Human Computer Interaction and Eye Tracking

Leana Copeland
Research School of Computer Science
Australian National University
Canberra, Australia

Overview

- Recap of HCI lecture (+ finish HCI)
- Eye tracking
- Eye tracking and HCI
- Eye tracking and eLearning

What is Human Computer Interaction?

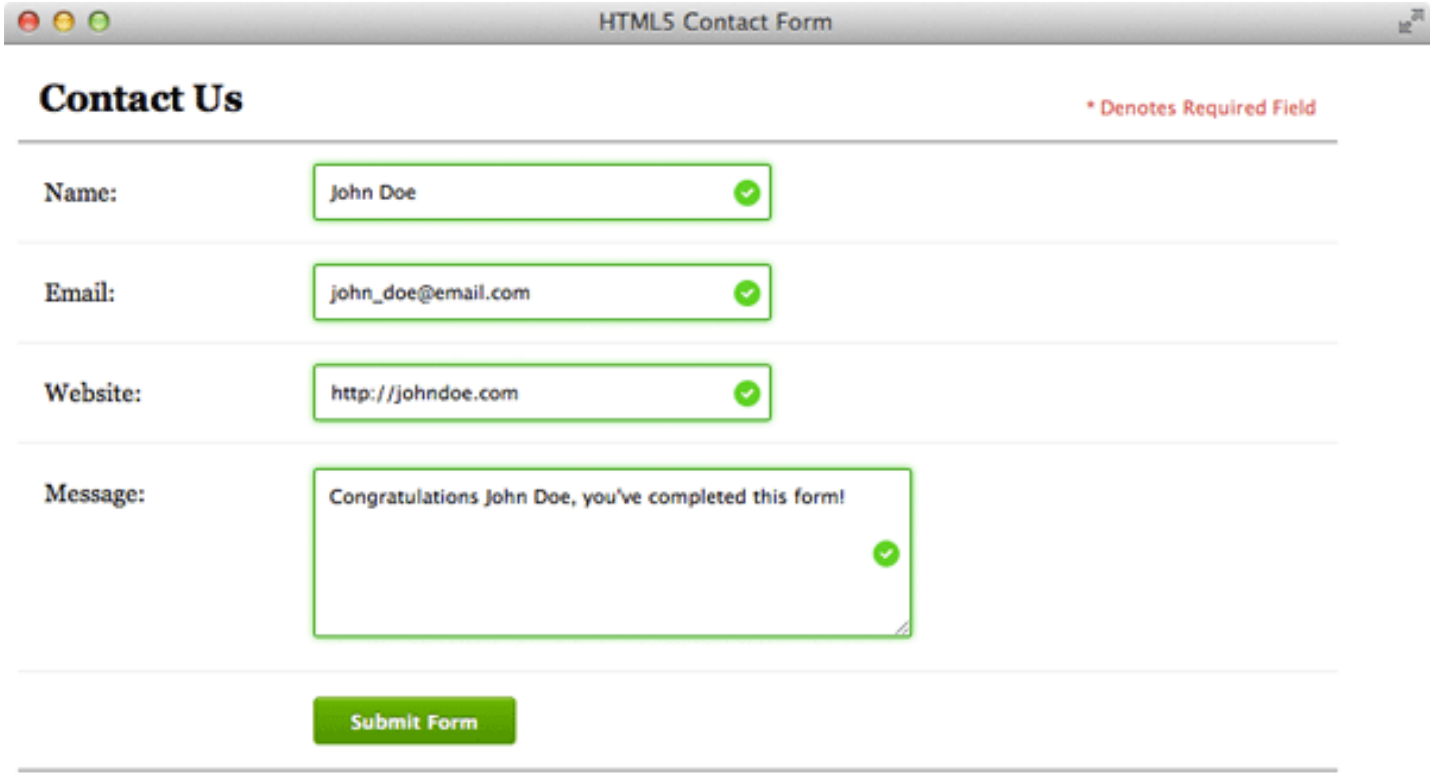
Some Design Principles

Partly based on Don Norman's The Design of Everyday Things, 2013

- Affordances
- Signifiers
- Mappings
- Feedback
- Constraints
- Conceptual model

Image taken from: http://abcofdesign.com/images/coffeepot.gif

Example


HTML5 Contact Form
Contact Us
* Denotes Required Field
Name:
John Doe
Email:
john_doe@email.com
Website:
http://johndoe.com
Message:
Congratulations John Doe, you've completed this form!
Submit Form

User centred design

- System centred design
  - Functionality driven
  - Emphasis on correct system
  - No consideration to the user
- User centred design
  - Emphasis on the end user tasks
  - Usability considered
  - Highly iterative

MOST END-USERS ARE NOT COMPUTER SCIENTISTS!

Usability

- Definitions :
  - "a measure of the ease with which a system can be learned and used, its safety, effectiveness and efficiency, and attitude of its users towards it"
    (Preece et al., 1994)
  - "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use"
    (ISO 9241-11)

Testing usability

Image taken from: http://jennycham.co.uk/wp-content/uploads/2011/08/20091122125022548l-292x300.jpg

Measuring usability

- What are good metrics?
- Qualitative
  - Ask users
- Quantitative
  - Error rate
  - Speed

Iterative cycle of Human Centred Design

1. Observation
2. Generate ideas
3. Prototyping
4. Testing
5. Start again…

Observation

- How you get more accurate requirements!
- Often the people who commission for something to be made are not the end users
- Actually see how the user base performs the task
  - Find the true needs, motives, interests

Idea generation

Image taken from: http://www.presentable.es/wp-content/uploads/2013/01/post-it-wall.jpg

Prototyping

- Very useful for checking your requirements
- Can be quick and rudimentary
  - Pencil sketch, spreadsheet, PowerPoint slides, cardboard or foam models, Lego,…
- Wizard of OZ trials

Image taken from:
http://tse2.mm.bing.net/th?id=OIP.M70befa61e79454592a39ed590ebbea1eo0&pid=15.1

Testing

- Get people to try out the solution
- Gather quantitative and qualitative data
- How good were your requirements?

NOW START AGAIN!!

What is HCI?

- Understand how humans interact with technology
- Ensuring the needs of people are met
- Creating understandable and usable products

What Is Eye Tracking?

Eye tracking overview

- Specialty equipment
- Measuring the point of gaze
- Measures what humans look at and for how long

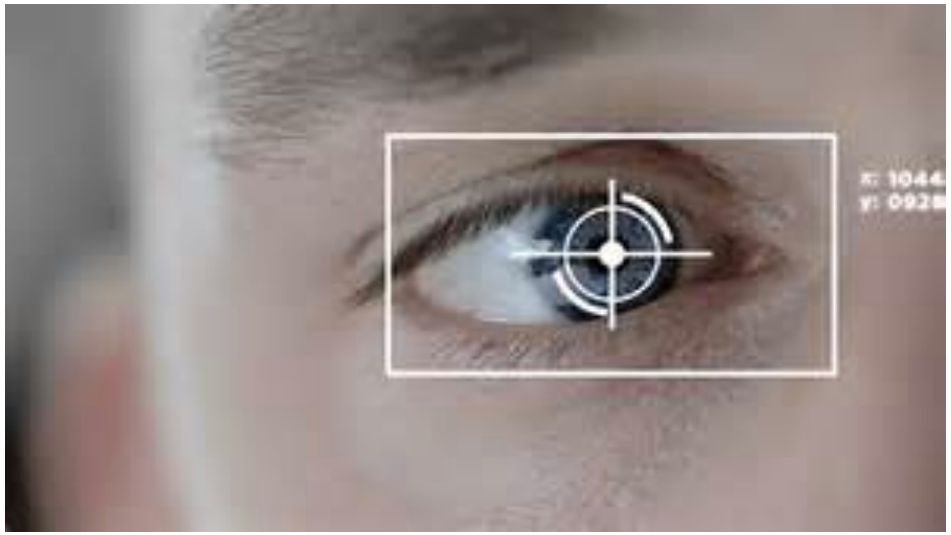


Image taken from: http://technologyadvice.com/wp-content/uploads/2014/03/Eye-Tribe-Eye-Photo.png

The anatomy of the eye

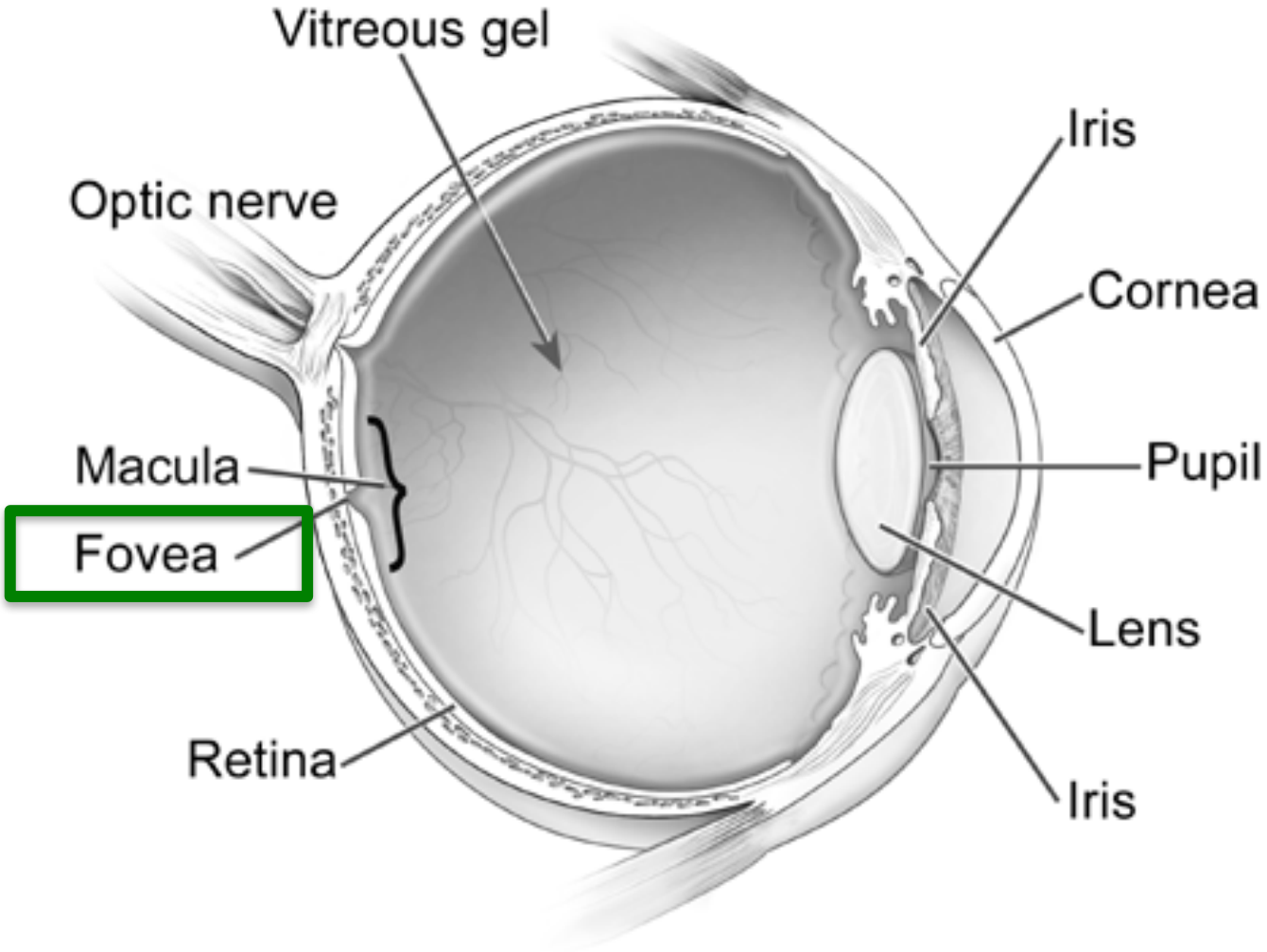
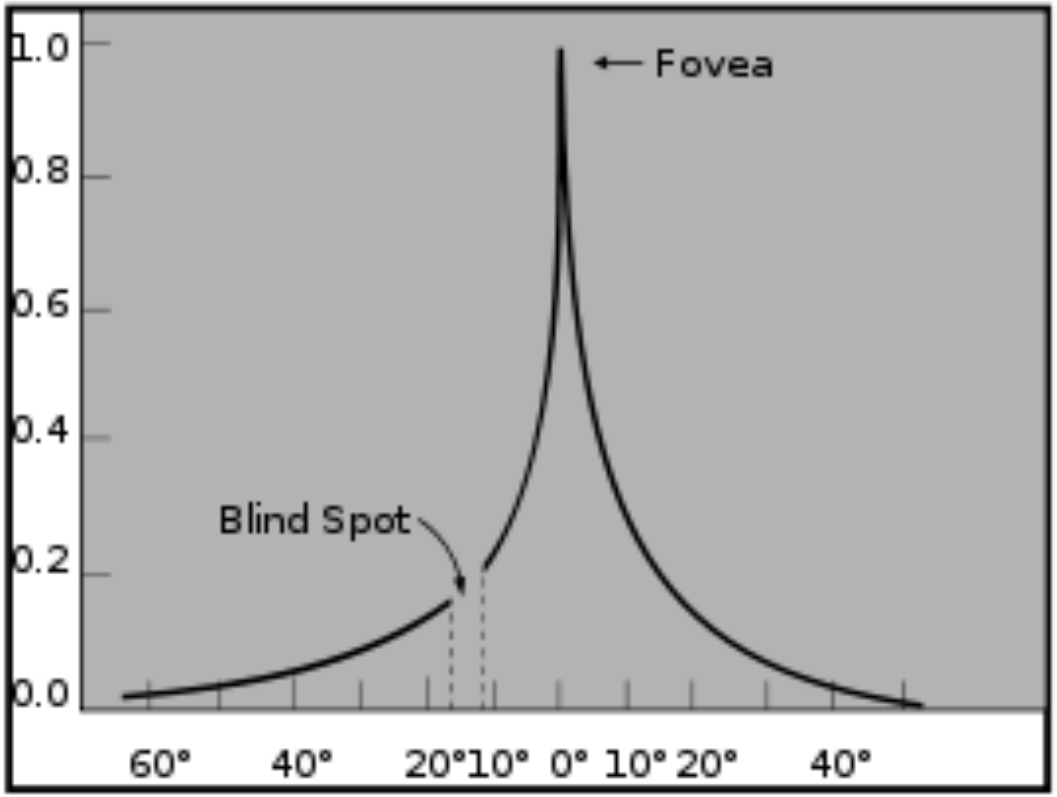


Image taken from: https://nei.nih.gov/sites/default/files/nehep-images/eyediagram.gif

How much do we really see?



The illusion of of "seeing"

Image taken from:
https://en.wikipedia.org/wiki/Fovea_centralis

Image taken from EAGLEMAN, D. 2011.
Incognito: The secret lives of the brain, New York, Vintage Books. Page 26.

The first eye trackers

- The first “eye tracker” was Louis Emile Javal in 1879
  - Direct observation
- Edmund Huey developed one of the first eye trackers in the early 1900’s
  - Contact lens based
  - Acted as a pointer
- Both for reading analysis!

Eye trackers

- Capture where the eye is looking
- Contact lens based
- Infrared video based
- Electric potential measurement

Infrared video-based tracking

- Non-intrusive
- Measures eye rotation
- Uses IR-light (invisible to human eye)
  - causes bright or dark pupil, which helps the system to recognize pupil from video image
- The two features of eye are tracked used to track the eye and calculate eye rotation
  - corneal reflection
  - pupil
  - can use more features

Image taken from: http://dev.theeyetribe.com/general/

Common set up

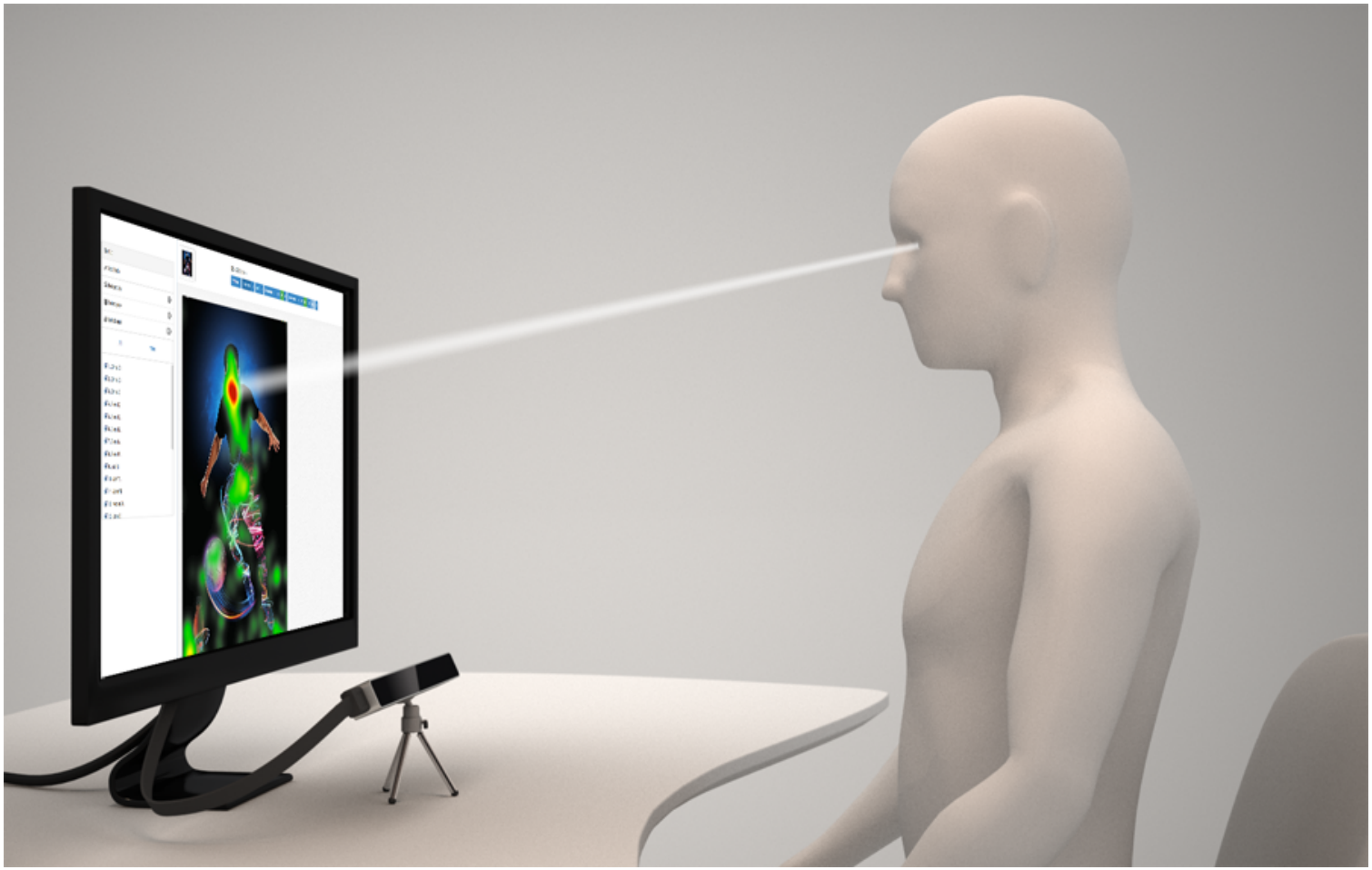
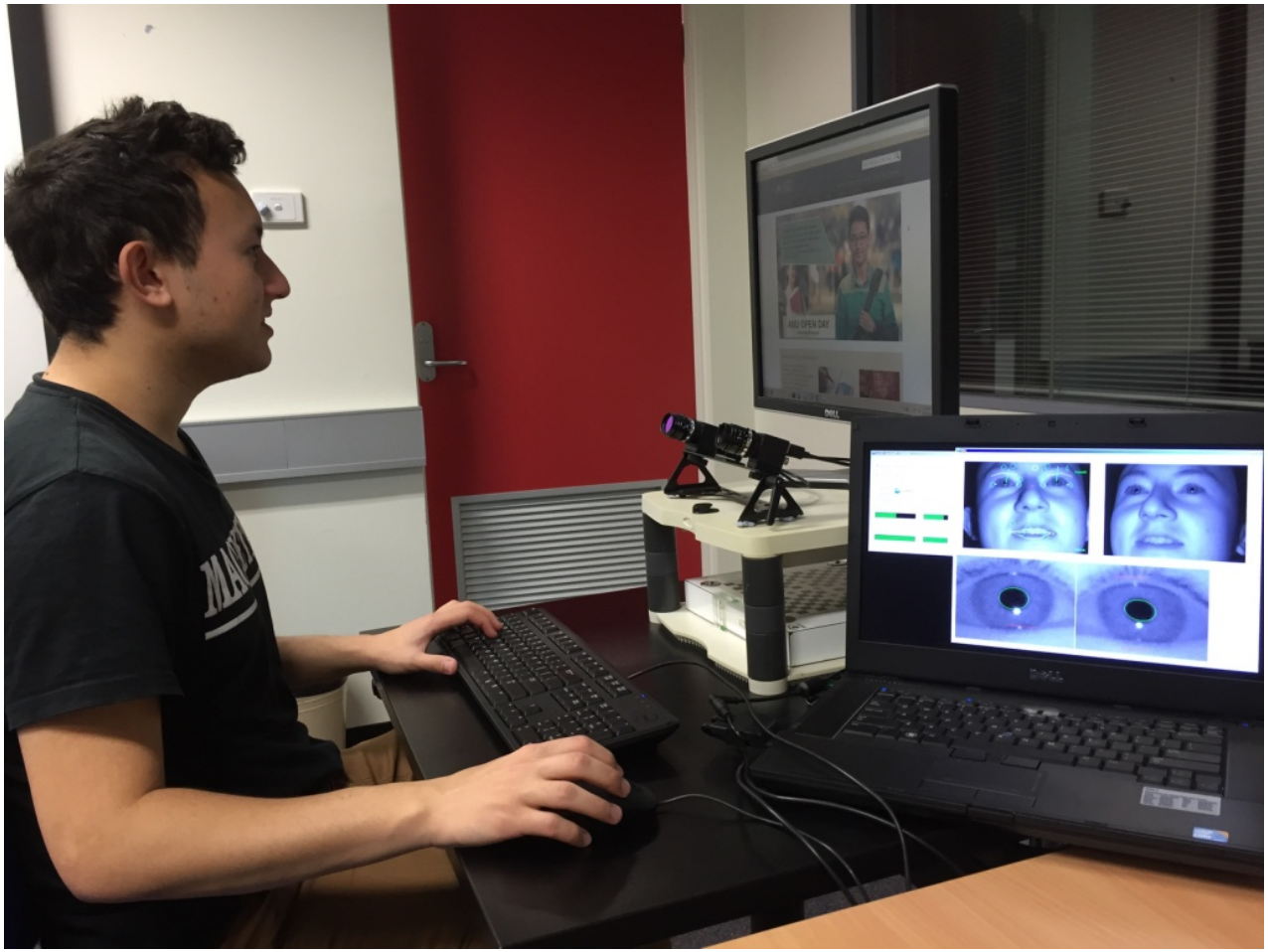


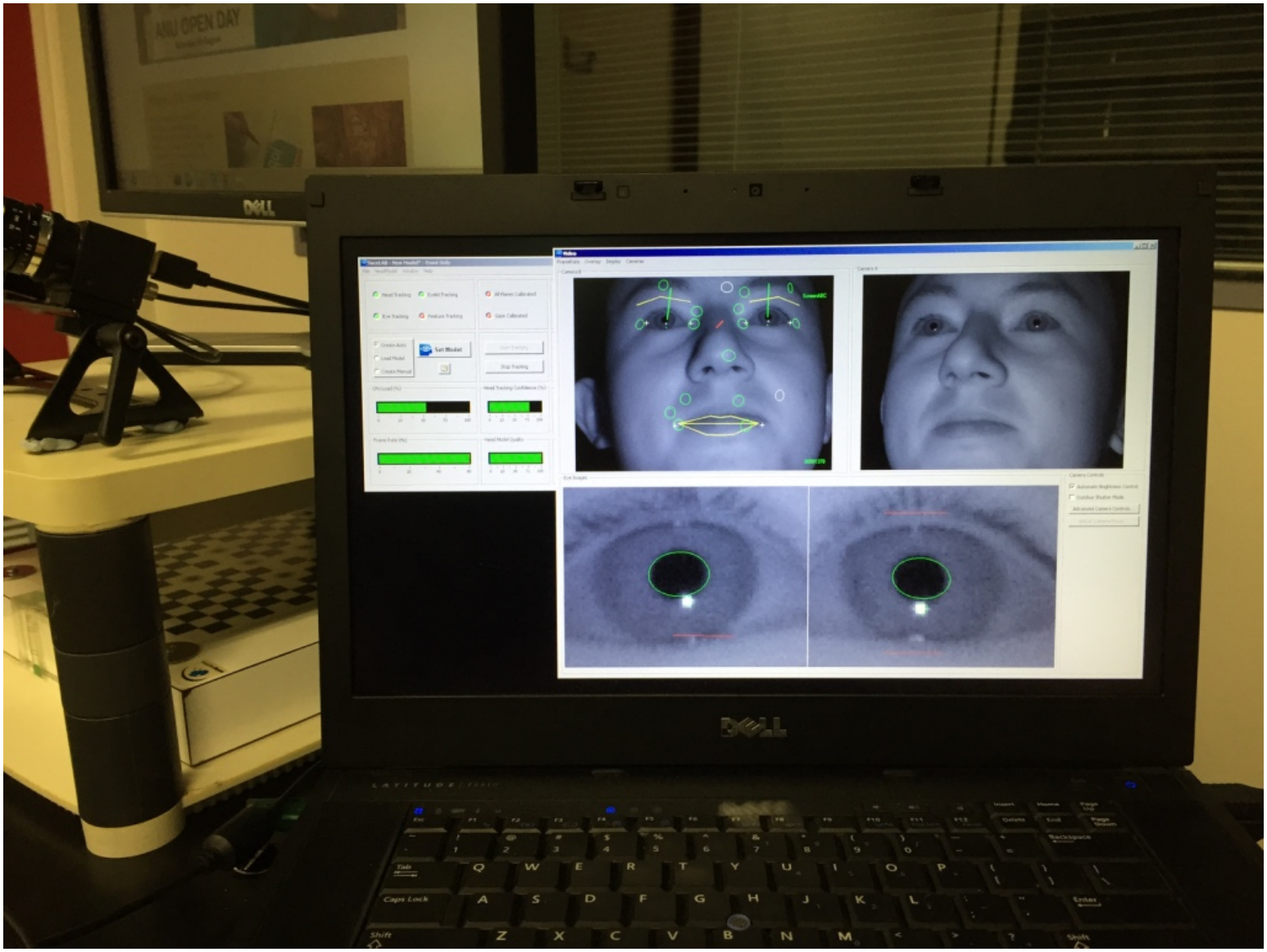
Image taken from: http://theeyetribe.com

Seeing Machines faceLAB 5

Experiment setup



Experimenter view



EyeTribe

Calibration sequence

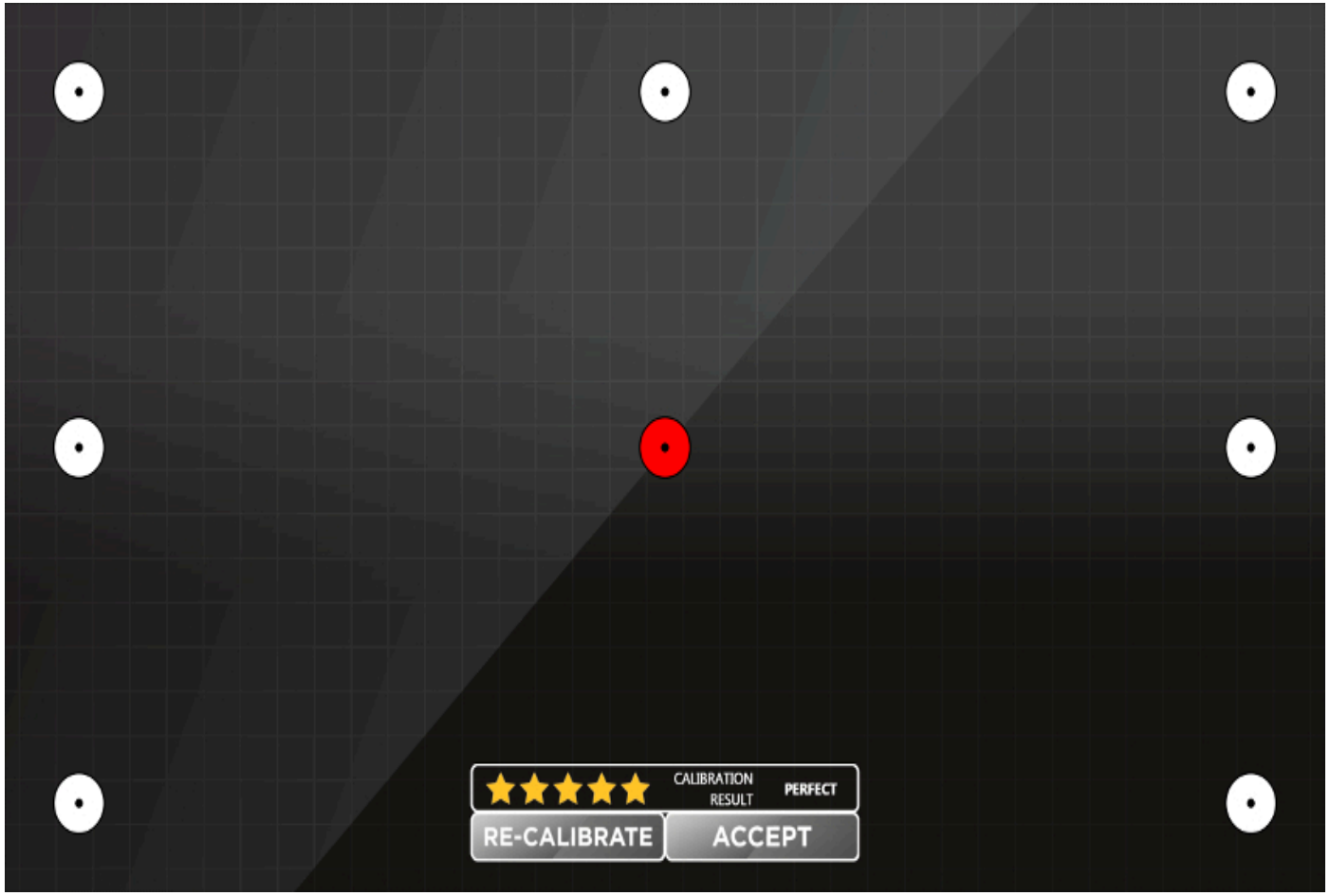


Image taken from: http://dev.theeyetribe.com/general/

Wearable eye trackers

Image taken from:
http://tse4.mm.bing.net/th?id=OIP.M0030072cc47b0571764bb7f432c83902H0&pid=15.1

Considerations

- Spatial Resolution
  - measurable change in eye position
- Accuracy
  - Typically 0.5-1 deg
- Temporal Resolution (sampling rate)
  - Number of recorded eye positions per second

Fixation identification

- Turn the signal into meaningful data
  - Fixations and saccades

    Remember: *fixations are when visual information is taken in!*
- Spatial vs temporal algorithms

Presentation of eye tracking data

- Replay
- Static representation
- Heat maps
  - Blind zone maps

Reading analysis

- 1800's - Javal observed that reading was not smooth
- Beginning of reading analysis:
  - Which words does the eyes stop on?
  - How long does the eye stop?
  - When does the eye move back to already read word?
- 1970's – resurgence in eye tracking because of reading analysis

Reading analysis

- Eye movements were used to study how we read
- Models for generation of eye movements made to help understand:
  - how and why the eye moves
  - the cognitive processes involved in reading

Analysing reading behaviour

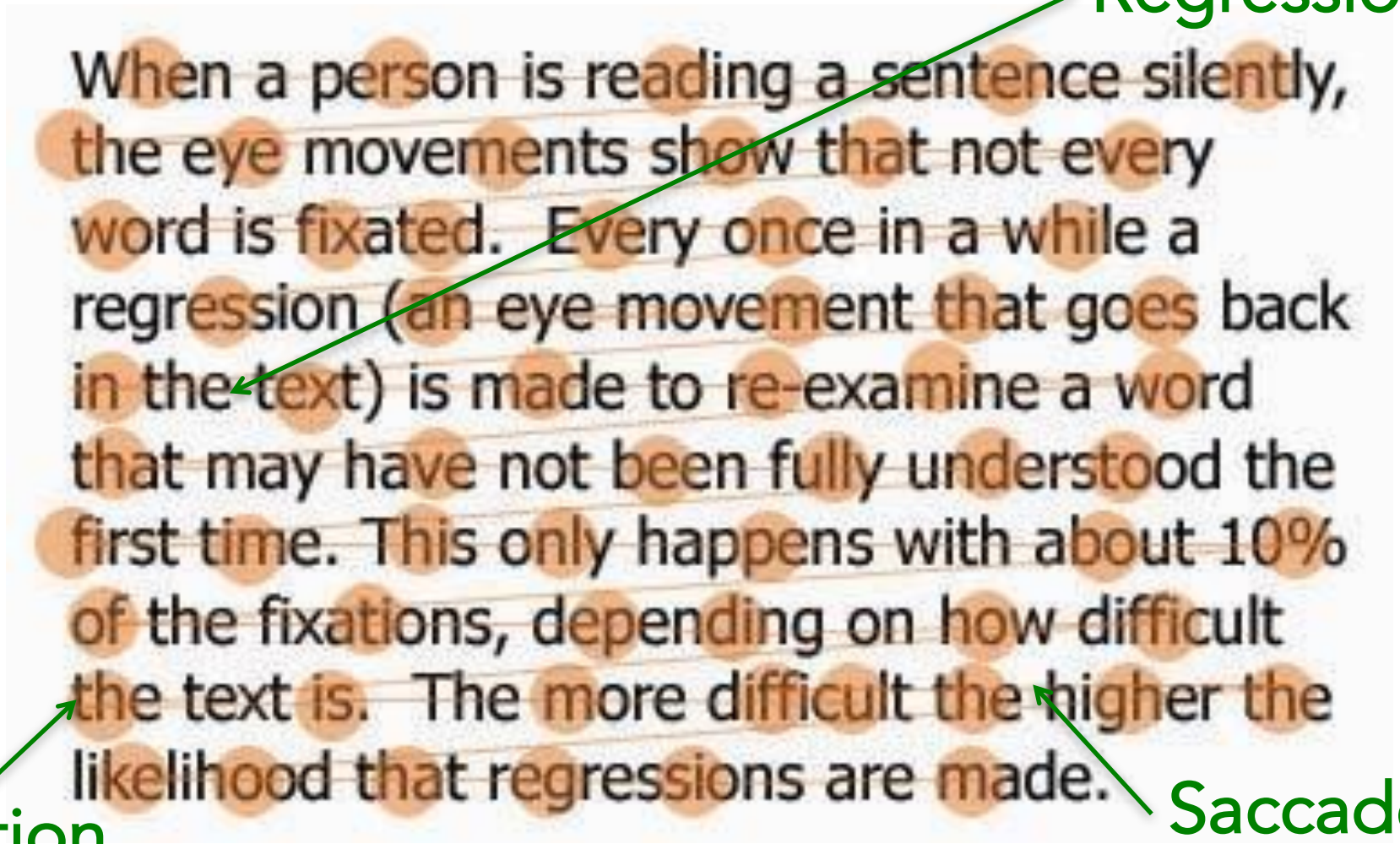


Image taken from: http://www.scholarpedia.org/article/File:Reading.jpg

Reading and the fovea

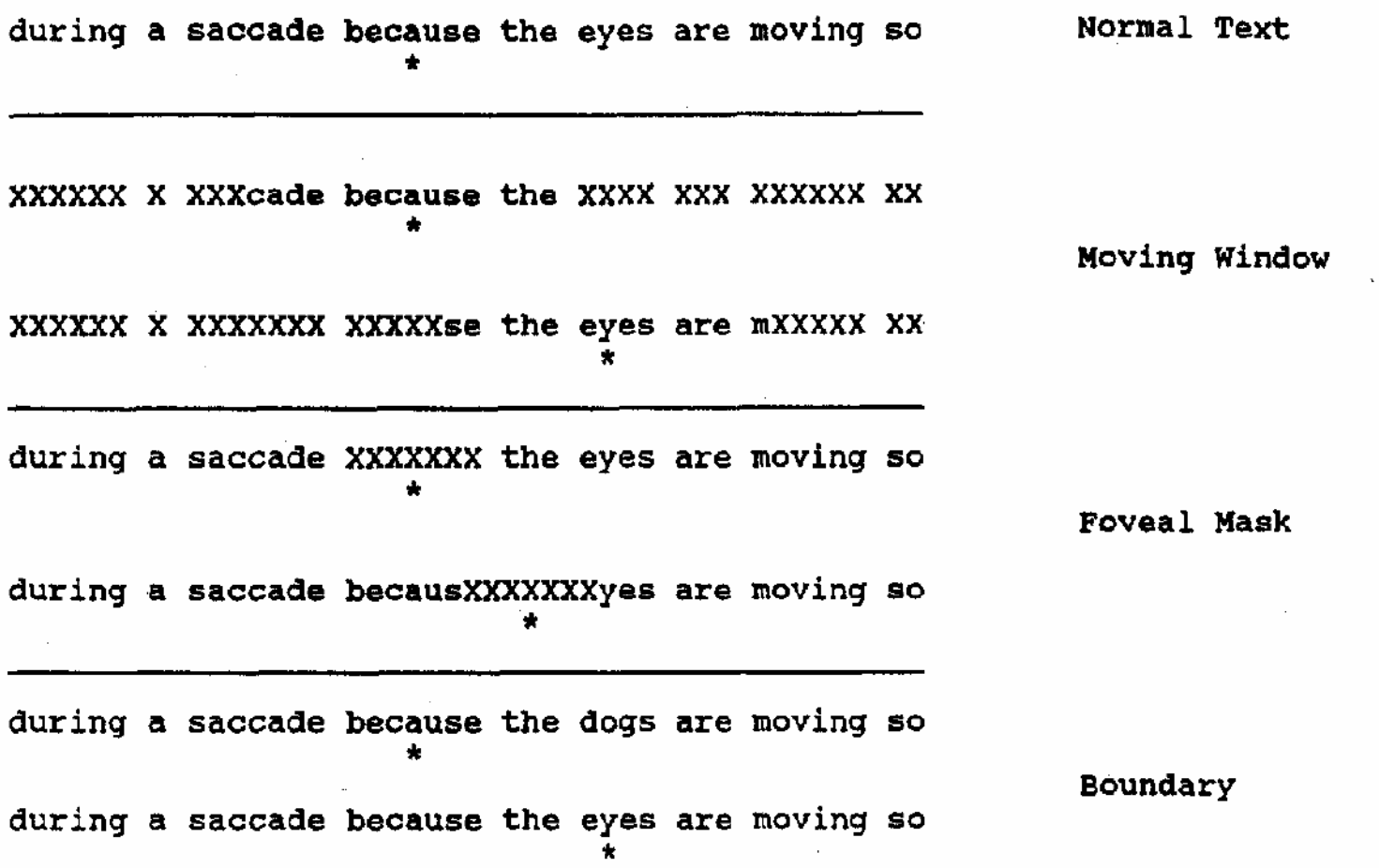


Image taken from (Rayner, 1998) examples of the moving window paradigm

Eye movements during reading

- Many words are not fixated
  - Content words are fixated about 85% of the time
  - Function words are fixated about 35% of the time
  - Frequency and predictability
- As word length increases, probability of fixation increases
  - 2-3 letter words are only fixated about 25% of the time
- Many other factors affect eye movements:
  - Typographical variables, line length, line spacing, print size and…

Eye movements & comprehension

- used to infer on-going cognitive processes that occur during reading
  - Processing difficulty influences eye movements
- reflect comprehension processes and failures
  - *"The old man the boat".*
  - Lexical, phonological, syntactic ambiguity; anaphora & coreference; semantic relationships; etc.
- reflect text difficulty
  - Increased number of regressions and longer fixations observed as text difficulty increases

Scene perception

- Yarbus, in the 1960's, showed that an eye gaze was dependent upon the question they were asked

The visitor

The visitor

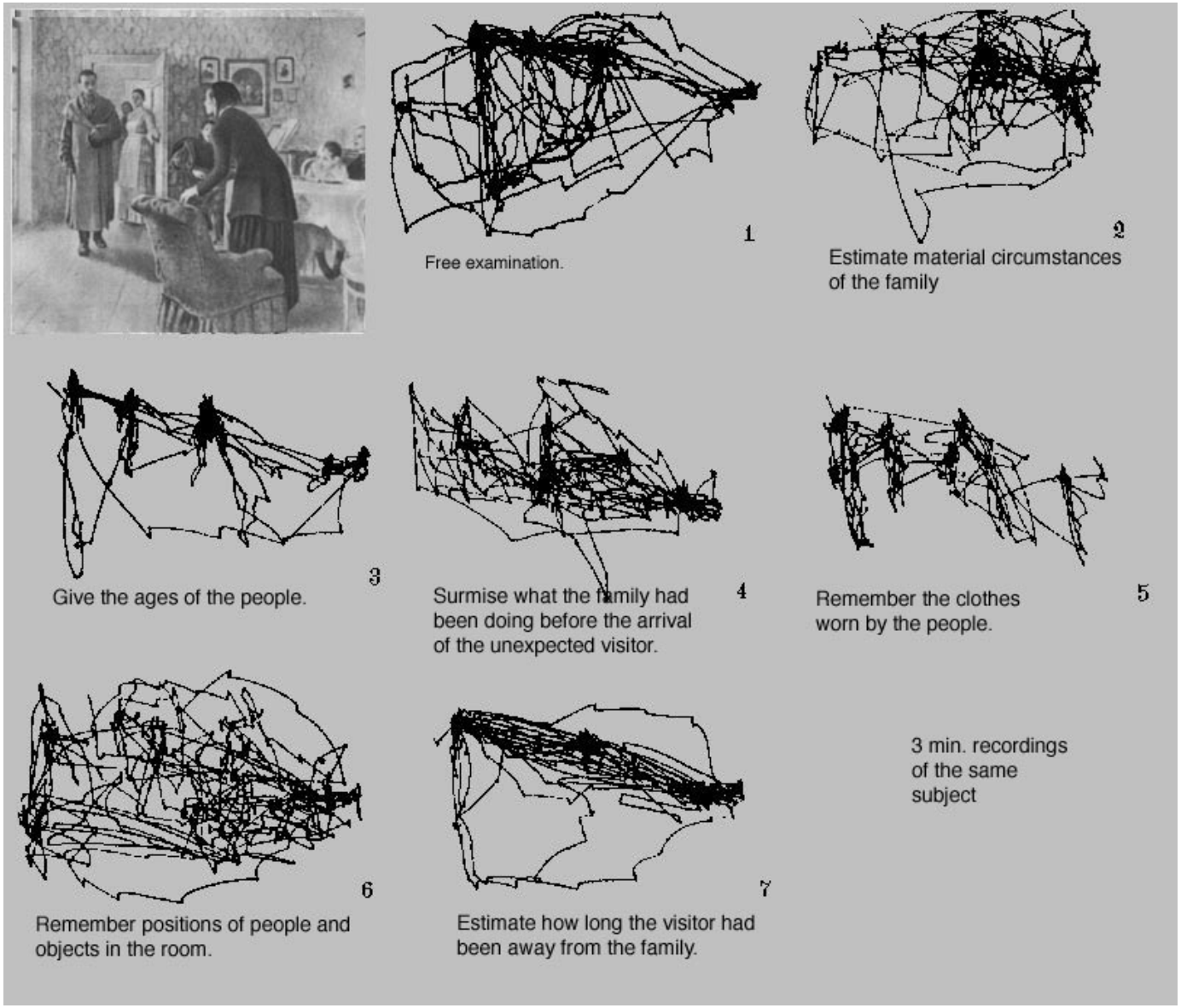


Image taken from: http://upload.wikimedia.org/wikipedia/commons/d/d2/Yarbus_The_Visitor.jpg

How Does Eye Tracking And HCI Fit Together?

Overview

- Usability testing (and research into interfaces)
- Input
- Intelligent interfaces

Usability testing

- Eye tracking is useful for interface design and usability testing
  - Eye gaze shows attention and visual processing trail
  - Observe where people look in the interface
  - Do they look in the right areas? Do they ignore areas?
  - Under different situations where do they look?

Website example

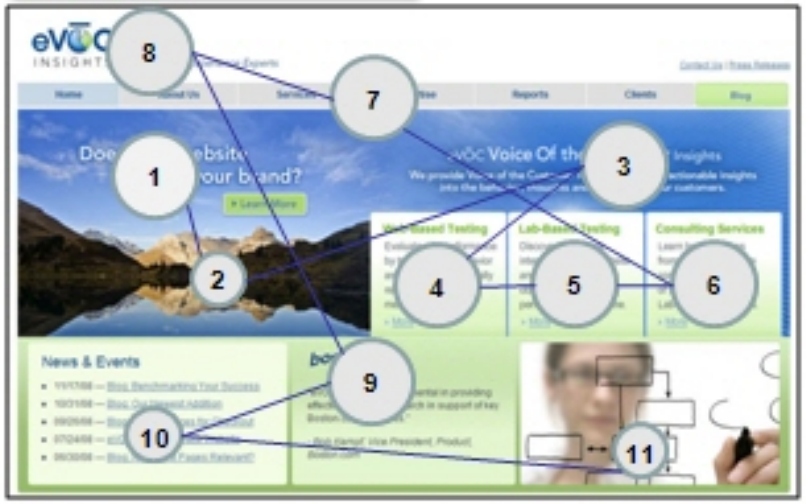
Aggregated Heat Map

Intensity of Viewers

Low → High

Sample	12
Time of Snapshot	20 sec

Chronological Gaze Plot



# of Viewers Per Area

Low → High

Sample	12
Avg. Time on Page	20 sec

Image taken from: http://www.evocinsights.com/img/eVOC_Eye_Tracking_Data.jpg

Web search example

Image taken from: http://www.website-design.it/wp-content/uploads/2012/08/Eye-tracking-Google-Image-by-University-of-Bournemouth.jpg

Eye gaze as an input

- Target acquisition usually requires the user to look at the target first before actuating the cursor control
- Facilitates hands free operation
- natural, little conscious effort
- Can resolve RSI problems (repetitive stress injury)

Examples

- Keyboard (Salvucci and Anderson, 2001, Lankford, 2000)
- Clicking device (Murata, 2006, Lankford, 2000)

Pros & cons

- Pros
  - Fast and natural
  - The user most likely have to look at a visual stimuli, such as a button, anyway
- Cons
  - Over-response: “Midas Touch”
  - Under-response

Eye tracking on phones

- Samsung's Smart Scroll
- Amazon Fire Phone's stereoscopic view

Gaming

- Use eye gaze in gaming to (Isokoski et al., 2009):
  - dynamic rendering, added realism, control input, and therapeutic use
  - to create realism
  - more interaction

Intelligent Interfaces

- Indirect input + usability
- Interfaces that use the implicit information from eye tracking to
  - adapt to the user

“Rather than creating systems that see, think, and act as people do, we focus on expanding and augmenting people's capabilities”

~ Abigail Sellen,
Microsoft Research

Task Identification

- Task identification (Iqbal and Bailey, 2004, Salojarvi et al., 2005, Simola et al., 2008)
- Detect reading (Campbell and Maglio, 2001).
  - Detect reading and skimming (Buscher et al., 2008)

Examples

- Attention Assistant (Campbell & Maglio, 2003)
- Attentive Documents (Buscher et al., 2012)
  - Annotation of areas of text that are considered most important based on eye gaze
- Reading assistance
  - iDict (Hyrskykari et al., 2000)
  - The Reading Assistant (Sibert et al., 2000)

Eye Tracking and eLearning

Can eye tracking be used to support reading in eLearning?

- eLearning is becoming ubiquitous
  - Moodle, Blackboard, etc.
  - MOOCs
- Static, one size fits all
- but everyone is different!
  - Adaptive eLearning

Adaptive eLearning

- Predict the users state and dynamically change the environment to suit it
  - measured skill level (Chen, 2008)
  - learner style (Surjono, 2014, Mehigan et al., 2011, Spada et al., 2008)

Adaption methods

- User input
  - Questionnaires
  - Responses
- Biometric data
  - Mouse movements
  - Physiological signals (GSR, ECG, EEG)
  - Eye tracking!

Examples

- AdeLE (Adaptive e-Learning with Eye-Tracking) is (Gütl et al., 2005)
- e5Learning (enhanced exploitation of eyes for effective eLearning)
  - uses eye gaze metrics to identify the students' emotional state (Calvi et al., 2008).
- Gaze Tutor
  - uses eye gaze to determine the user's level of stimulation to alter the environment to stimulate the user (D'Mello et al., 2012)

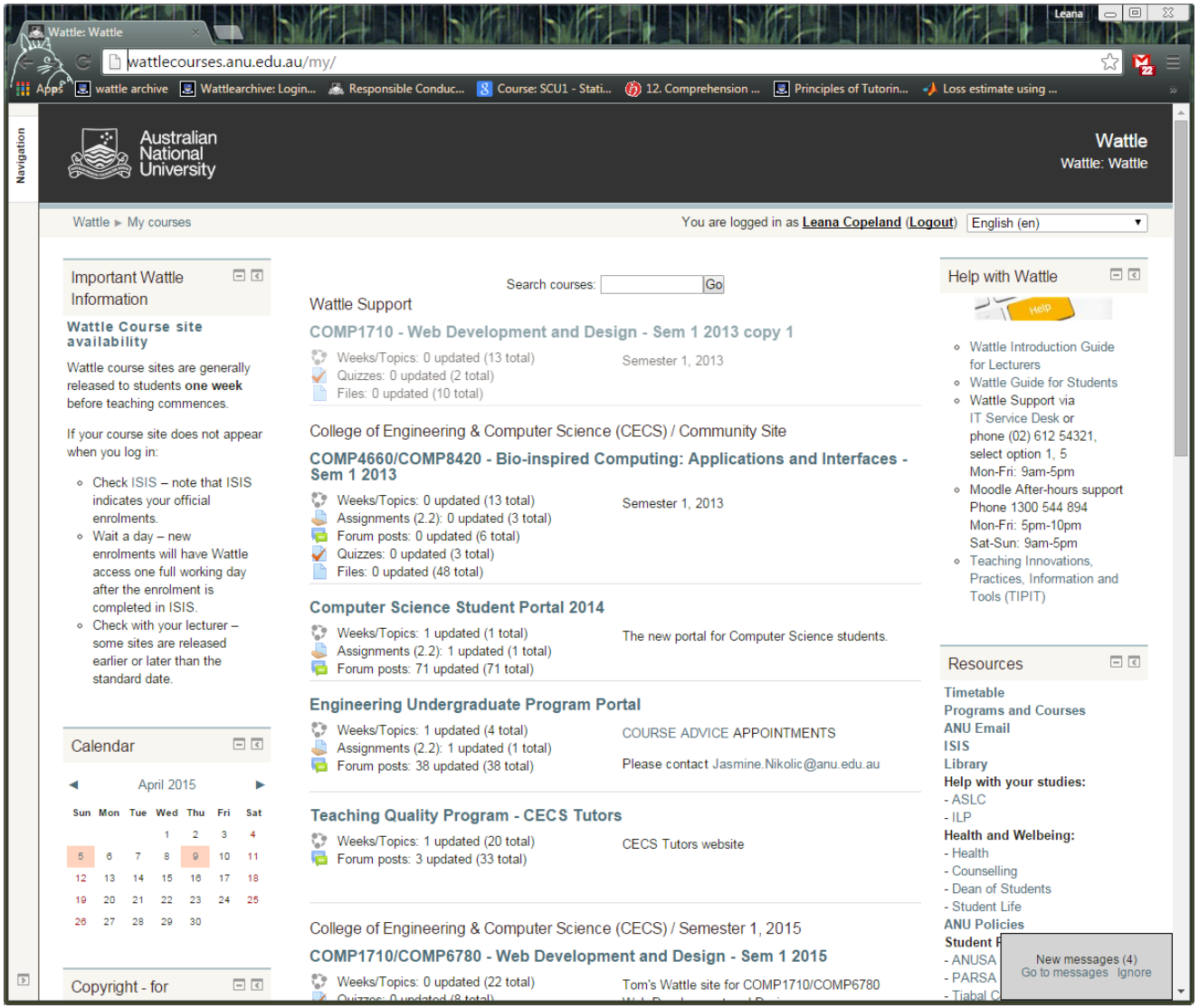
Text based learning

- Use eye gaze to dynamically change the text based on
  - Reading behaviour
  - Comprehension
- Provide feedback
  - Student learning behaviour
  - How good the materials are

User study

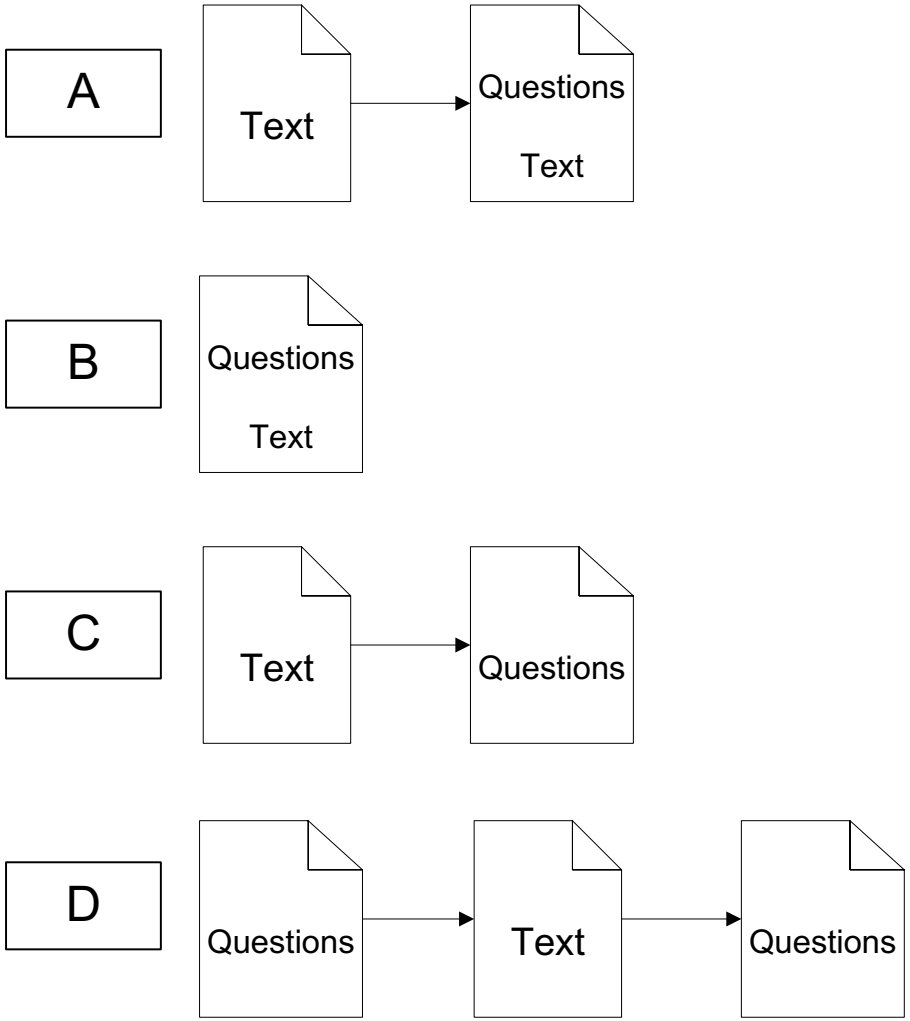
- Tutorial in ANU eLearning environment, called Wattle
- Try different presentations
  - Is one better than another?
  - Can we predict reading comprehension?

What is Wattle?



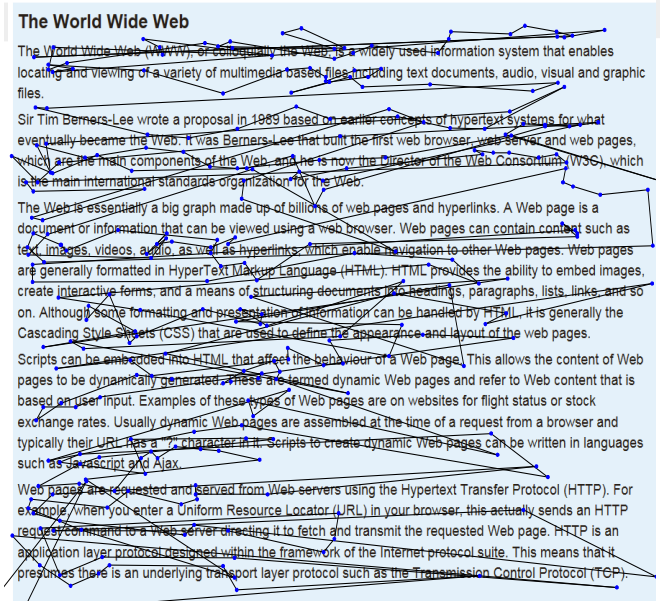
User Study

- Between-subjects design
  - Each participant shown 1 of 4 presentation sequences →
- Two questions per text page:
  - Multiple-choice
  - cloze

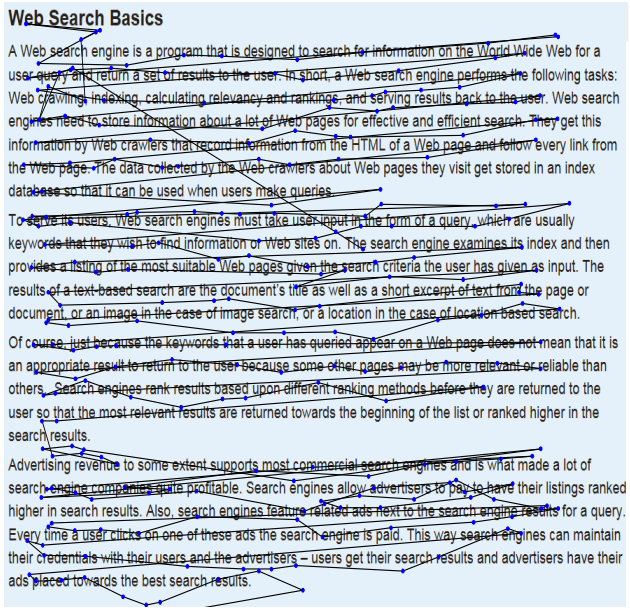


Example of reading behaviour for text only page

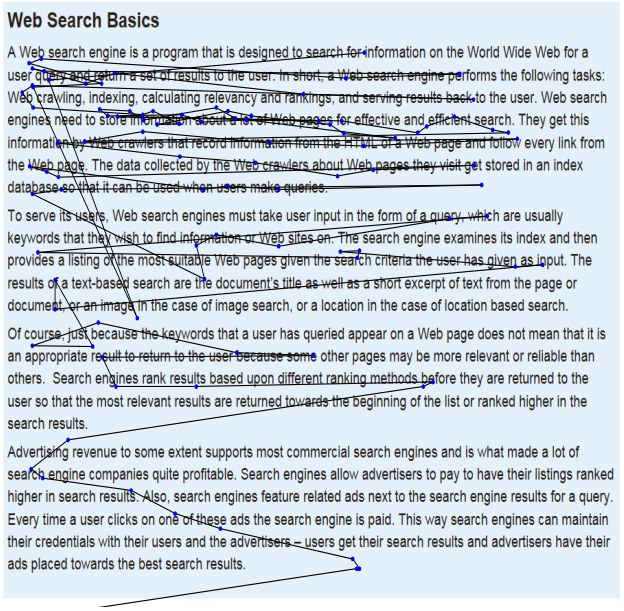
Format A

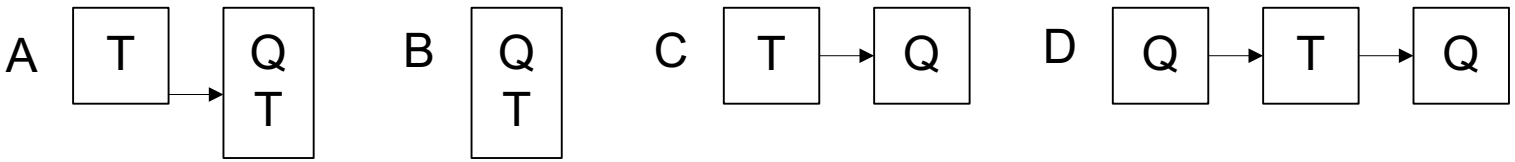


Format C



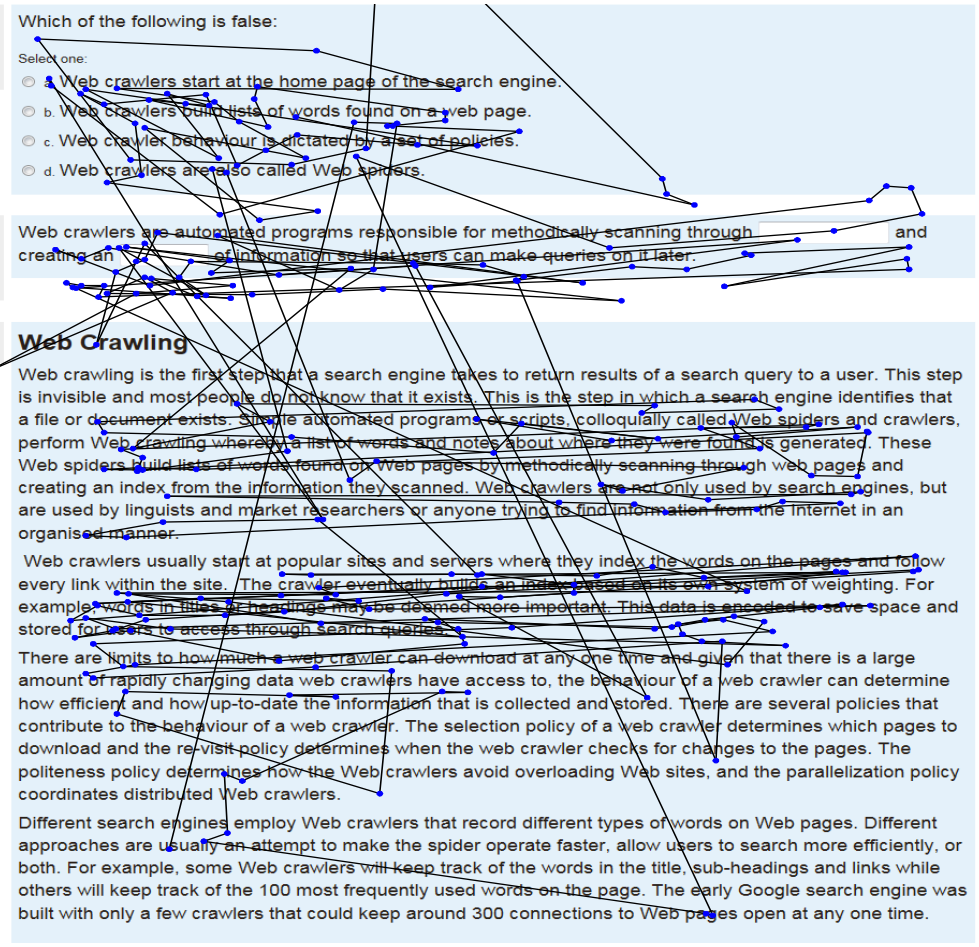
Format D



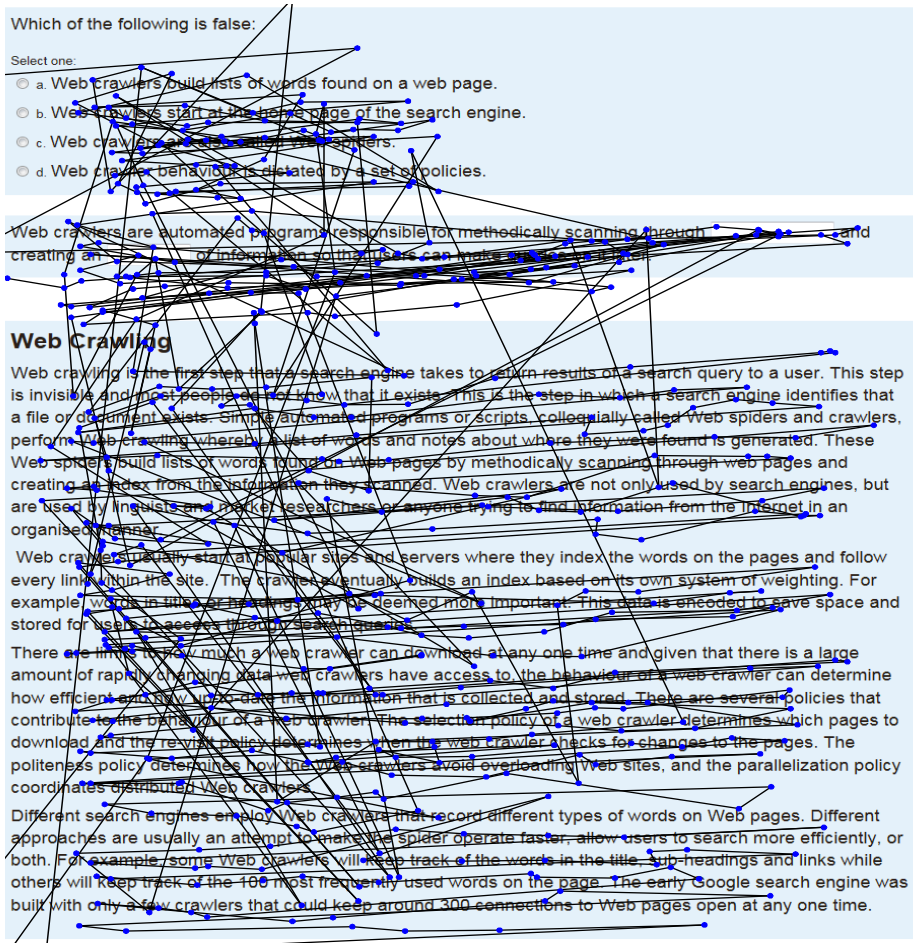


Example of reading behaviour for Questions and text page

Format A

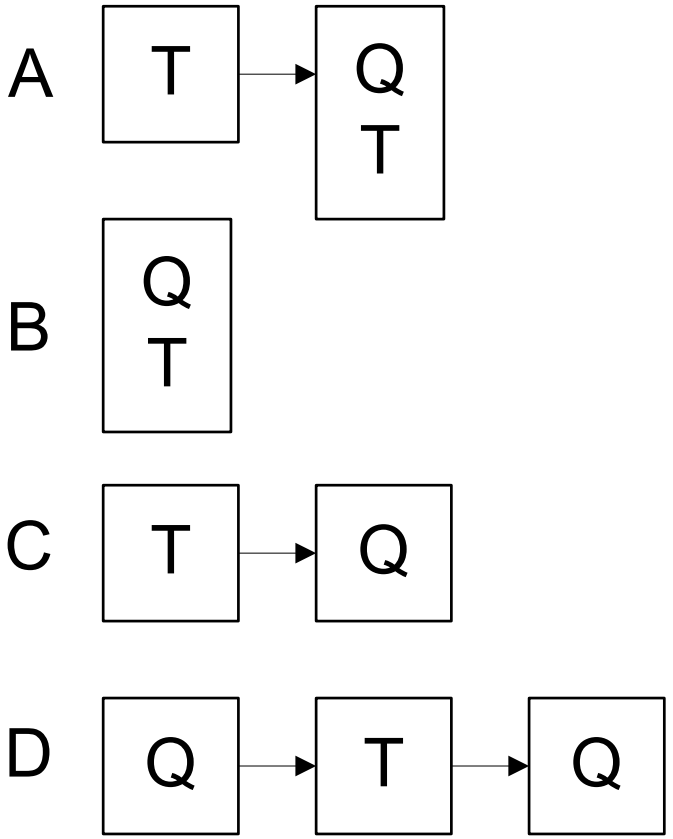


Format B

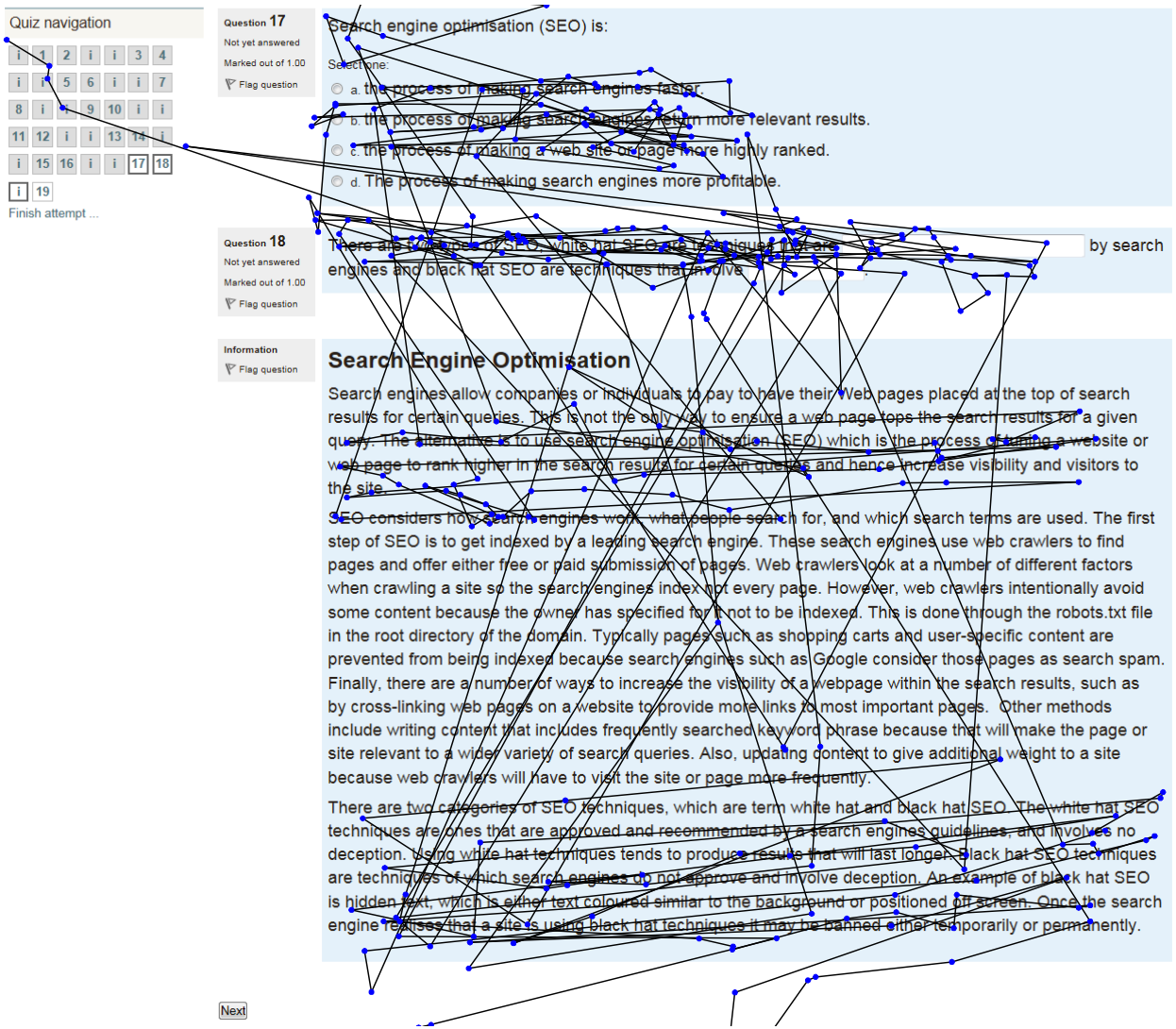


Effect on overall performance

- No difference in quiz scores between:
  - Formats A & B
  - Formats C & D
  - A & B > C & D
- Format A took the longest
- Format C & D:
  - strong positive correlation (r=0.9 & r=0.8, respectively) between quiz score & subjective understanding score



Answer-seeking behaviour



Multiple-choice vs. cloze

- Participants refer back to the text significantly more when answering the cloze questions compared to the multiple-choice questions
  - Cloze questions make students read more!

What this all means

- Presentation of text and evaluation resources impacts reading behaviour & learning outcomes
- Can be manipulated to promote:
  - reading -> non-direct reading goals
  - accurate self-assessment of understanding
  - learning of concepts being assessed
- Effective feedback tool!

Can we mitigate distractions during reading?

- Digital environments can be very distracting
  - Alerts, advertising, social media, Instant messaging (IM), emails, notifications, etc.
- What effect does this have on reading?

User Study

- Easy vs hard text
- Visually distracting environment
- 2 mitigation signals

The ”distracting” environment

phpsite-leanaco.rhcloud.com

Working with Digital Images

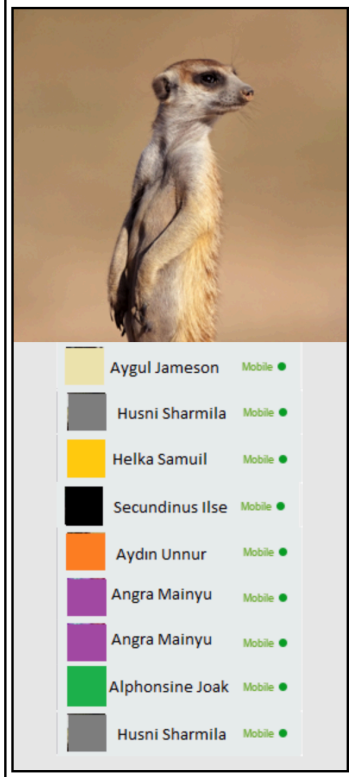
Digital images come in many forms; photographs, icons, clipart, graphs, diagrams and sketches to name a few. They have many sources including scanning, photography, born digital art and video stills.

Digital images can be either vector or raster graphics. Vector graphics are created using mathematic descriptions such as lines and curves. The vector graphics we know best are fonts, but they are also used for clipart and icons. Raster graphics images are better known as bitmaps. Bitmaps include the digital photographs we know as JPGs, TIFFs and PNGs. They store a dot matrix of individual pixels to compose an image. Raster graphics are more common than vector graphics even though they are not as compact and cannot be scale as well to different sizes.

Digital cameras arrived in Australia in 1998, and rapidly overtook conventional photography. Today digital photographs are the most prevalent type of digital image. Over the years cameras have been included in many devices including mobile phones and tablets. Millions of digital photos find their way onto websites every day as media content, where they provide communication, information and entertainment.

Digital cameras work by registering the light that falls on the camera sensor when the shutter button is pressed. Camera sensors are normally CCDs (Charge Coupled Devices) or CMOSs (Complementary Metal-Oxide Semiconductors). Together with other hardware and software within the camera, sensors record a series of bits known as pixels. Pixels (short for picture elements) store information about the light that fell on the sensor. The camera or your computer then assembles the pixels into an image that you can see.

Digital photographs are an assemblage of information your camera stores about the pixels that make up the image. The quality and quantity of the information is dependent upon the bit depth and resolution respectively, which construct the pixels that form your image.



Mitigation signal A

Working with Digital Images

Digital images come in many forms; photographs, icons, clipart, graphs, diagrams and sketches to name a few. They have many sources including scanning, photography, born digital art and video stills.

Digital images can be either vector or raster graphics. Vector graphics are created using mathematic descriptions such as lines and curves. The vector graphics we know best are fonts, but they are also used for clipart and icons. Raster graphics images are better known as bitmaps. Bitmaps include the digital photographs we know as JPGs, **TIFFs** and PNGs. They store a dot matrix of individual pixels to compose an image. Raster graphics are more common than vector graphics even though they are not as compact and cannot be scale as well to different sizes.

Digital cameras arrived in Australia in 1998, and rapidly overtook conventional photography. Today digital photographs are the most prevalent type of digital image. Over the years cameras have been included in many devices including mobile phones and tablets. Millions of digital photos find their way onto websites every day as media content, where they provide communication, information and entertainment.

Mitigation signal B

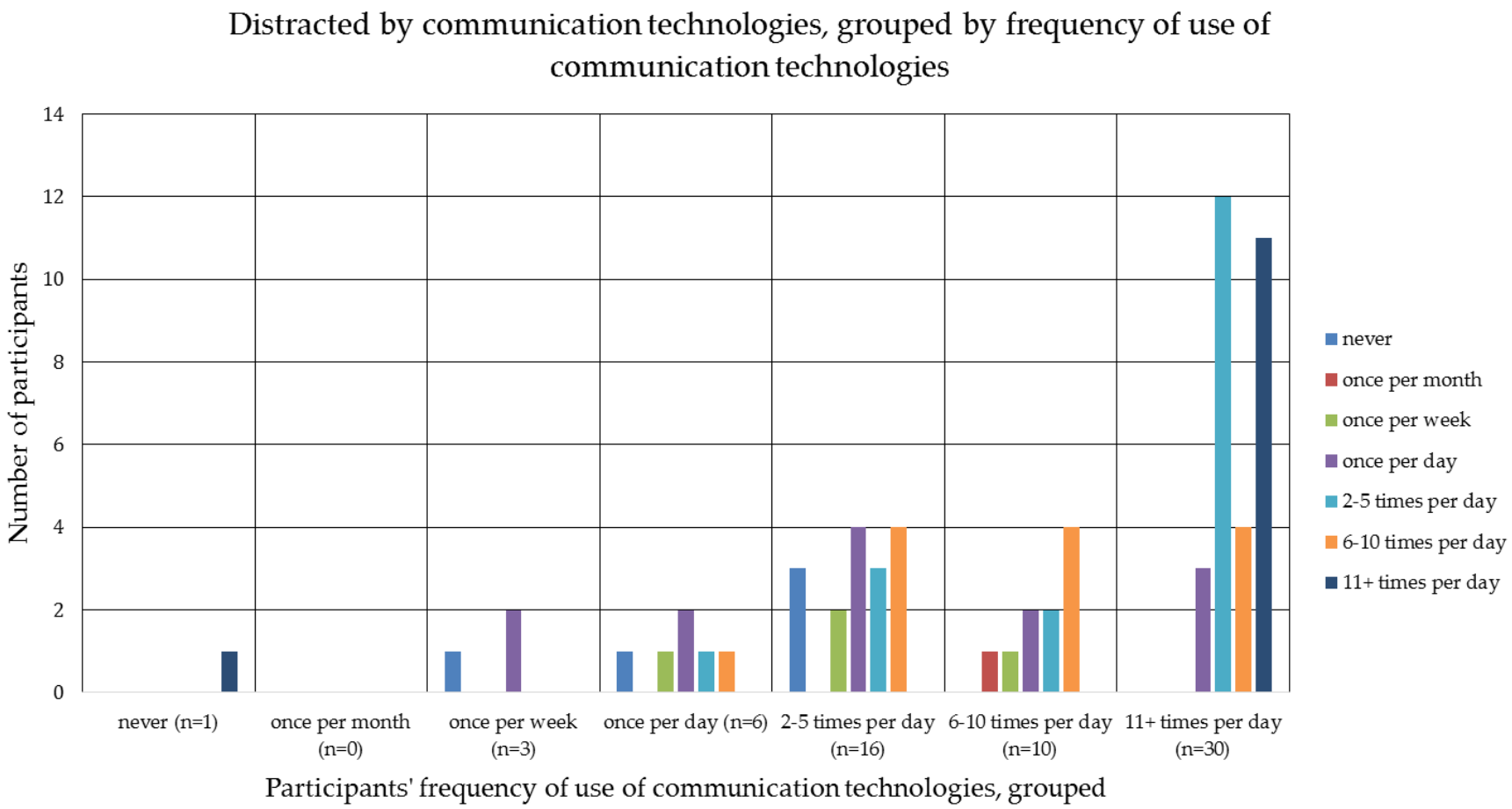
Working with Digital Images

Digital images come in many forms; photographs, icons, clipart, graphs, diagrams and sketches to name a few. They have many sources including scanning, photography, born digital art and video stills.

Digital images can be either vector or raster graphics. Vector graphics are created using mathematic descriptions such as lines and curves. The vector graphics we know best are fonts, but they are also used for clipart and icons. Raster graphics images are better known as bitmaps. Bitmaps include the digital photographs we know as JPGs, TIFFs and PNGs. They store a dot matrix of individual pixels to compose an image. *Raster* graphics are more common than vector graphics even though they are not as compact and cannot be scale as well to different sizes.

Digital cameras arrived in Australia in 1998, and rapidly overtook conventional photography. Today digital photographs are the most prevalent type of digital image. Over the years cameras have been included in many devices including mobile phones and tablets. Millions of digital photos find their way onto websites every day as media content, where they provide communication, information and entertainment.

How distracted do students think they are?



Results

- Neither mitigation signal nor text difficulty affected reading time or comprehension
- BUT... The eye gaze showed that distraction rate was very low!
  - ~4 distractions
  - only 2% of fixations on distractions

What did the participants think

- 82% of participants stated that they were distracted whilst reading
  - However of the 18% most stated something about the images changing
- Most did not see the the greyed out signal
- Most stated that the yellow highlighting was helpful

Where to next?

- Adaptive content generation
- Document annotation
  - Comprehension
  - Reading metrics
  - Distraction metrics

Where to next?

- Adaptive content generation
- Document annotation
  - Comprehension
  - Reading metrics
  - Distraction metrics

Image taken from: http://www.opencolleges.edu.au/informed/features/student-driven-learning/