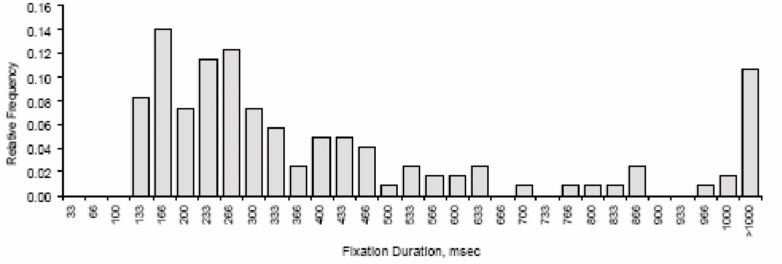
Activity Detection 1: Distribution of Fixation Durations



reading



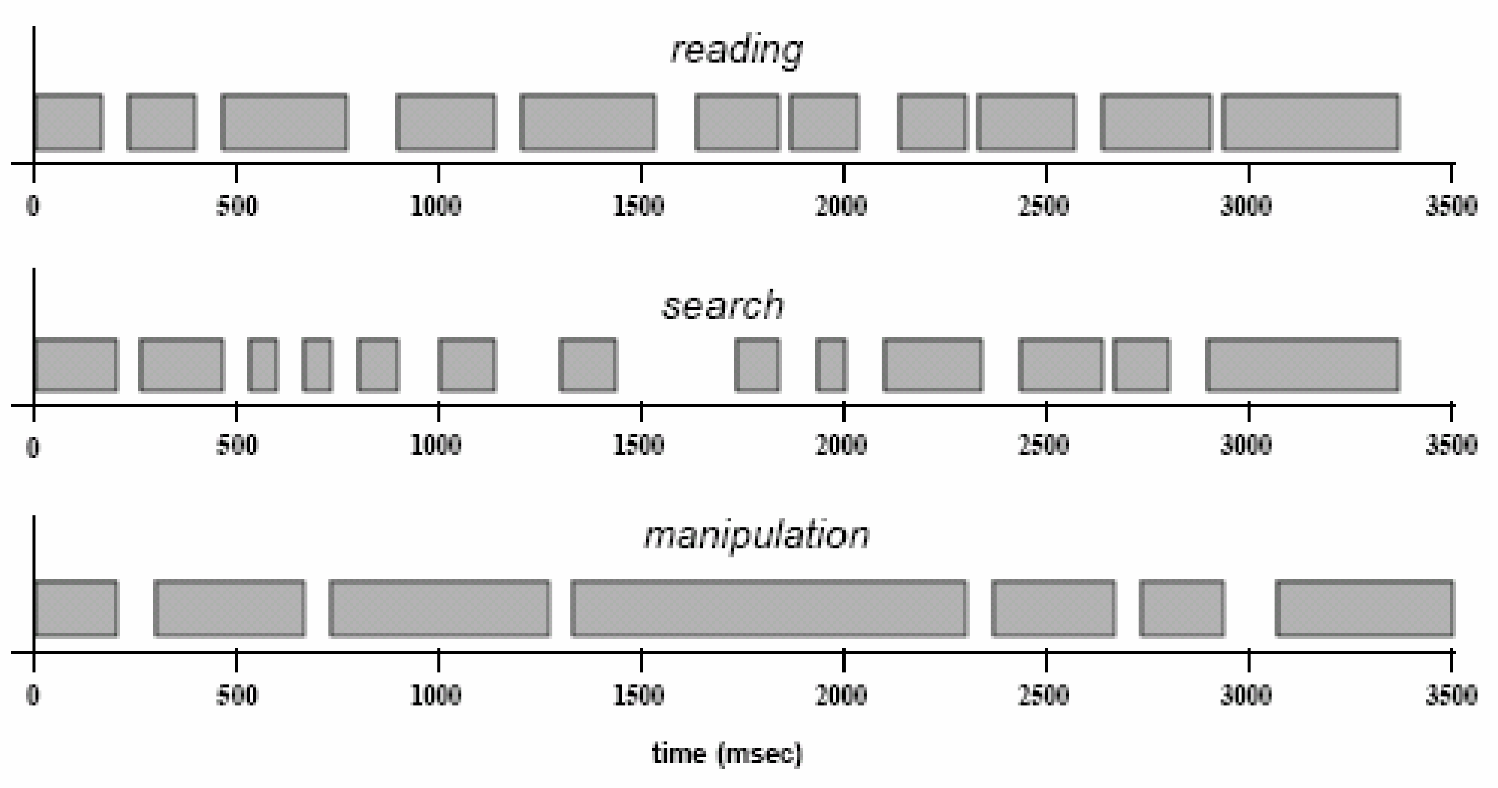
search



manipulation

Source: Pelz, Canosa, & Babcock (2000)

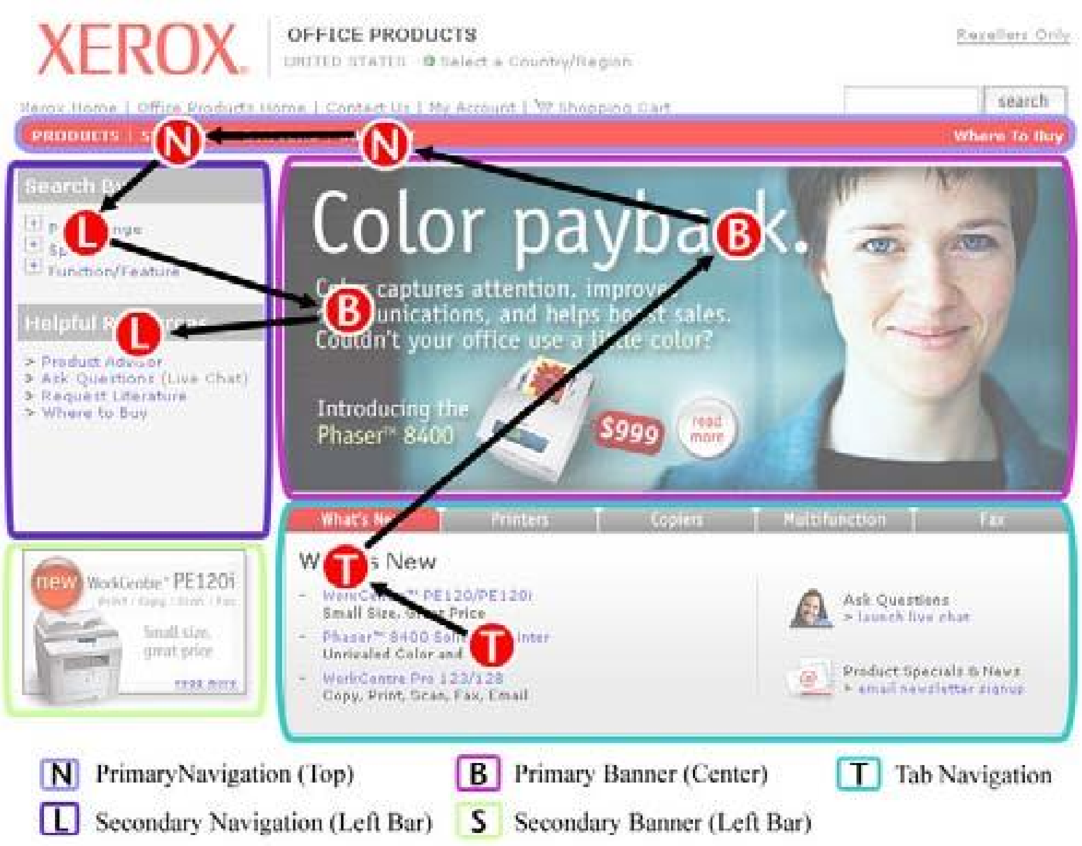
Activity Detection 2: Sequences of Fixation Durations



Source: Pelz, Canosa, & Babcock (2000)

Sequences – an Abstraction of the Data

- Fixation sequence: TTBNNLBL
- Gaze sequence: TBNLBL
- Abstracted away
  - duration
  - exact location



Source: West et al. (2006)

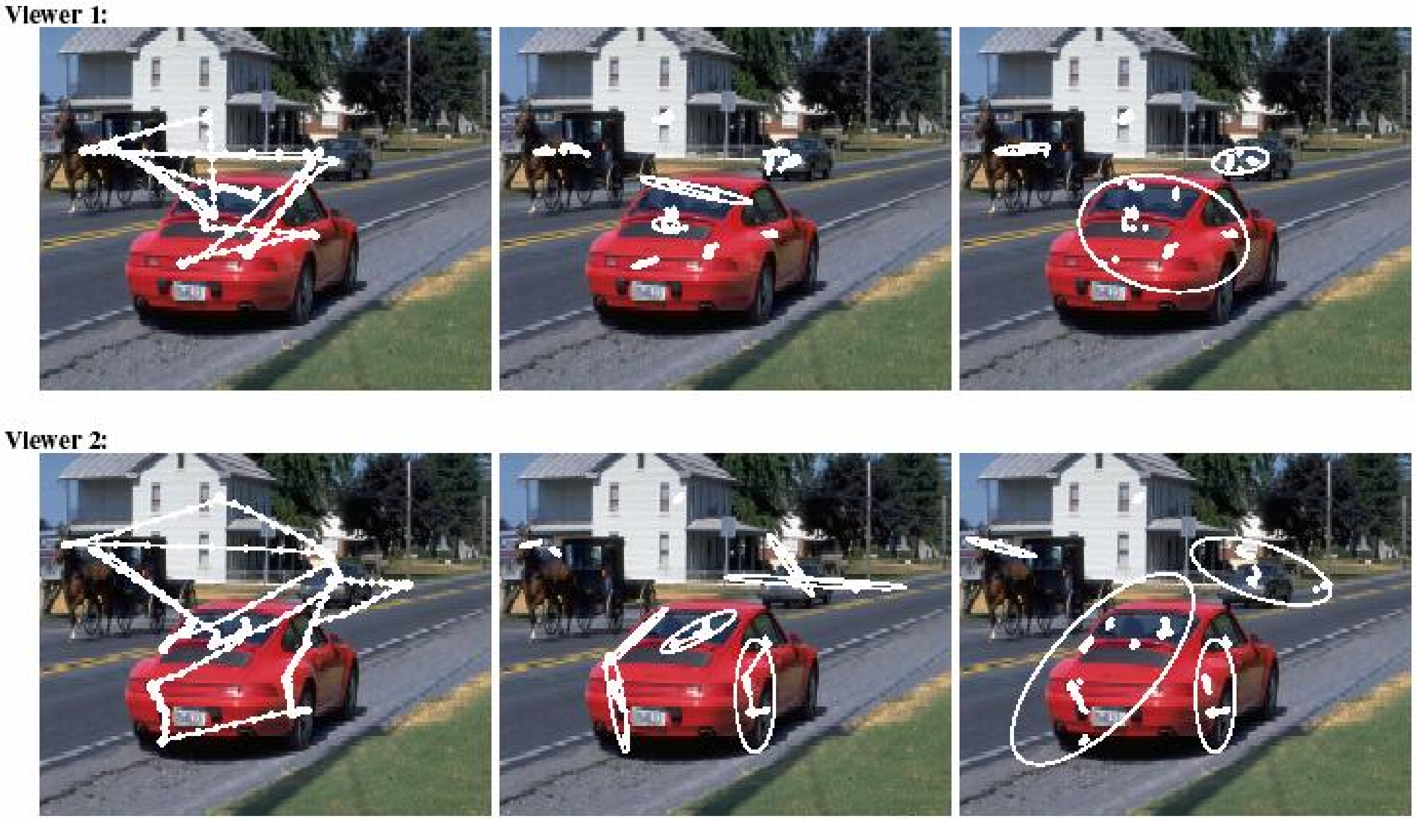
Possible Problems

- Inaccuracy of eye trackers – borderline fixations assigned incorrectly
- With natural targets, it is difficult to know what the interesting areas are
  - especially in advance
  - but also after the data has been collected

Clustering

- Blocks of fixations that seem to belong together are computed automatically *from the data*
- Privitera & Stark (2000)
- DeCarlo & Santella (2004)
- Heminghous & Duchowski (2006)

Gaze Clusters



POR data | Gaze clusters with $\sigma_s = 100, \sigma_t = \frac{1}{3}$ | Regions-of-interest with $\sigma_s = 100$

Source: DeCarlo & Santella (2004)

String Edit Distance 1/2

- Minimum number of insert and delete operations needed to transform one string into the other
- Example: find the distance between TTBNNLBL and TBBNLBL
- Trivial solution:
  TTBNNLBL à ~~TTBNNLBL~~ à TBBNLBL 15
- Distance always at most the sum of the lengths of the strings
- A better solution:
  TTBNNLBL à T~~T~~BN~~N~~LBL à TBBNLBL 3

String Edit Distance 2/2

- Origin in stringology and data structure research
- Can be efficiently computed by dynamic programming
- Also called “Levenshtein distance”
- Extensively used (and extended) in bioinformatics

- For us: can serve as a measure of similarity of two gaze paths

Is It a Good Measure?

- What do “delete” and “insert” mean in terms of AOI’s?
  - One user has seen something that the other has not
  - This may be highly significant or meaningless depending on the area in question – this is ignored by the metric
- A transposition is a costly operation (1 delete + 1 insert = 2)
  - In practice, it may have little meaning
- Is the cost function the right one?

Variations

- Take “transpose” as one of the primitive (cost 1) operations
- Make the cost function more dynamic
  - Different costs depending on the areas
  - Different costs depending on the operation
  - …
- A collection of cost functions (“penalties”) can be used: the Needleman-Wunsch algorithm

Eye Patterns as Strings

- Each gaze path is represented as a string
  - ABCABBCDFFGGA
  - AGGFFDSBBACBA
  - GAGFFDSBBACBA
  - GSF
  - GFGFGFGAAAGGF
  - ABABABFFCDFFGGA
- Are they similar? How similar? Are there groups of similar paths?

Shortest Common Supersequence

- Find a sequence, as short as possible, so that you can embed each of the gaze paths in that sequence
- Probably not a good idea
  - Almost similar paths can produce a much longer supersequence
    ABCA
    ABDA
    ABEA è supersequence ABCDEFGA
    ABFA
    ABGA
  - NP-complete è computationally hard

Averaging Gaze Paths

Browsing

Memorizing

Source: Hembrooke, Feusner, & Gay (2006)

Possible Problem

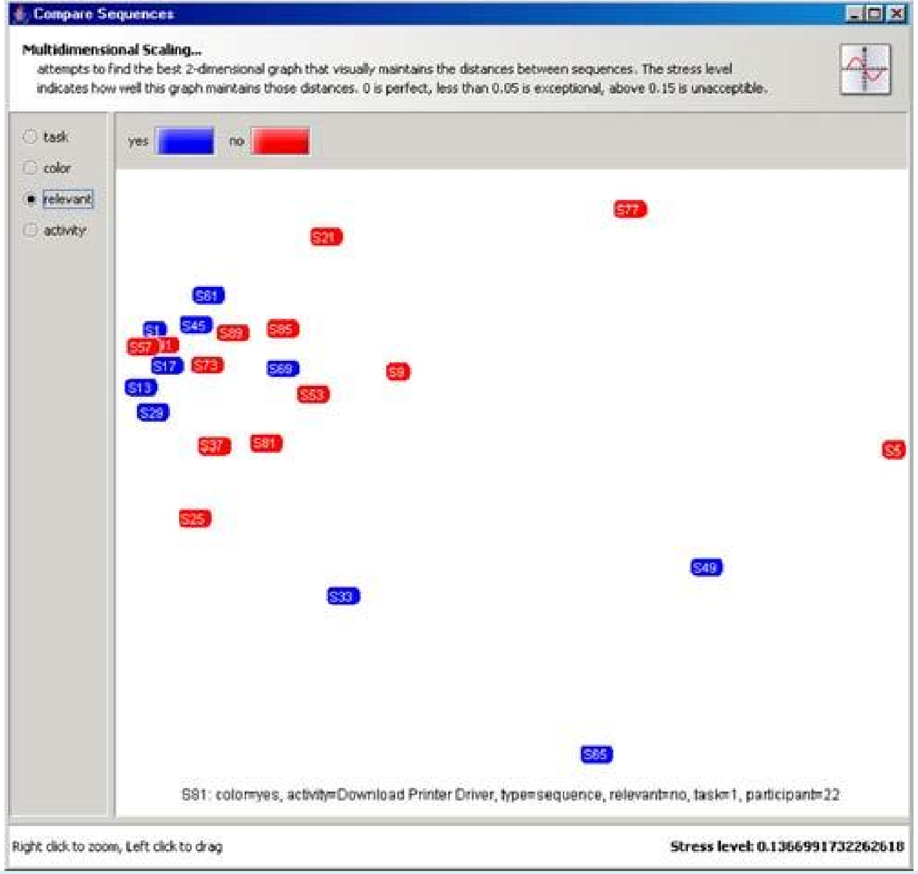
- The average path *may* look quite different from any of the paths in the set
- Hembrooke, Feusner, & Gay claim that this is not the case
- More experience needed

Interactive Tool: eyePatterns

- Let the user explore the collection of gaze paths interactively
- Functions include
  - Visualize sequence similarity
  - Find common patterns in the paths, including longest common subsequence
  - Compute transition probabilities between AOI's
  - Compute average gaze path ("consensus sequence")

Source: http://juliamae.com/eyepatterns/, also West et al. (2006)

Visualization of Sequence Similarity



Compare Sequences

Multidimensional Scaling...

attempts to find the best 2-dimensional graph that visually maintains the distances between sequences. The stress level indicates how well this graph maintains those distances. 0 is perfect, less than 0.05 is exceptional, above 0.15 is unacceptable.

○ task
○ color
● relevant
○ activity

yes 🟦 no 🟥

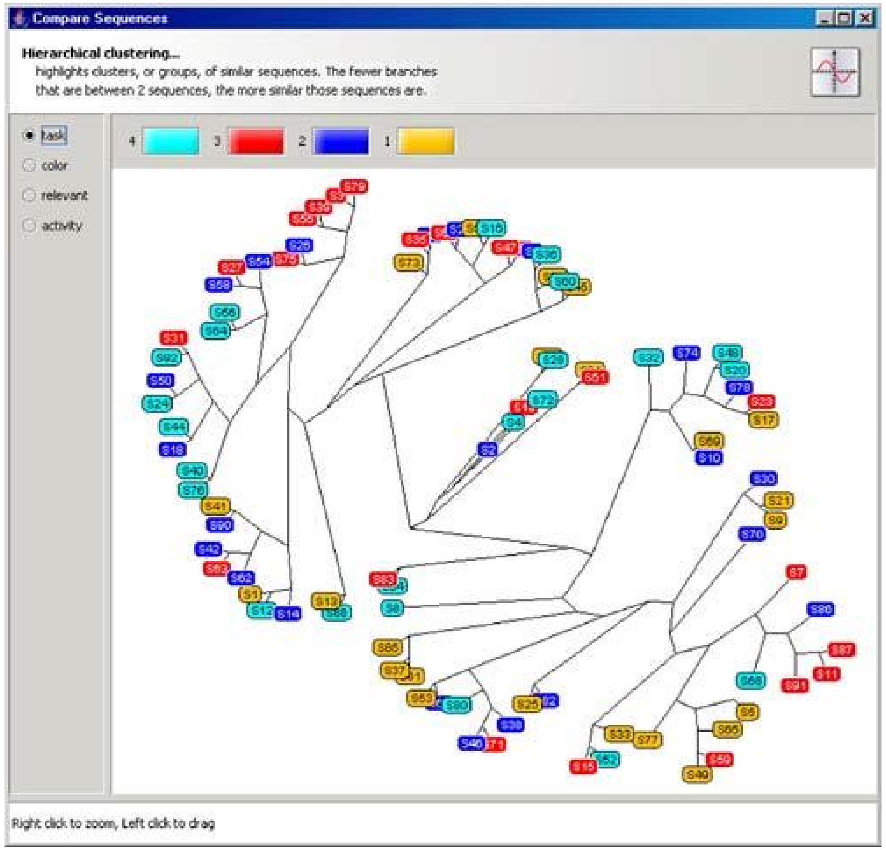
S81: color=yes, activity=Download Printer Driver, type=sequence, relevant=no, task=1, participant=22

Right click to zoom, Left click to drag

Stress level: 0.1366991732262618

Source: West et al. (2006)

Cluster-Based Visualization



Compare Sequences

Hierarchical clustering...

highlights clusters, or groups, of similar sequences. The fewer branches that are between 2 sequences, the more similar those sequences are.

● task
○ color
○ relevant
○ activity

Right click to zoom, Left click to drag

Source: West et al. (2006)

Are Sequences Too Simple?

- Another abstraction: probabilistic automata
- In particular, Hidden Markov Models

- Lots of room for experimentation!

References

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