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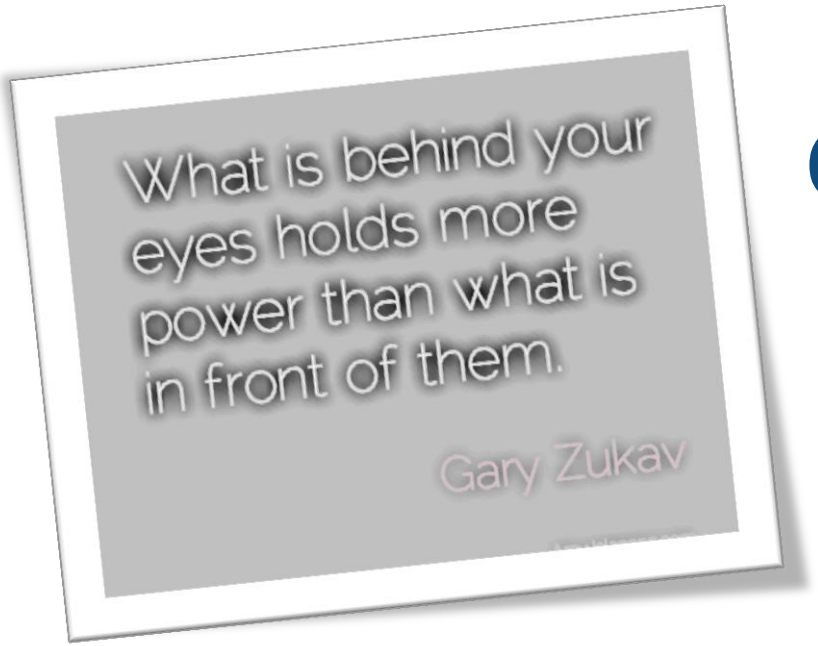
FACULTEIT WETENSCHAPPEN



DESIGNING AND CONDUCTING USER STUDIES

MODULE 4:

When and how to apply Eye Tracking

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carto gis research unit

geografie vakgroep Universiteit Gent

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Eye Tracking – Application Domains

- Usability research
  - Software, websites, etc.
- Virtual reality and simulators
- Psychological research
  - Brain imaging, reading, visual search, scene perception, etc.
- Marketing/advertising
  - Print advertising, ad placement, product label design
- Computer science
  - Eye based interaction

WHAT IS EYE TRACKING?

Time	Type	Trial	L POR X [px]	L POR Y [px]
15256356851	SMP	1	589,64	590,82
15256365267	SMP	1	586,6	587,1
15256373592	SMP	1	824,04	396,63
15256390210	SMP	1	589,08	584,7
15256398588	SMP	1	592,91	580,93
15256406933	SMP	1	588,32	578,83
15256423568	SMP	1	594,35	580,26
15256431942	SMP	1	594,57	579,7
15256440305	SMP	1	598,26	575,05
15256448557	SMP	1	598,33	571,11
15256456954	SMP	1	597,96	569,4
15256465310	SMP	1	597,92	571,55
15256481930	SMP	1	600,35	570,2
15256490314	SMP	1	601,55	571,8
15256498681	SMP	1	603,14	568,78

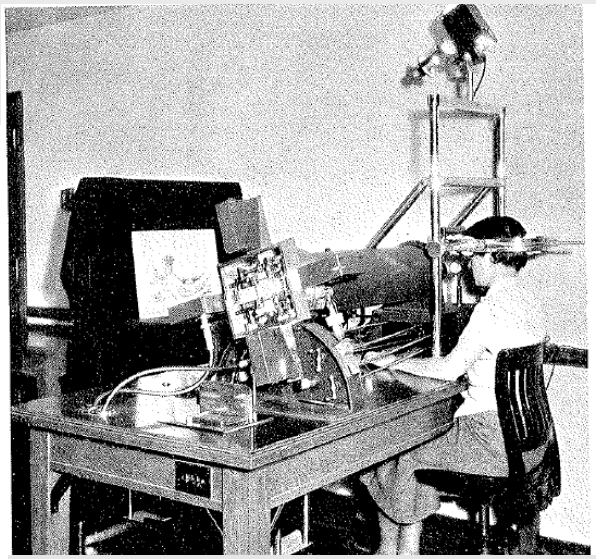
- Tracking the user's eye movements
  - Sampling rate (times/second)
  - Current location of eyes on screen/picture/etc.
  - (x,y,t) → 'raw data'

- Metrics and measurements
  - Deriving meaningful metrics from raw data
    - *fixations, saccades, smooth pursuit*

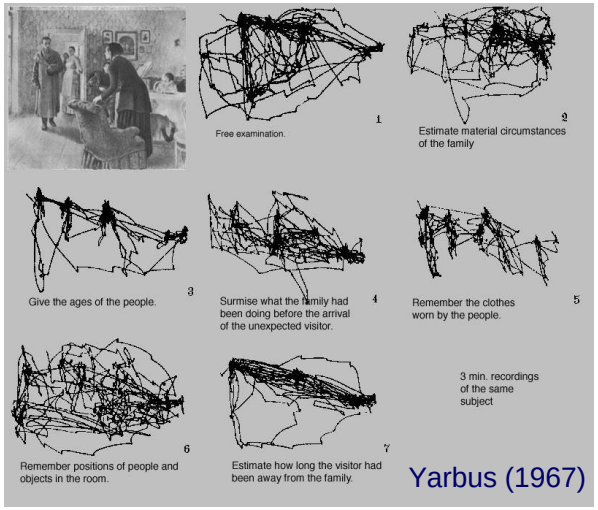
- Stimuli and tasks?
  - Medium: paper, screen, etc. ?
  - Subject: VR, websites, simulators, maps, etc.
  - Analysis: qualitative, quantitative, visual, statistical, etc.

… A LITTLE BIT OF HISTORY

- Earliest research: 1880 – 1920
  - Basis facts about eye movement discovered
- Phase with more applied focus, little research
  - Buswell: “How people look at pictures” (1935)
  - Tinker (1946)
    - *Cannot learn much from eye tracking data*
    - *Limits of technology*
  - Fits et. al (1950)
    - *Study eye movements of pilots in cockpit*
    - *First use in usability engineering*
- Clear visualization of eye movements
  - Yarbus (1967)
  - Shows importance of eye movement recordings



Source: http://psych.wfu.edu/art_schirillo/articles/Buswell,%201935.pdf



Yarbus (1967)

… A LITTLE BIT OF HISTORY

- Recent evolution
  - *1970s:*
    - *Improvements in eye movement recording systems*
    - *Advances in psychological theory*

  - *1980s:*

    → Use of eye tracking in real time

    -Human-Computer interaction

    -Disabled users

  - *1990s*

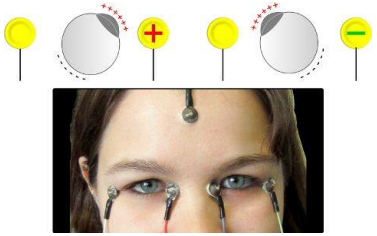
    → Solving usability problems

    -Internet, websites, emails, video-conferencing, …

EYE TRACKING … TECHNIQUES

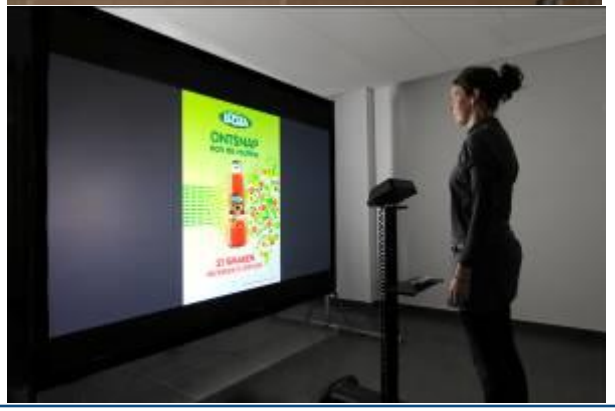
- Eye tracker: device for measuring eye movements
  - Two types of eye movement techniques
    1. *Measure position of the eye relative to the head*
    2. *Measure orientation of the eye in space*
       - *"point of regard"*
       - *Most suited for graphical and interactive applications*
  - Four categories of eye tracking methodologies
    1. *Electro-OculoGraphy (EOG)* *(mid '70)*
    2. *Scleral contact lens/search coil* *(earliest)*
    3. *Photo-OculoGraphy (POG) or Video-OculoGraphy (VOG)*
    4. *Video-based combined pupil and corneal reflection*

       (currently most used methodology)



EYE TRACKING … TECHNIQUES

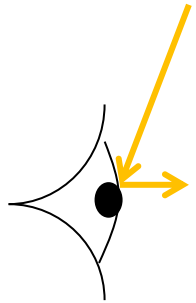
- Video-based combined pupil and corneal reflection

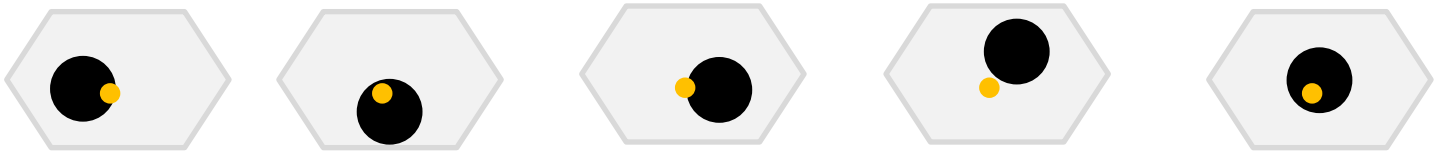


EYE TRACKING … TECHNIQUES

- Video-based combined pupil and corneal reflection
  - Gives 'point of regard' (POR) measurements!
    - Head must be in a fixed position, or
    - multiple ocular features must be measured:
      → *corneal reflection*
      → *pupil center*

  - Corneal reflections (from infra-red light source)
    - Purkinje reflections or images
    - Eye rotations: relative positional difference with pupil center
    - Appropriate callibration: determining user's POR





… DEMO …

- Measurements:
  - Points Of Regard at certain sampling rate
    - *Calibration!*
    - *x, y: screen coordinates*
    - *Timestamp*
    - *Huge amount of 'raw data'*

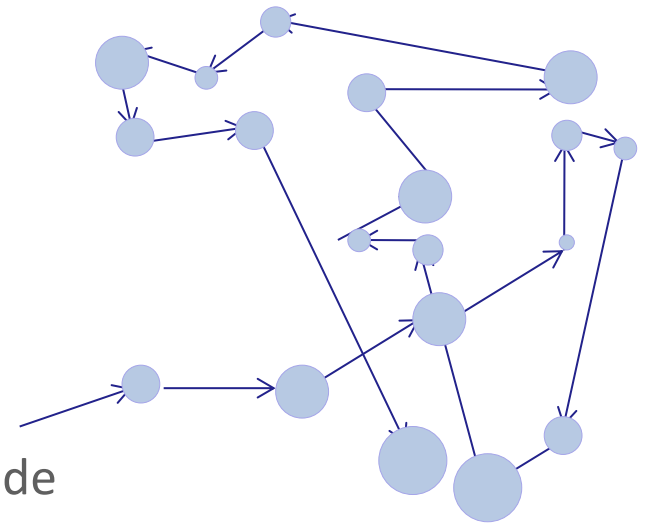
  - Deriving metrics:
    - Fixations, Saccades, (Smooth Pursuit)

METRICS

- Metrics:
  - Fixations
    - Stable relative position pupil – corneal reflection

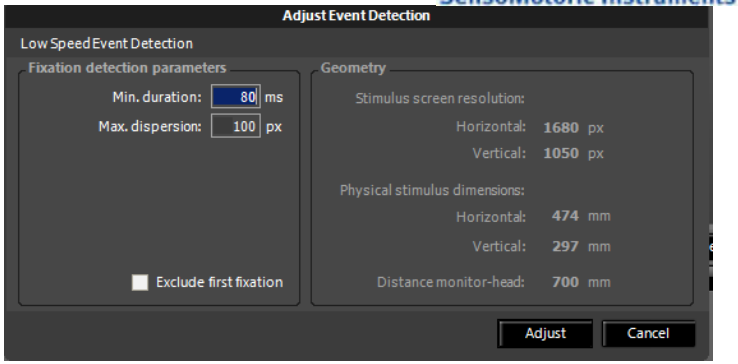
      → *dispersion = ??? (40px; 0.5° visual angle; …)*
    - During certain period

      →*minimum duration = ??? (80 – 150 ms)*
  - Saccades:
    - Rapid eye movements
    - Reposition of fovea
    - Person does not ‘see’ anything during saccade

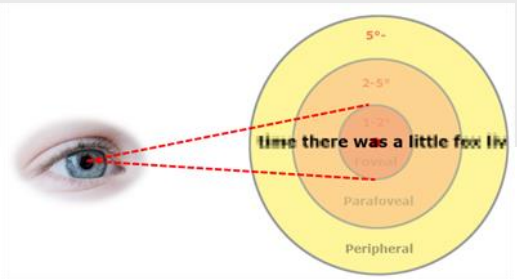


…DEMO…

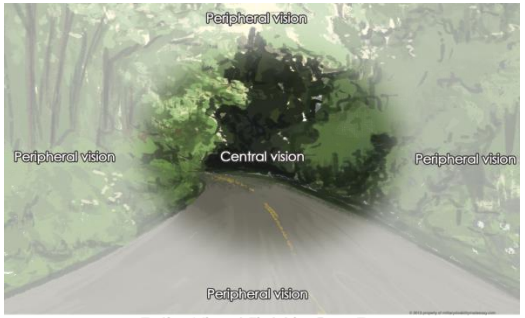
- Raw eye movements vs. fixations
  - Example dataset SMI 120Hz
  - Example in OGAMA
    - 60 Hz



METRICS & MEANING



- Metrics → meaning?
  - Link eye movements - attentive behavior
    - *Can shift attention without movement of the eyes!*
    - *Central and peripheral vision*
    - *Attention precedes a saccade to a certain location*
    - *Complex task → link is very tight*



Entire Visual Field in One Eye

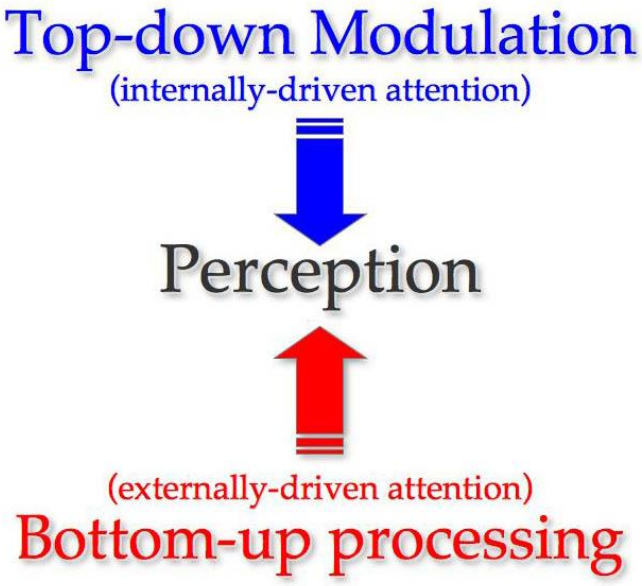
    - *Need of peripheral vision*

    - *Need of attention*

METRICS & MEANING

METRICS & MEANING

- Metrics → meaning?
  - Link eye movements - attentive behavior
  - Data Interpretation



"Information processing is guided by **higher level mental processes**. When we construct our perception drawing on our **past experiences** and **expectations**"

"The most **basic sensation** and **perception**. Entry Level" sensory analysis"

METRICS & MEANING

The forest has eyes

METRICS & MEANING

- References:
  - Book of Holmqvist et. al (2011)
  - Jacob & Karn (2003)
    - *20 different usability studies*
    - *Most commonly used metrics:*
      - *Number of fixations, overall*
      - *Gaze % (proportion of time) on each of the AOIs*
      - *Fixation duration mean, overall*
      - *Number of fixations on each of the AOI*
      - *Gaze duration mean, on each of the AOI*
      - *Fixation rate,overall (fixation/saccades)*

METRICS & MEANING

- Related to Fixations *(Overview by Poole & Ball, 2005)*

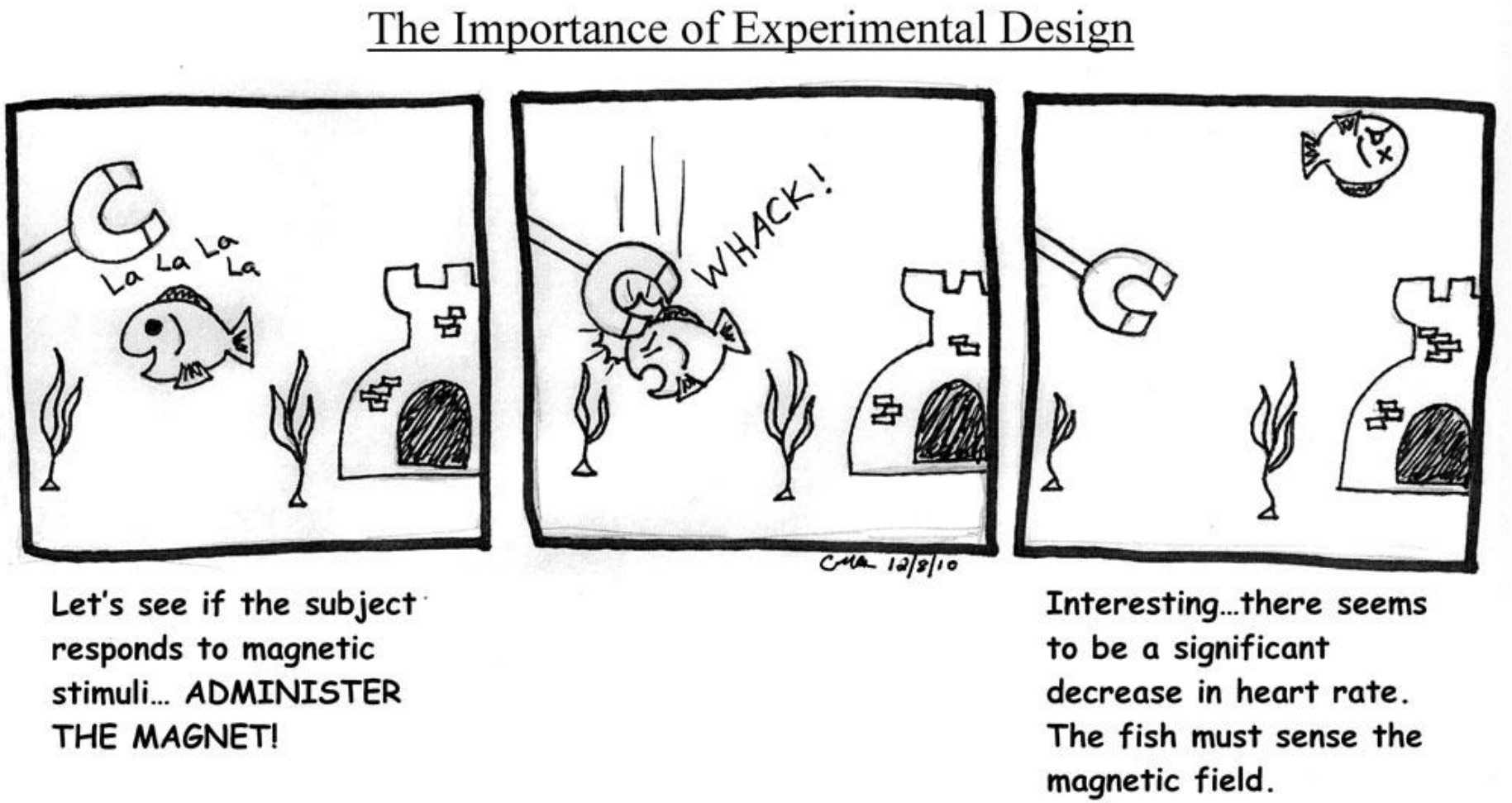
Eye-Movement Metric	What it Measures	Reference
Number of fixations overall	More overall fixations indicate less efficient search (perhaps due to sub-optimal layout of the interface).	Goldberg & Kotval (1999)
Fixations per area of interest	More fixations on a particular area indicate that it is more noticeable, or more important, to the viewer than other areas.	Poole et al. (2004)
Fixations per area of interest and adjusted for text length	If areas of interest are comprised of text only, the mean number of fixations per area of interest should be divided by the mean number of words in the text. This is necessary to separate out: (i) a higher fixation count simply because there are more words to read, from (ii) a higher fixation count because an item is actually harder to recognise.	Poole et al. (2004)
Fixation duration	A longer fixation duration indicates difficulty in extracting information, or it means that the object is more engaging in some way.	Just & Carpenter (1976)

METRICS & MEANING

- Related to Saccades *(Overview by Poole & Ball, 2005)*

Eye-Movement Metric	What it Measures	Reference
Number of saccades	More saccades indicate more searching.	Goldberg & Kotval (1999)
Saccade amplitude	Larger saccades indicate more meaningful cues, as attention is drawn from a distance.	Goldberg et al. (2002)
Regressive saccades (regressions)	Regressions indicate the presence of less meaningful cues.	Sibert et al. (2000)
Saccades revealing marked directional shifts	Any saccade larger than 90 degrees from the saccade that preceded it shows a rapid change in direction. This could mean that the user's goals have changed or the interface layout does not match the user's expectations.	Cowen et al. (2002)

Study Design

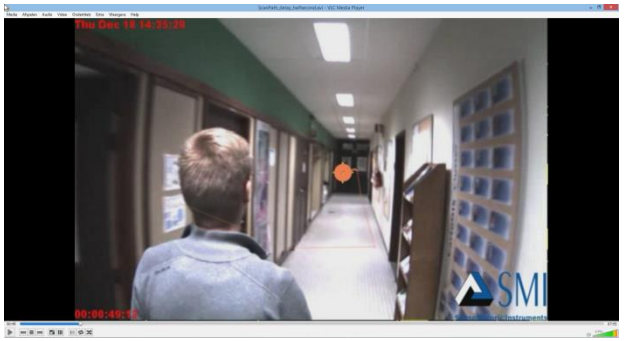


Study Design

- Stimuli
  - *Static vs. interactive*
  - *Picture vs. video*
  - *In the field*

  - *Dimensions*
    - *(Virtual) Environment → Projection → Monitor → Mobile applications*

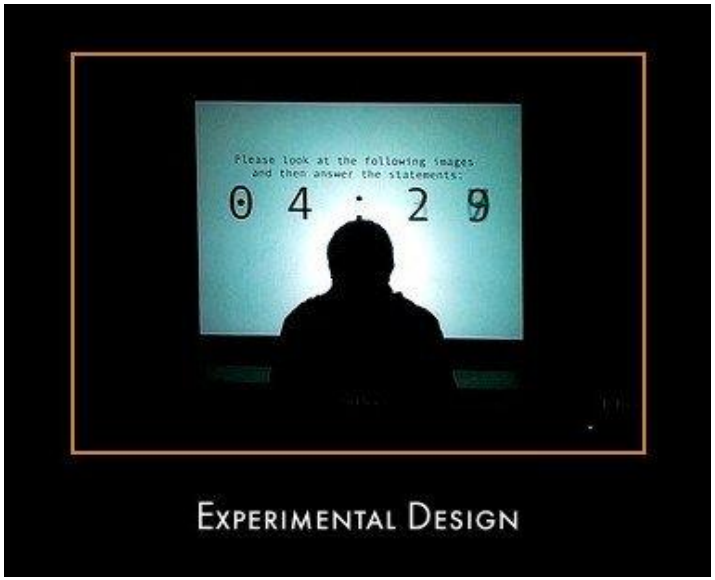
- Evaluate characteristics of stimuli
  - Different designs
  - !!!Learning effect →multiple groups of users



Study Design

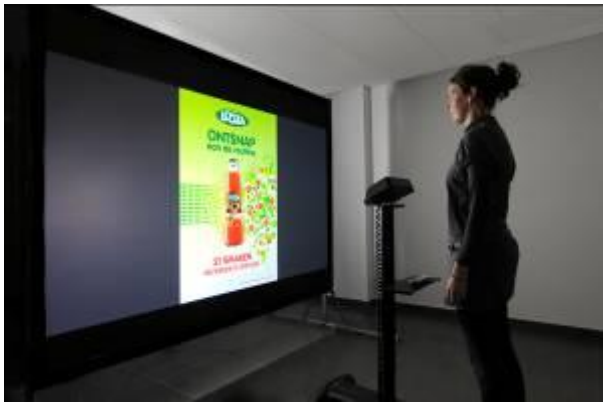
- Tasks
  - Realistic
    - What are users normally expected to do?

  - Examples
    - Free viewing
    - Visual search
    - Solve problem based on stimuli
    - Task in application



Study Design

- System / Aparatus
  - » *Chin rest, remote, stand alone, mobile*
  - » *Accuracy, environment, display options, stimuli, etc.*



Study Design

- Other methods
  - Qualitative vs. Quantitative
  - Questionnaires
  - Thinking aloud
  - Response time measurements
  - Sketching
  - Scoring
  - Mouse & keyboard logging
  - Observation
  - Interview
  - EEG
  - …

Study Design

- Software
  - *Setting up experiment*
  - *Recording data*
  - *Interpretation 'raw' data*
  - *Analyses*
  - *Vendor specific*
  - *Open Source*
  - *Statistical Packages*
  - *Spatial analyses*

tobii
World leader in eye tracking & eye control

EyeMMV toolbox

OGAMA

SPSS

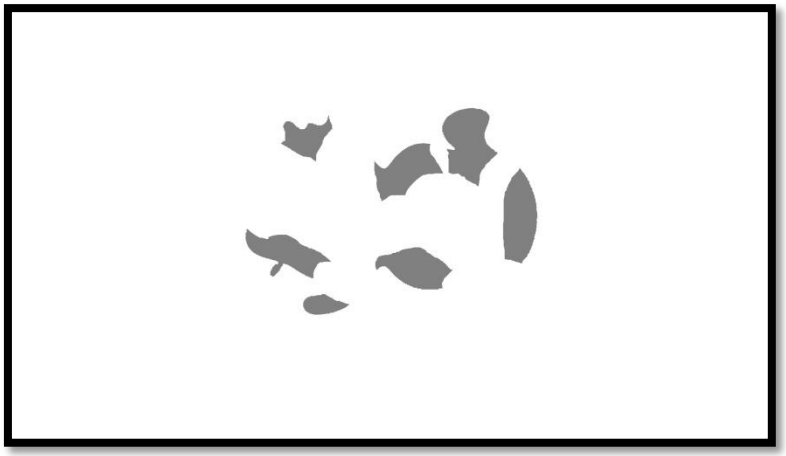
PyGaze

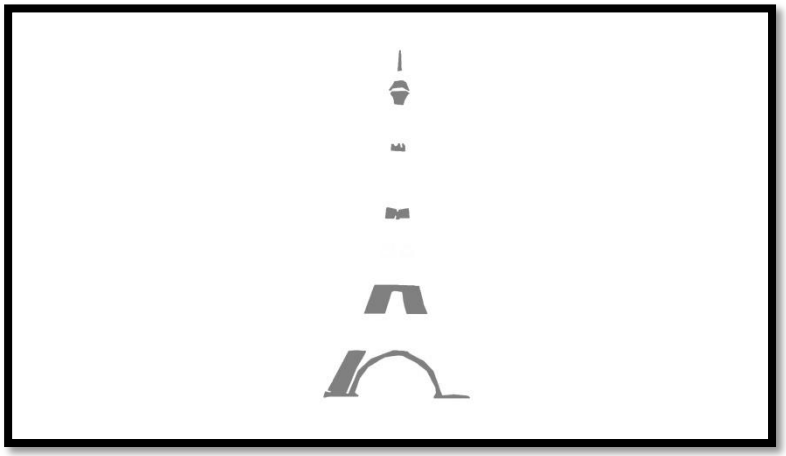
MATLAB
The Language of Technical Computing

Visual Analytics of Movement

… Demo …

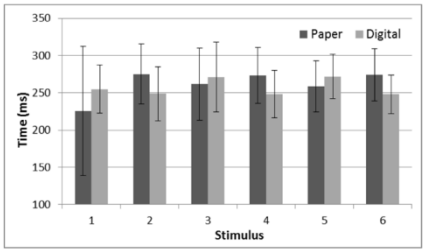
- Study Gestalt

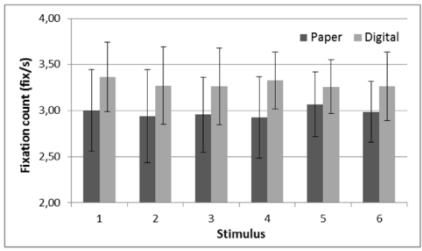


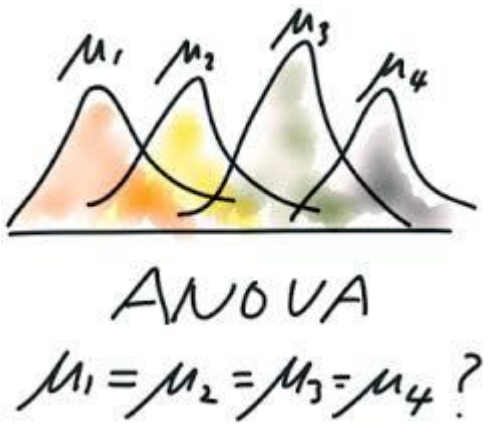


ANALYSES

- Measurements → Metrics → Results → Conclusion
  - Select relevant metrics
    - Dependent on null-hypothesis
  - Quantitative analysis
    - Dependent vs independent factors
    - Statistical analysis

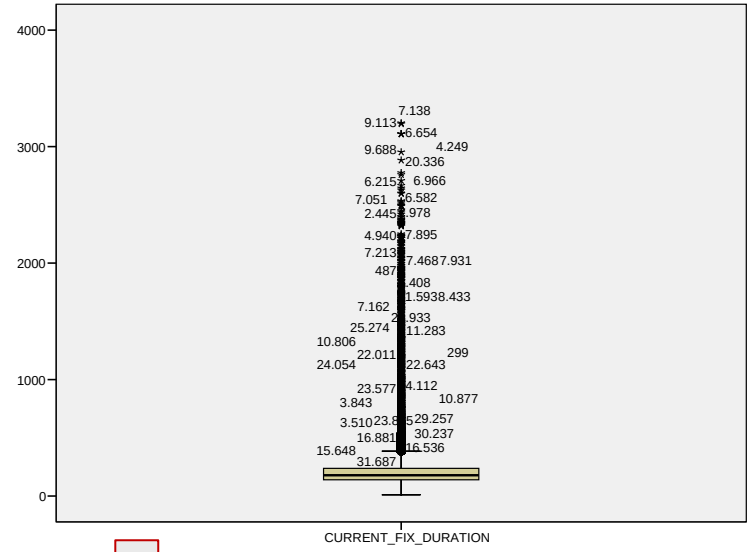




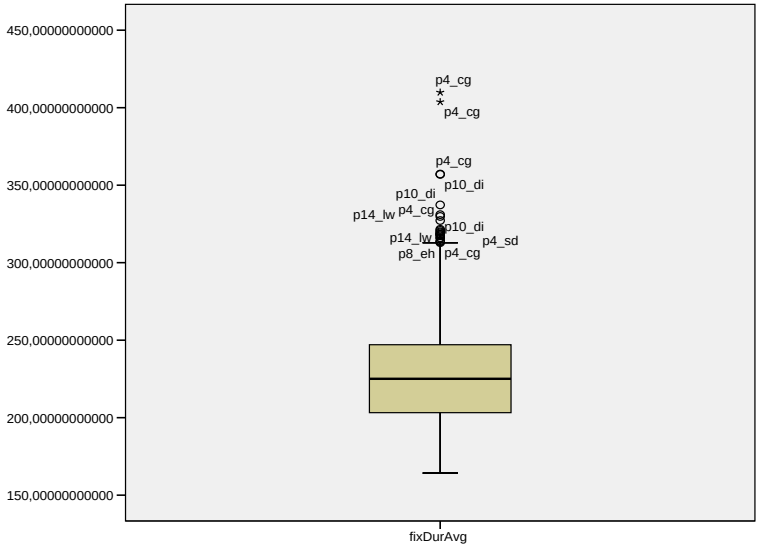


ANALYSES

- Measurements → Metrics → Results → Conclusion
  - Quantitative analysis
    - Normal distribution?



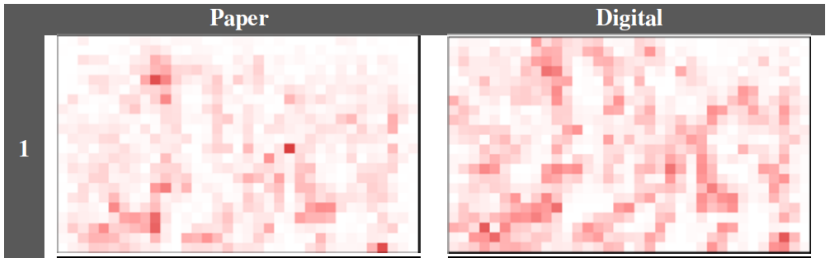
Calculate average per person/ Stimulus/trial

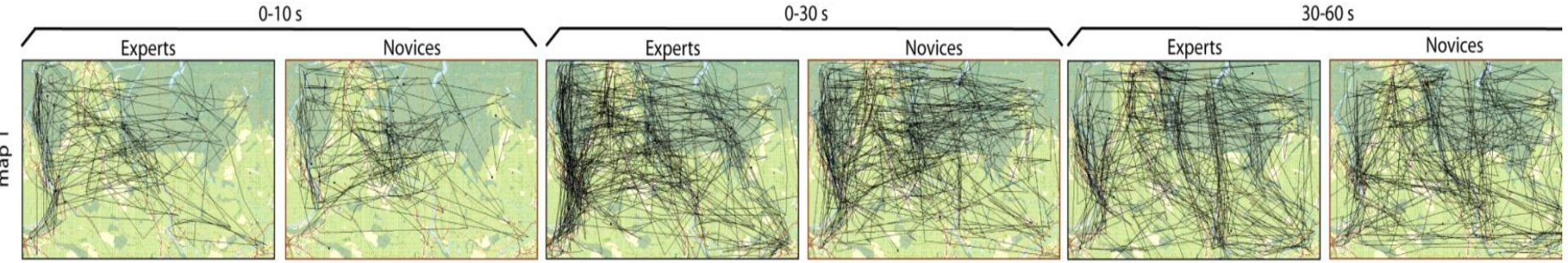


Non-parametric tests

ANALYSES

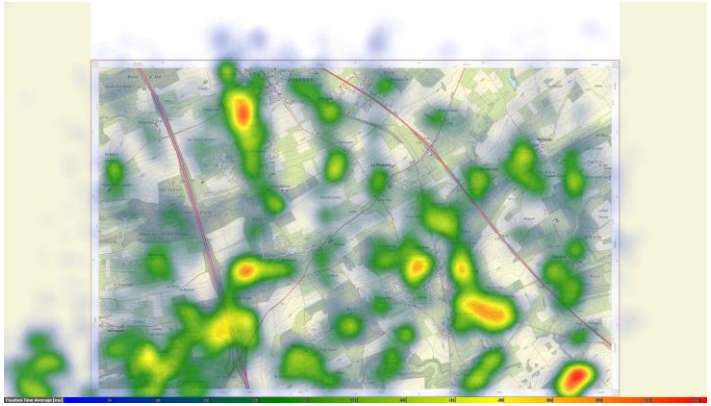
- Measurements → Metrics → Results → Conclusion
  - Qualitative analysis
    - 'Scanpaths'
    - Heatmaps – Attention maps
    - Other visualization techniques
    - !Overplotting → aggregation/clustering necessary

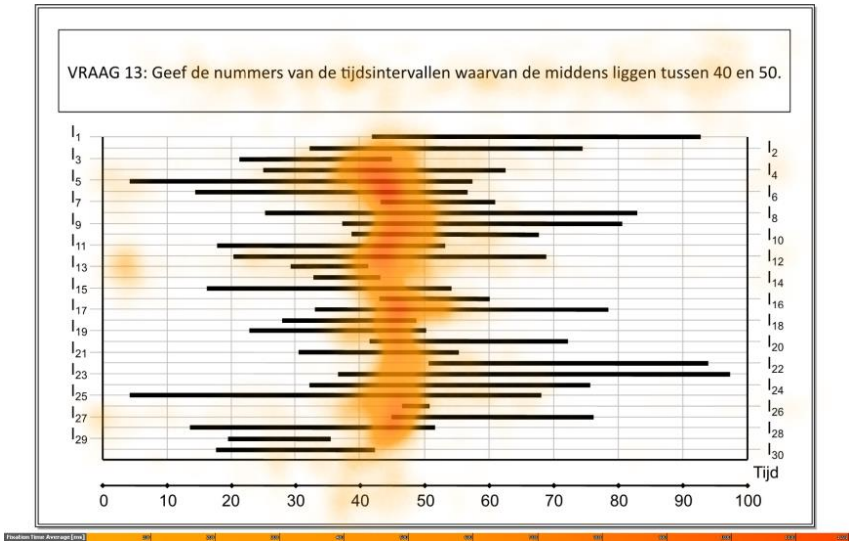


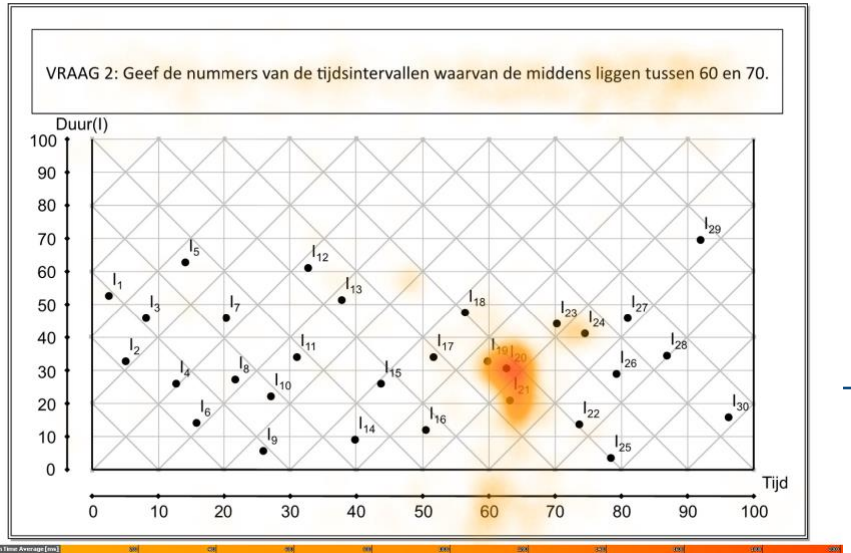


ANALYSES

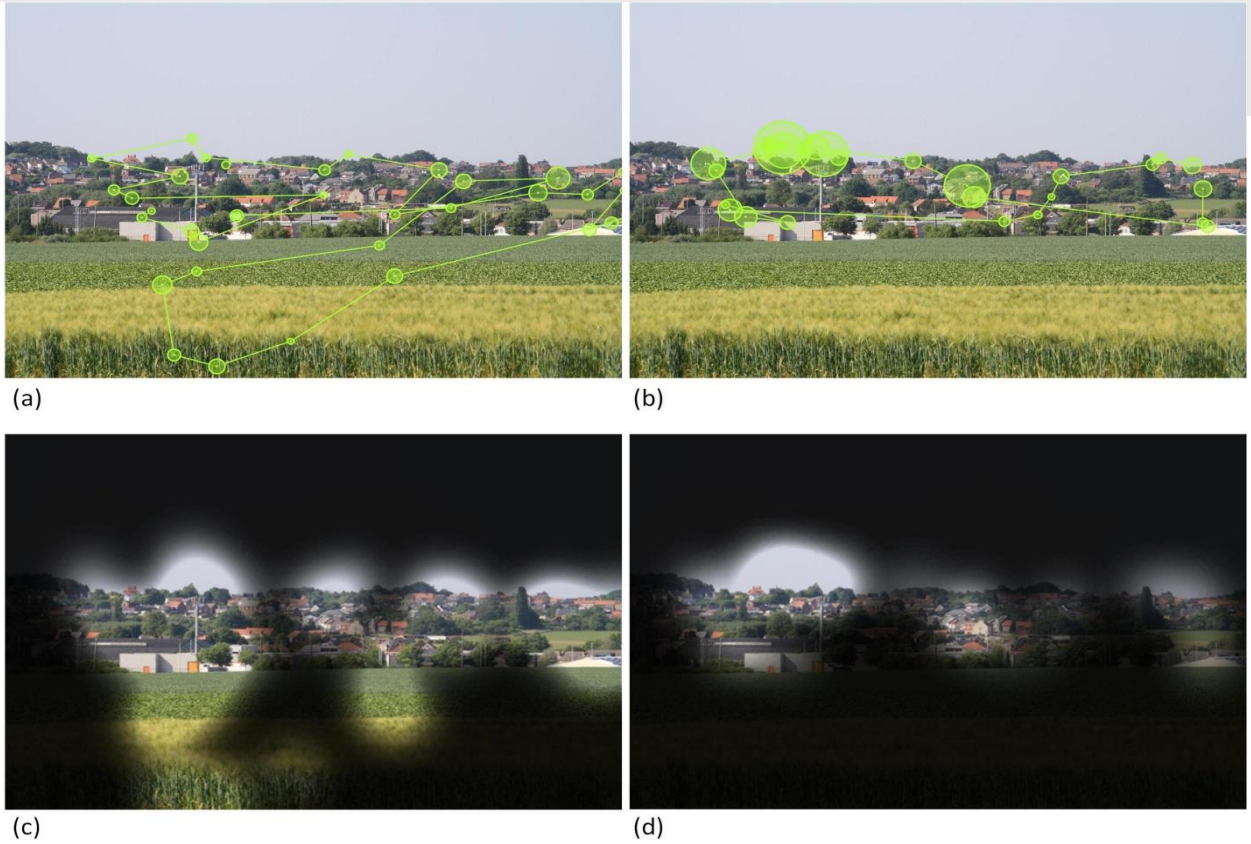
- Measurements → Metrics → Results → Conclusion
  - Qualitative analysis
    - Heatmaps





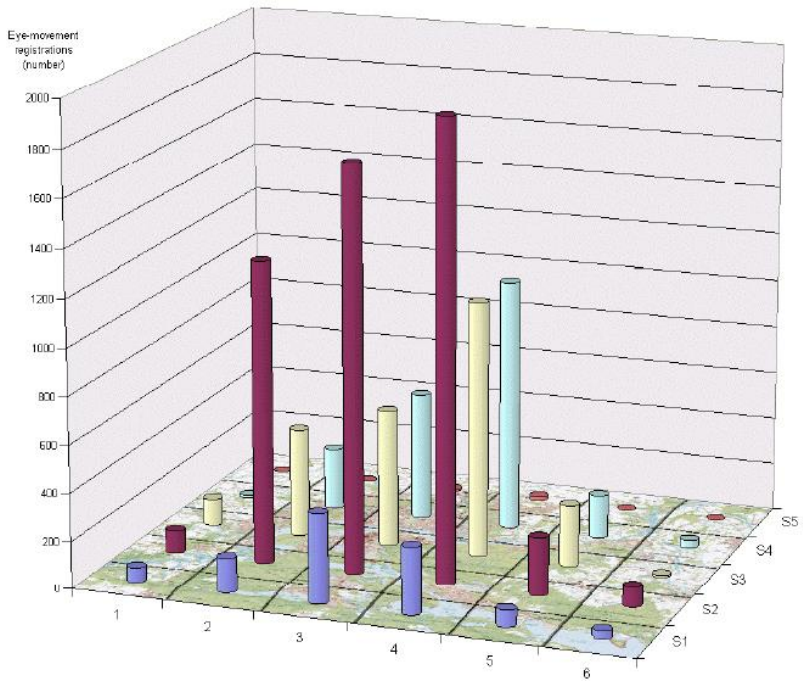


ANALY

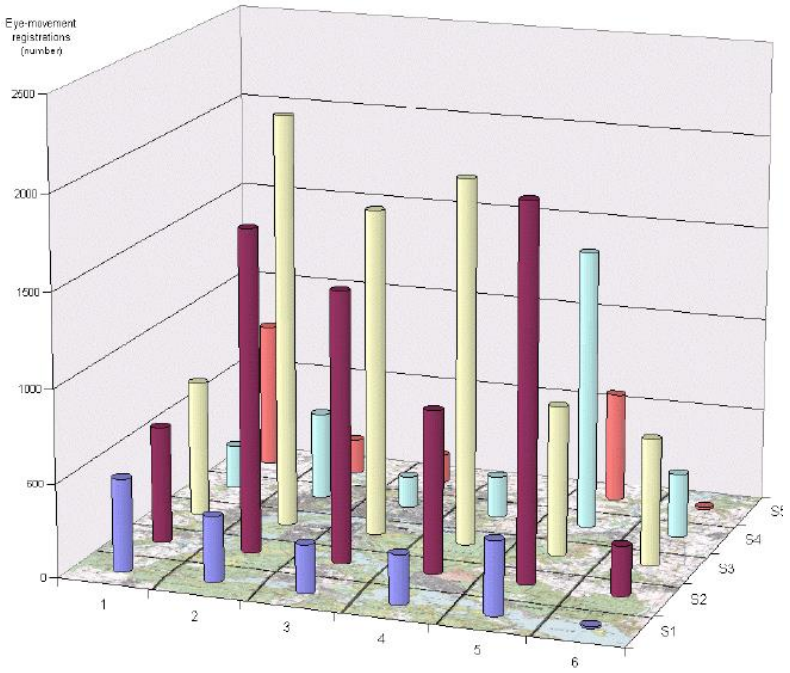


EXAMPLE

- National Survey and Cadastre – Denmark

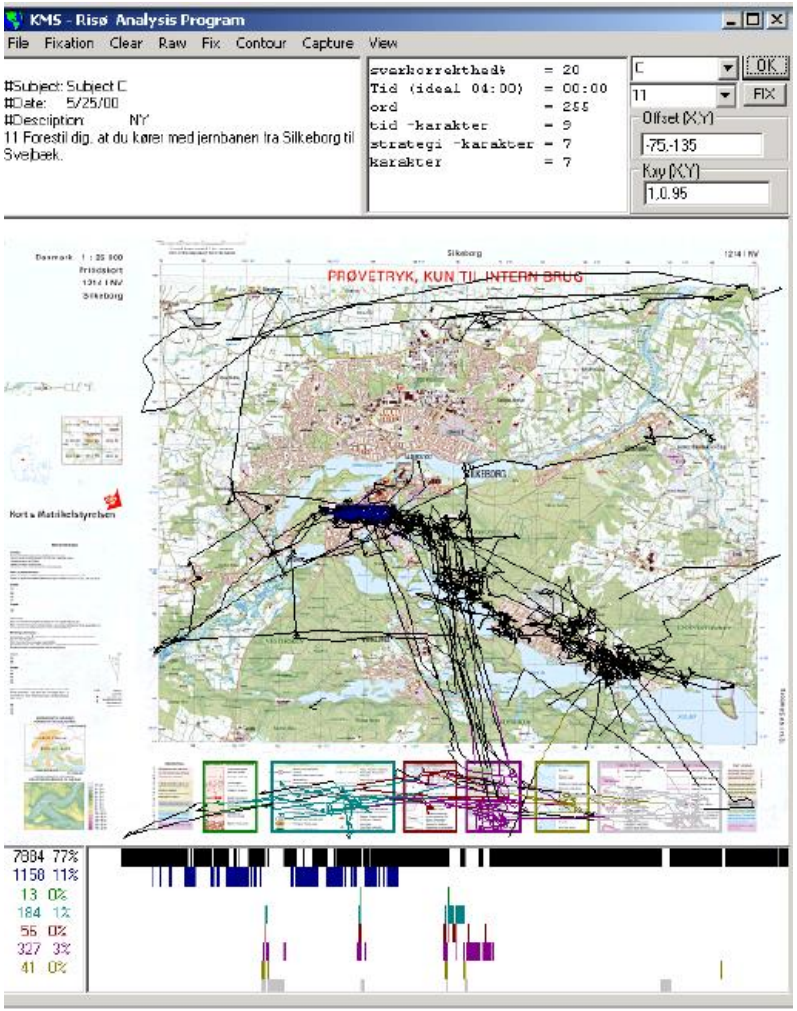


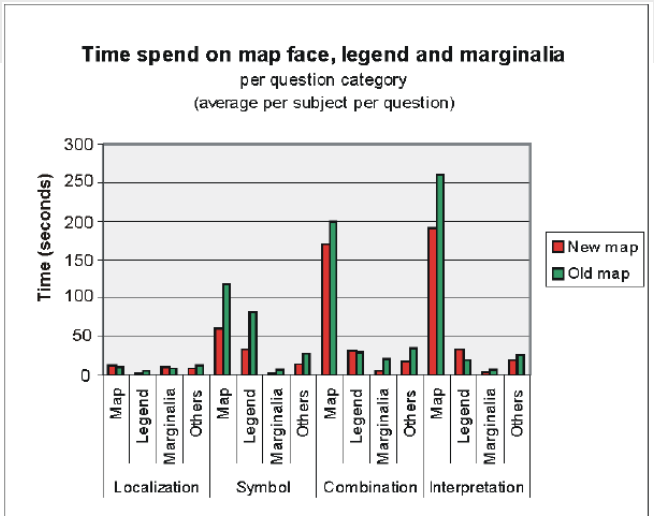
Dwell dispersion: Question 3 – "Point out a meadow on the map"

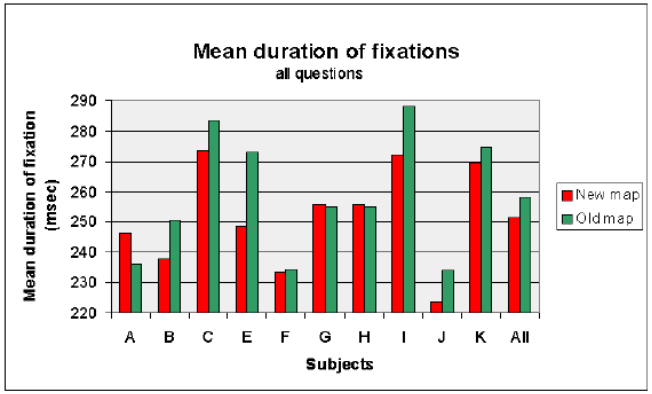


Dwell dispersion: Question 10 – "If you had to move to Silkeborg, where would you like to live?"

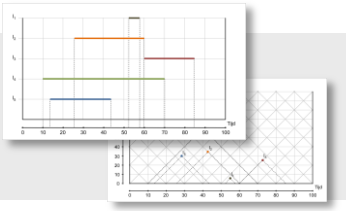
EXAMPLE

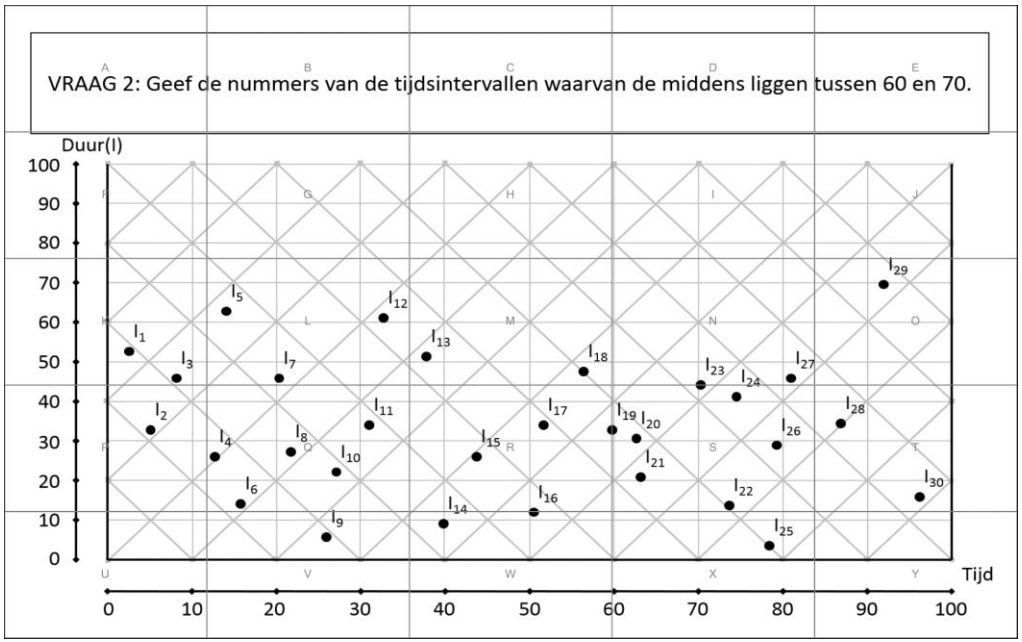

KMS - Risø Analysis Program
File Fixation Clear Raw Fix Contour Capture View
#Subject: Subject C
#Date: 5/25/00
#Description: NY
11 Forestil dig, at du kører med jernbanen fra Silkeborg til Svebæk.
svarkorrekthed = 20
Tid (ideal 04:00) = 00:00
ord = 255
tid -karakter = 9
strategi -karakter = 7
karakter = 7
OK
FIX
Offset (X,Y)
-75,-135
Kay (X,Y)
1,0.95
PRØVETRYK, KUN TIL INTERN BRUG
7884 77%
1158 11%
13 0%
184 1%
55 0%
327 3%
41 0%


Time spend on map face, legend and marginalia
per question category
(average per subject per question)
Time (seconds)
300
250
200
150
100
50
0
Map
Legend
Marginalia
Others
Localization
Symbol
Combination
Interpretation
New map
Old map

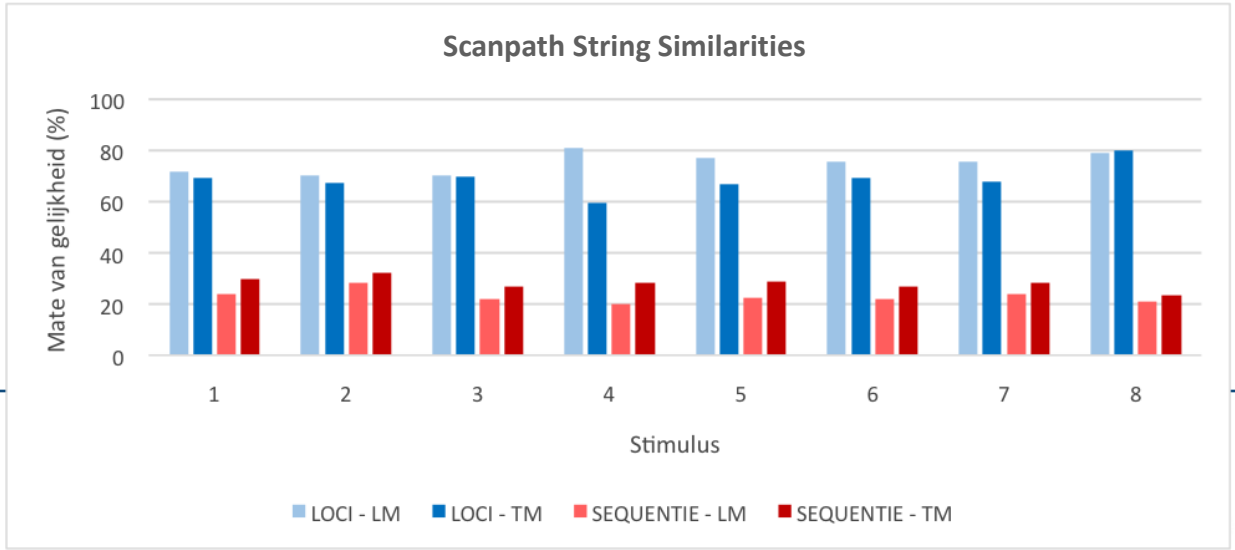

Mean duration of fixations
all questions
Mean duration of fixation (msec)
290
280
270
260
250
240
230
220
A B C E F G H I J K All
Subjects
New map
Old map

EXAMPLE





Part.	Gender	SCANPAD STRING
P01	M	MMBACCDEDCCCCDDEEBBBBBCBCDEDDE EDDSWWRSSSSSSSSSSSSSSNSRWSSSSS SSSWWSSMNSSDEEDCCDDDEFDDRSXWS
P02	F	MLAABBBBCCDDDDDDDEDEEDDDWWXSSR RRSSSSSSSSWCDEEXWSXSSWXSSSSSSS WSSSSSSSNSRDEBDDRSSSSSNNSSSRRM MLRRNSSWXXXXWXDDEWSSSSSSNSNSSS SWNSSSSS
P03	M	MMHBABBCDDCCDERWSSSSSXXIDEBBBBC CCCDDDEESSSXXRSSSSSSSXDESRRWSSS SNSSSSSSSD
P05	F	MMLBCCCCDDDDEENXXWSSSSSSSSSSXW RCDDCBCBBRSSSRSWWRMRLLIRRWWR
P06	F	MMBBABBCDDDEEDEDEWWWWWXSSSSSS SRSSSSSWSSSXXWSSWN



EXAMPLE

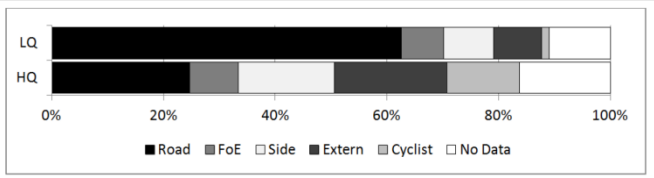


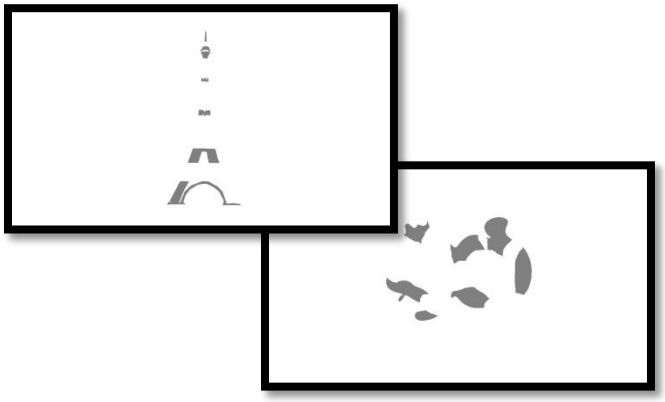
Figure 3 : Sum of percentages of gaze towards road, Focus of Expansion, side and external and the percentage of gaze that was missing or unclear for low quality and high quality bicycle track.

Output Mobile Eye Tracker

… Demo …

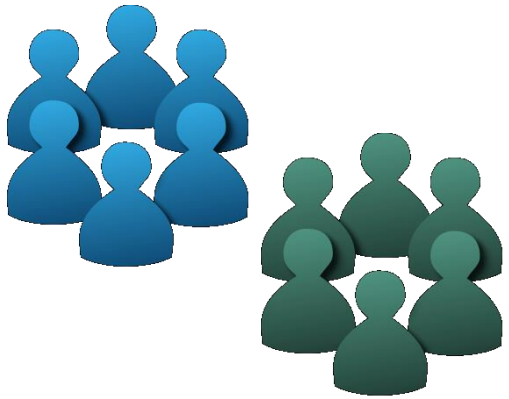
- Study Gestalt?
  - Within user:

Stimulus 1
vs.
Stimulus 2



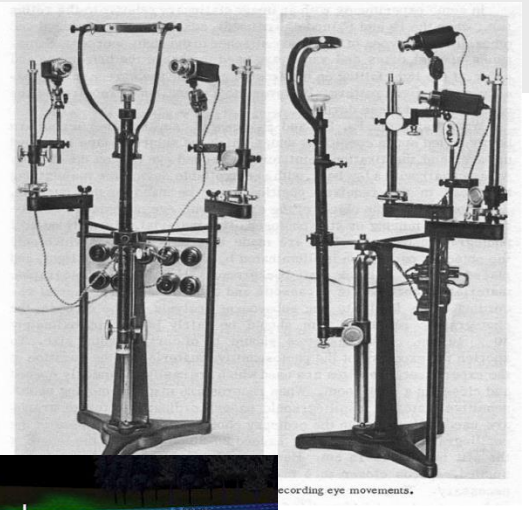
  - Between user:

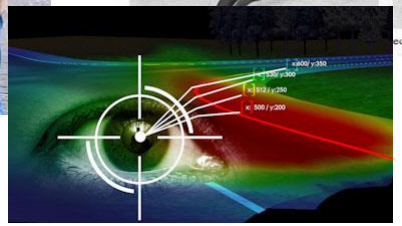
Original participants
vs.
Workshop participants



Issues with Eye Tracking

- Technical problems…
  - In the past:
    - Inaccurate – intrusive
    - Time consuming – expensive
  - Noise infra-red → sunlight
    - Especially mobile systems
    - Preferable indoor
  - Mobile systems
    - Callibration vs. varying fixation distances
    - Parallax
  - Still some problems with minority of participants (10-20%)





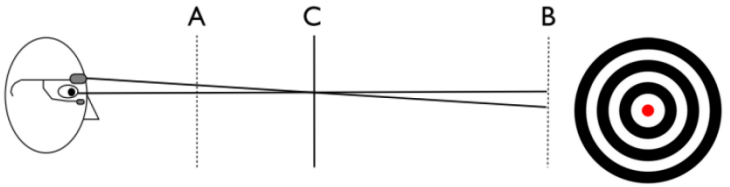


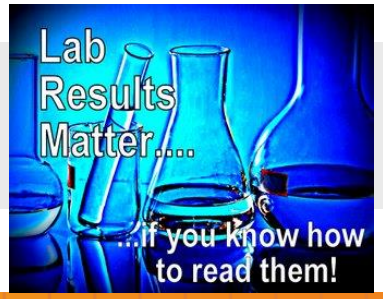
Figure 1 : Illustration of parallax effect (Left; Figure from Evans et al. 2012), and an example of a calibration target that could be used to measure accuracy (Right).

Issues with Eye Tracking

- Data extraction
  - A huge amount of raw data
  - Fixations & saccades
    - No standard dispersion
    - No standard time threshold
    - Some algorithms: based on saccades

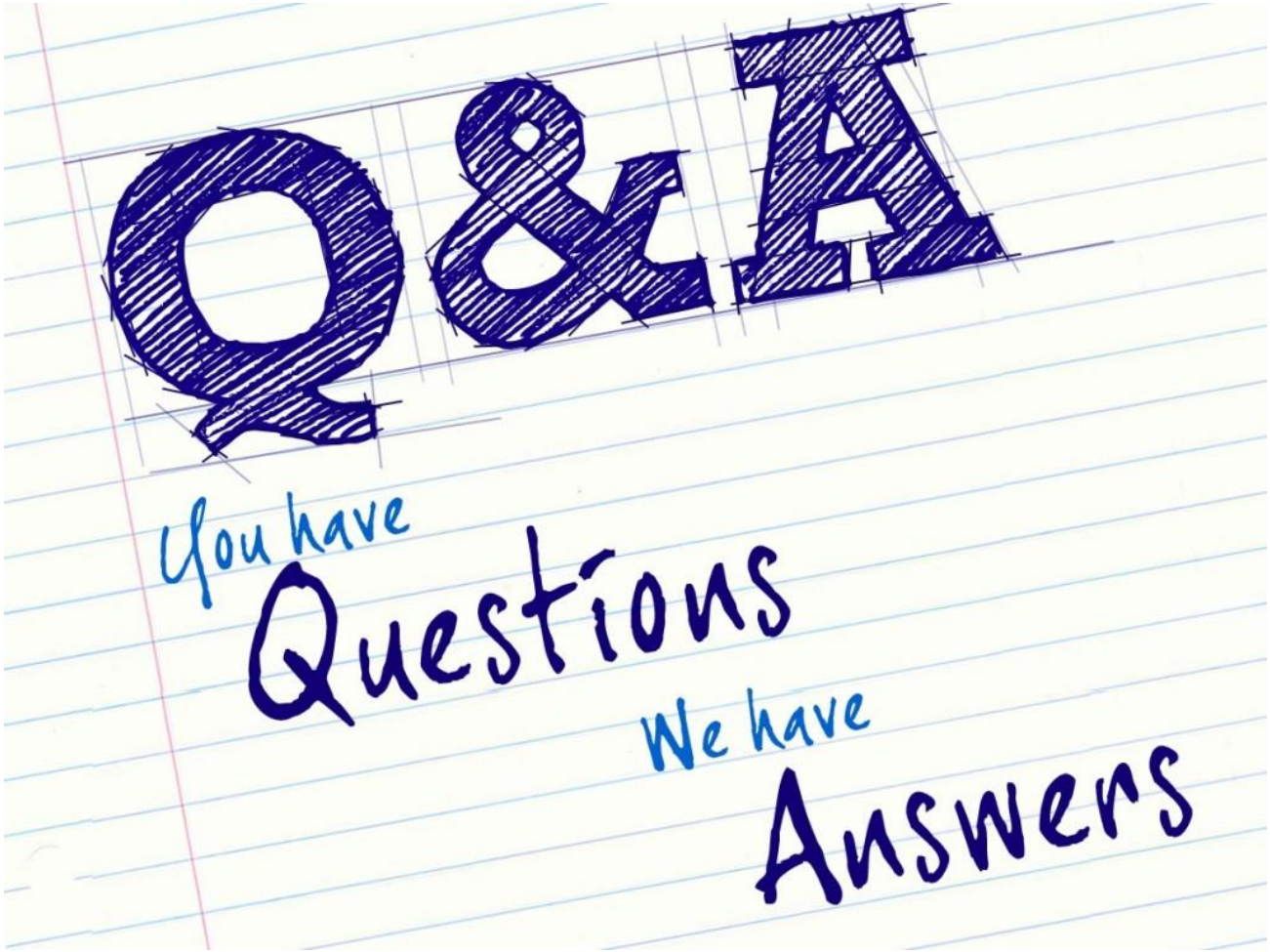
      → *Mostly not mentioned when reporting experiments*
  - What was a user looking at?
    - Videos
    - Dynamic stimuli
    - Interactive stimuli

Issues with Eye Tracking



- Data interpretation
  - Location of fixations vs. attention?
  - Fixation metrics: what do they mean
    - E.g.: longer fixations
      → more difficult to interpret
      → interesting to look at
    - E.g.: more fixations
      = attention is attracted to it because…
      → of its beauty
      → of its ugliness
  - Solution: combine multiple methods

REQUESTS AUDIENCE?



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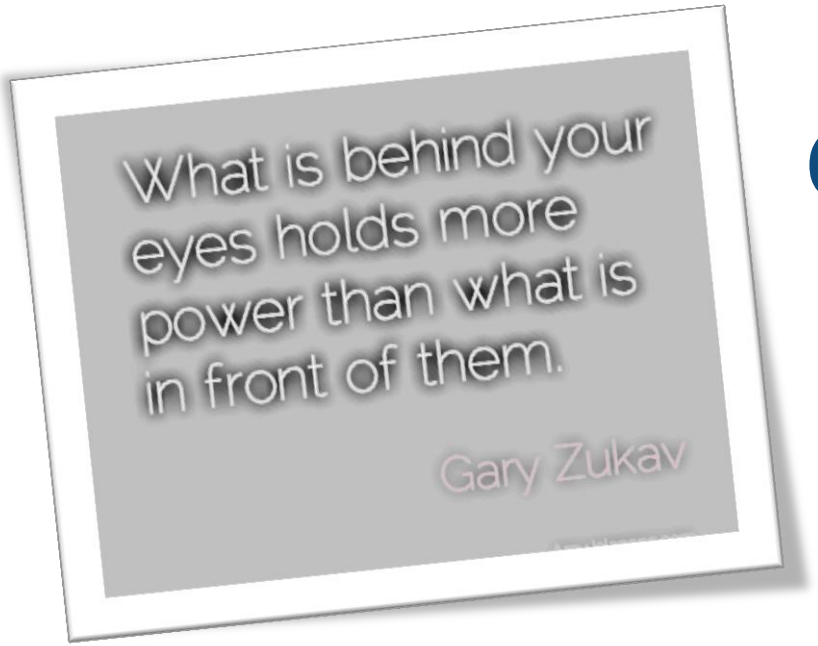

DESIGNING AND CONDUCTING USER STUDIES

MODULE 4:

When and how to apply Eye Tracking

carto gis research unit

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