

Eye Movement and Glance Tracking

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Overview

- Introduction
- Eye movements
- Eye movements - indicator for mental activity
- Eye tracking
- Video-based tracking
 - head-mounted systems
 - environmentally fixed systems
- Pupillometry

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Motivation

- Can we measure usability?

- Can we measure distraction?
 - Information Overload (IO)
 - Change Blindness (CB)
 - Perceptual Tunneling (PT)
 - Cognitive Capture (CC)

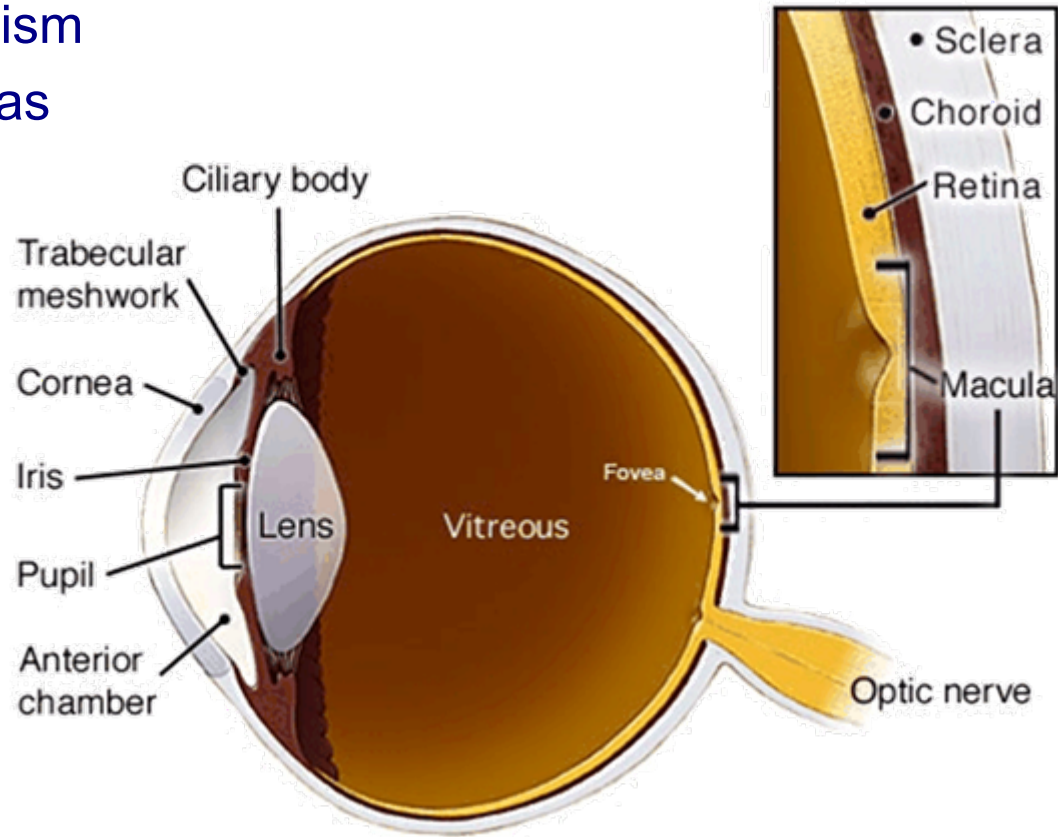
Introduction

- vision
 - highly complex process
 - large amount of information

- human visual system
 - eyes
 - optic nerves
 - brain

The Human Eye

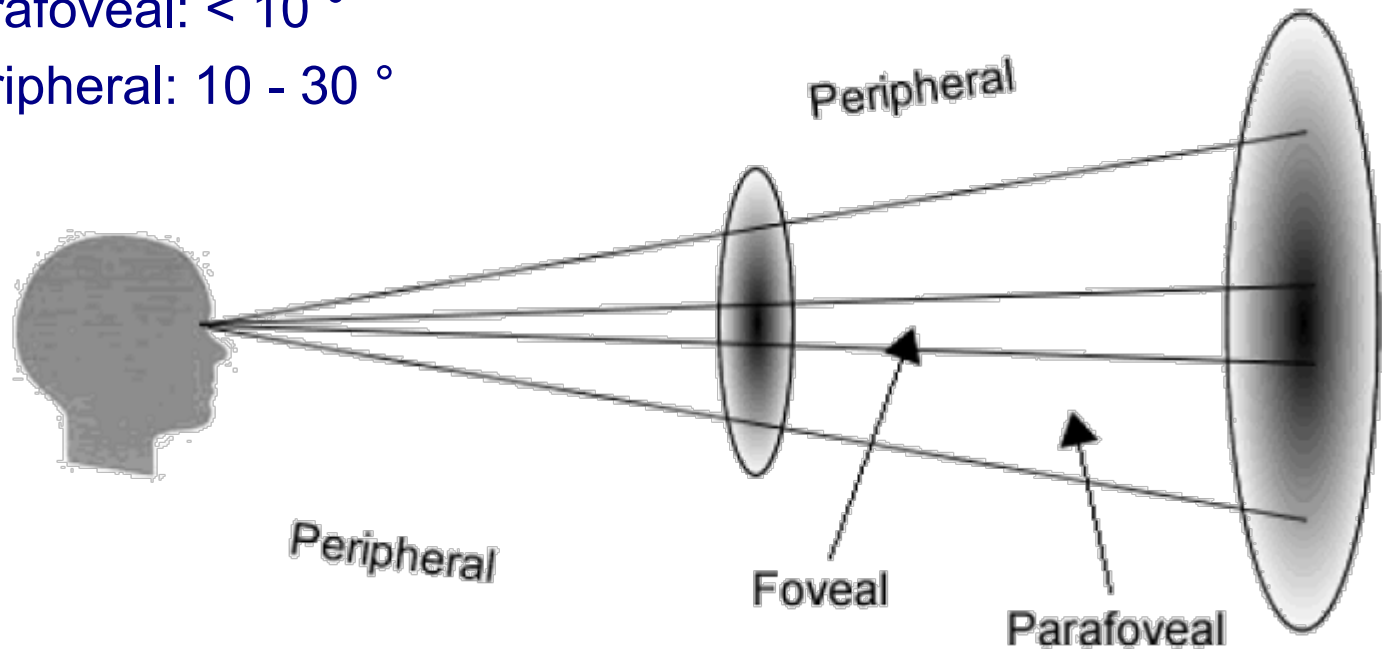
- similar mechanism
found in cameras



anatomy of the human eye

Visual Fields

- 3 visual fields
 - foveal: $< 2^\circ$
 - parafoveal: $< 10^\circ$
 - peripheral: $10 - 30^\circ$

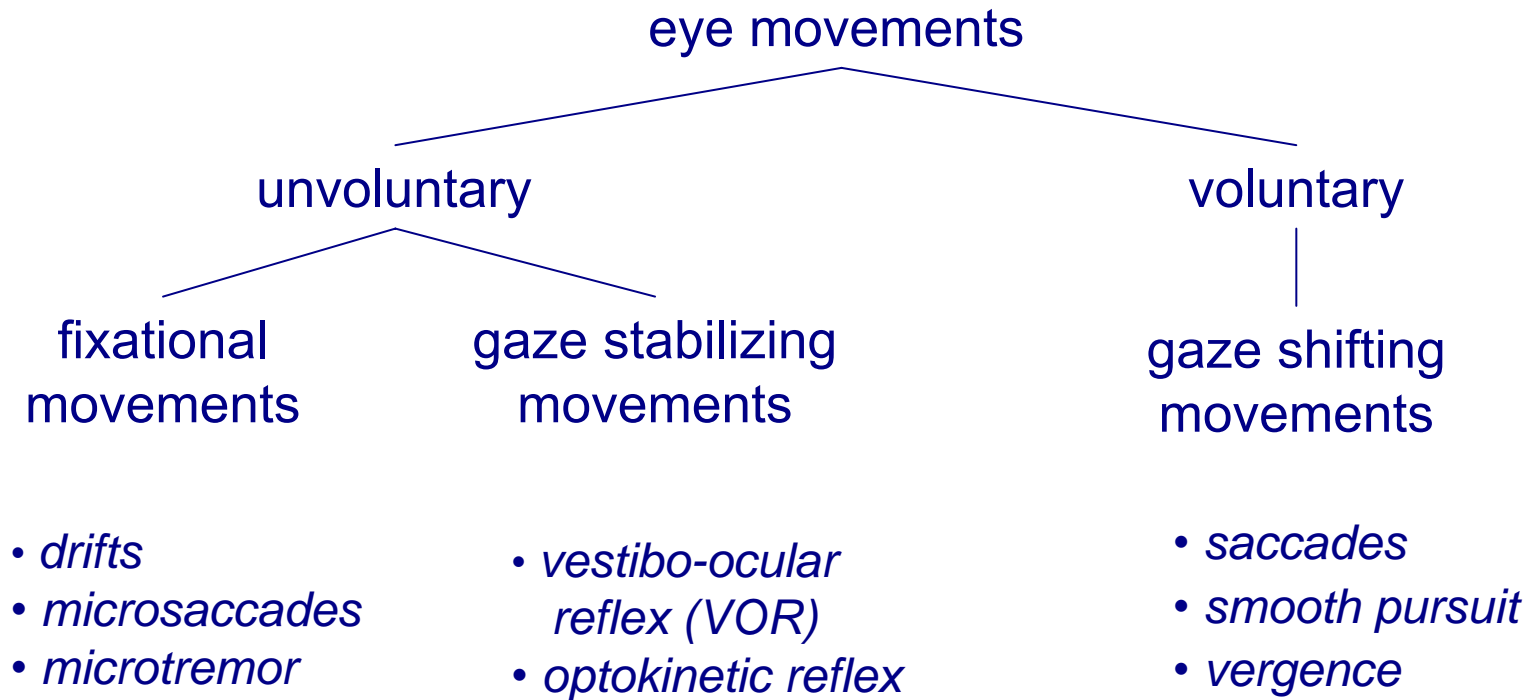


the three visual fields

Overview

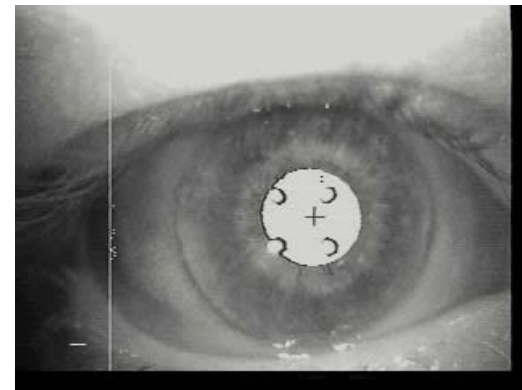
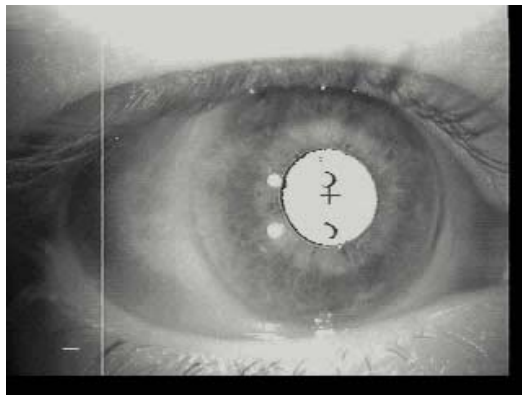
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Types of Eye Movement



Saccades vs. Smooth Pursuit

- primary purpose of saccades
 - locating new points of interest
 - only for steady objects
- primary purpose of smooth pursuit
 - following moving objects



videos by Micromedical Technologies Inc.

Saccades and Fixation

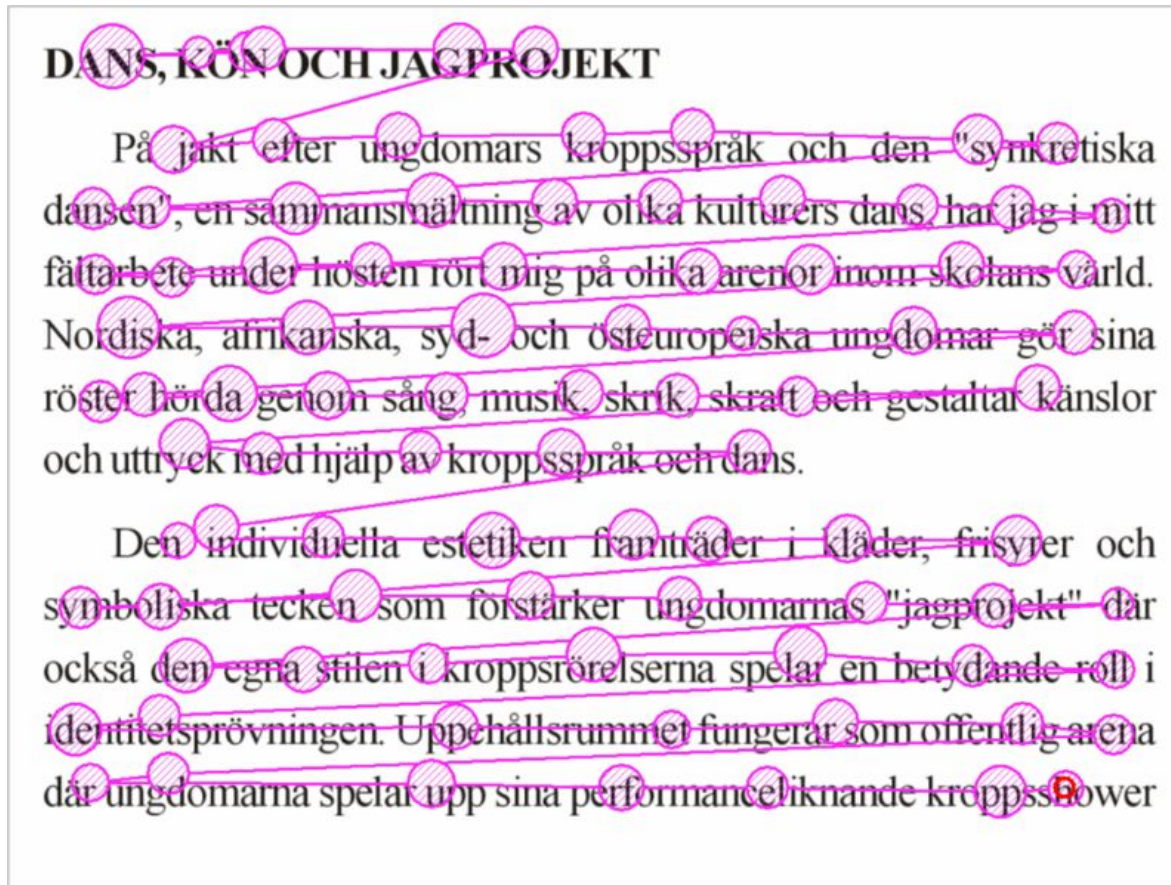
- fixation
 - period between two consecutive saccades
 - typical duration: 200 - 600 ms
- visual perception in humans
 - only during a fixation
 - no perception during saccades



Saccades

- quick, simultaneous movements of both eyes in the same direction
- ballistic
 - cannot be suppressed once initiated
- common values
 - duration: 10 - 80 ms
 - amplitude: 2 - 50 °
 - angular velocity: ~ 1000 °/s

Saccades, Fixations and Reading



study of speed reading made by Humanistlaboratoriet, Lund University

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Eye Movement and Mental Activity

- relationship first demonstrated by Yarbus (1967)



Free view



Estimate the ages of the people



Original image



Remember the positions of the people



Surmise what the family was doing

Impact of Mental Workload on Visual Activity

	... when workload increased ↗
median fixation time	increase ↗
median amplitude of saccade	decrease ↘
saccades per time unit	decrease ↘

Characteristics of Glance Behaviour

- amount of glances
 - reduced amount of glances may be an indicator for cognitive capture (CC)
 - percentage of non task relevant glances
 - available after classification of the glances
 - maximum glance duration
 - accumulated glance duration
 - median glance duration
- } during a secondary task

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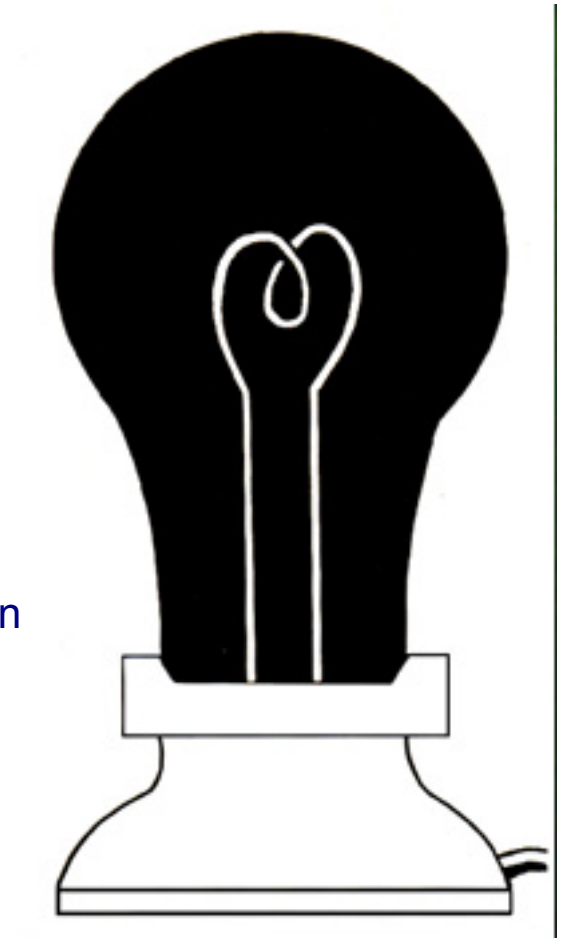
Methods for Eye Movement Measurement

- subjective measurement
- contact-based measurement
- video-based measurement

Subjective Approach

- very simple technique
- based on
 - direct observation or
 - subject's description of what he's seeing (experiments with afterimages)

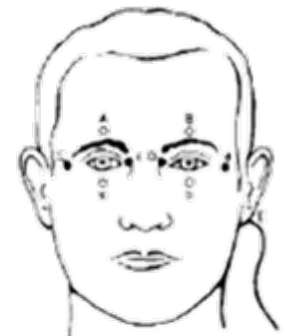
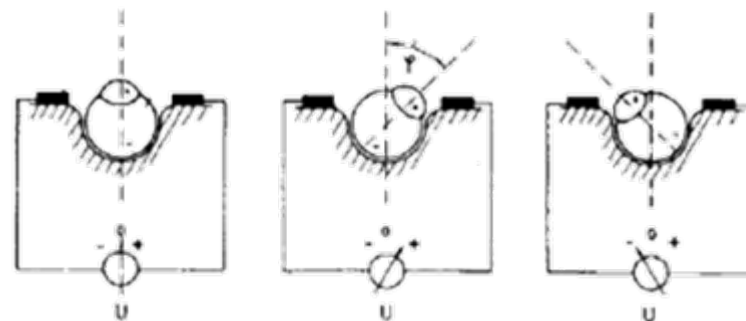
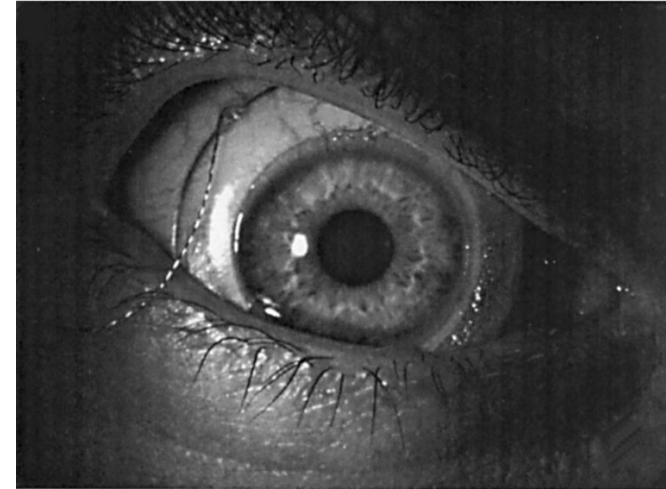
Staring at the light bulb for 30 s will cause an afterimage of a glowing light bulb!



Contact-based Approach

- search coil
 - induced electric current due to eye movement in a magnetic field

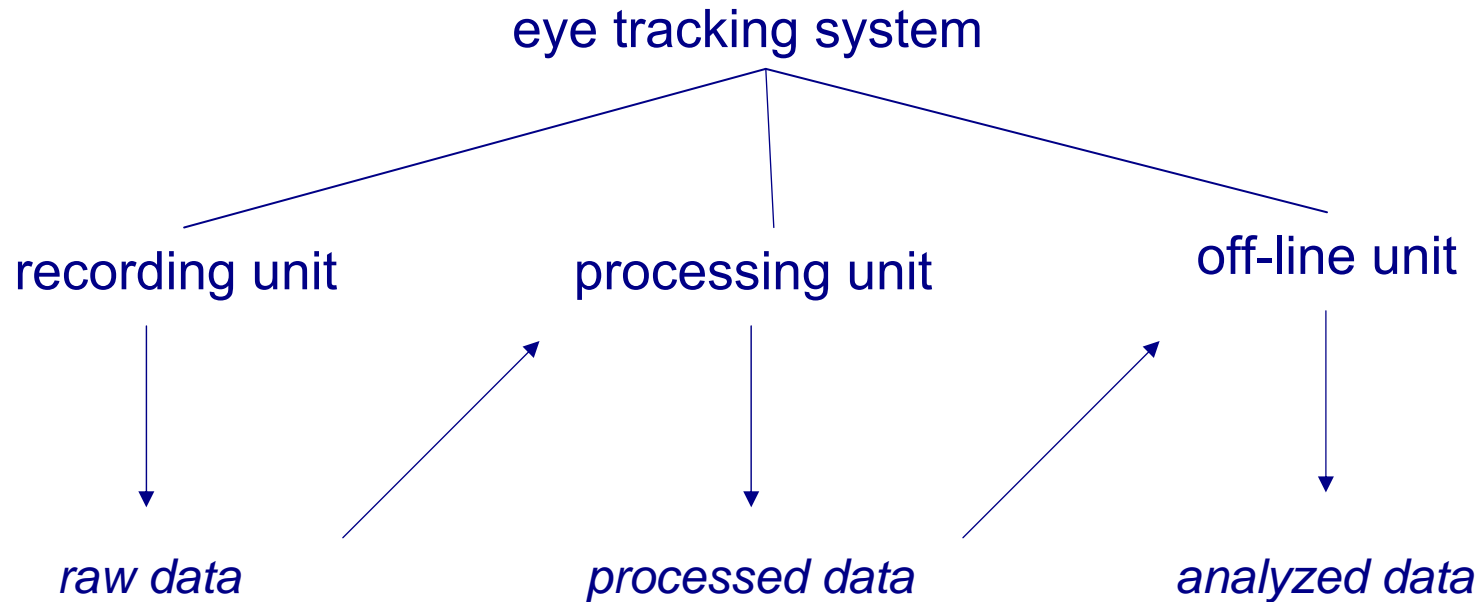
- electrooculography
 - measurement of the potential difference between cornea and retina



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Video-based Eye Tracking



Video-based Eye Tracking

- Requirements
 - robust
 - easy to calibrate
 - high sample rates
 - comfortable for users
 - little influence on glance behaviour

Video-based Eye Tracking Standards

- Standards
 - CCIR Standard (Europe):
 - 625 lines
 - 50 frames/s → 25 images/s
 - NTSC Standard (USA, Japan):
 - 525 lines
 - 60 frames/s → 30 images/s

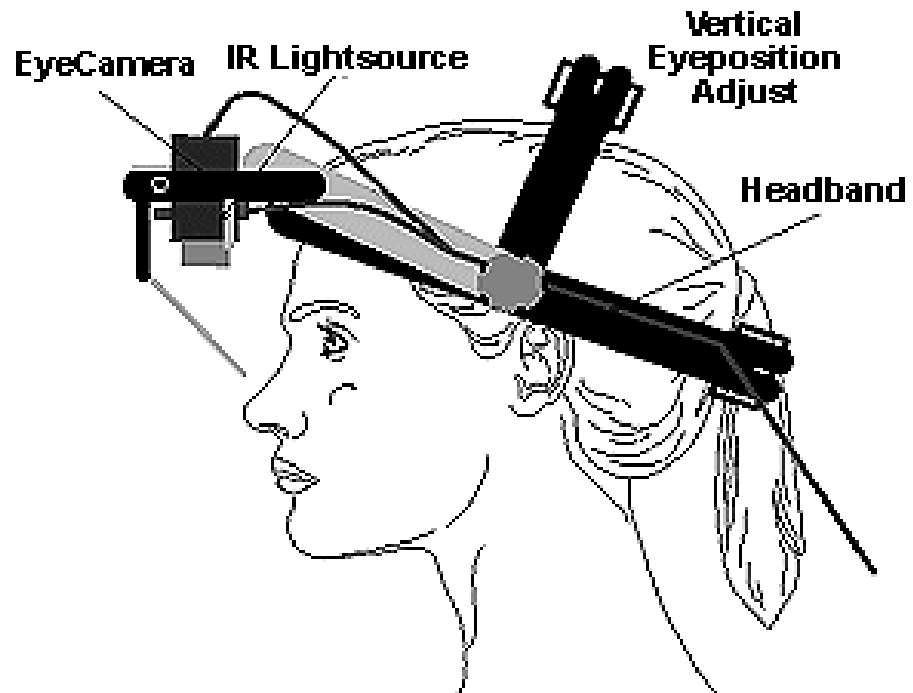
Types of Eye Tracking Systems

- head-mounted systems
 - + precise
 - intrusive (may alter normal glance behaviour)

- environmentally fixed systems
 - + non-intrusive (do not affect normal glance behaviour)
 - less accurate

Head-mounted Systems

- illumination with infrared (IR) light
- eye serves as retroreflector



Eye Tracking Techniques

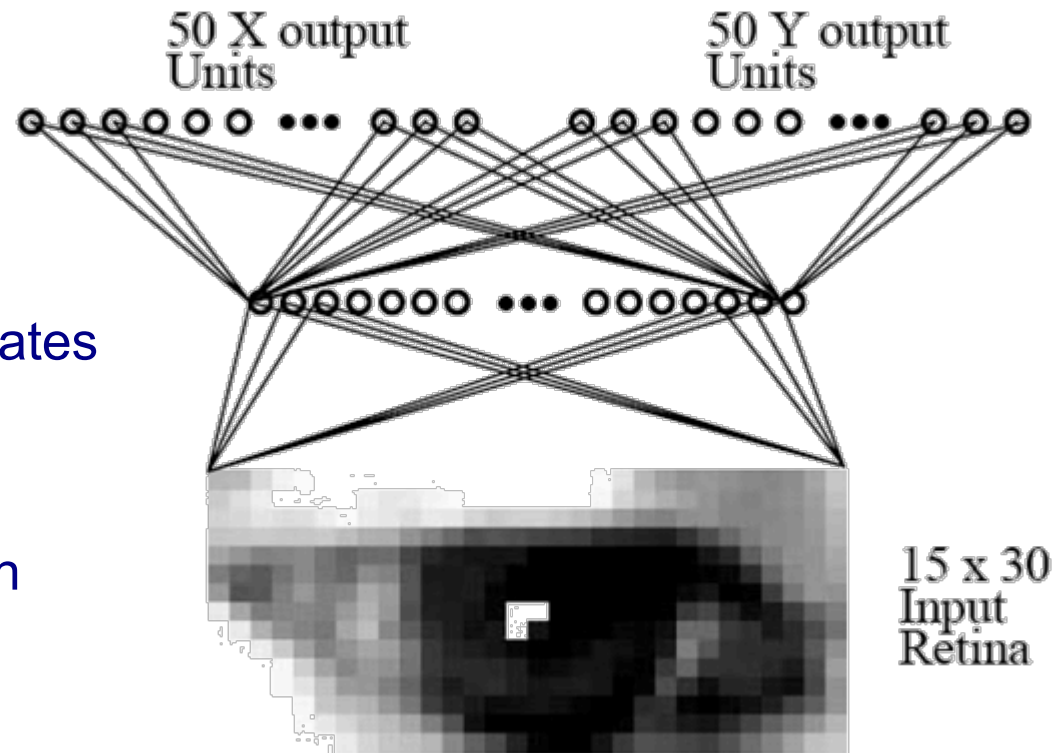
- bright pupil
 - on-axis IR light source
 - + detailed iris pigmentation information
 - + applicable in various lighting conditions
 - not suitable for outdoor tracking ← interference
- dark pupil
 - off-axis IR light source
 - less precise alignment required
 - no interference even for large eye movements
 - reduced quality of image

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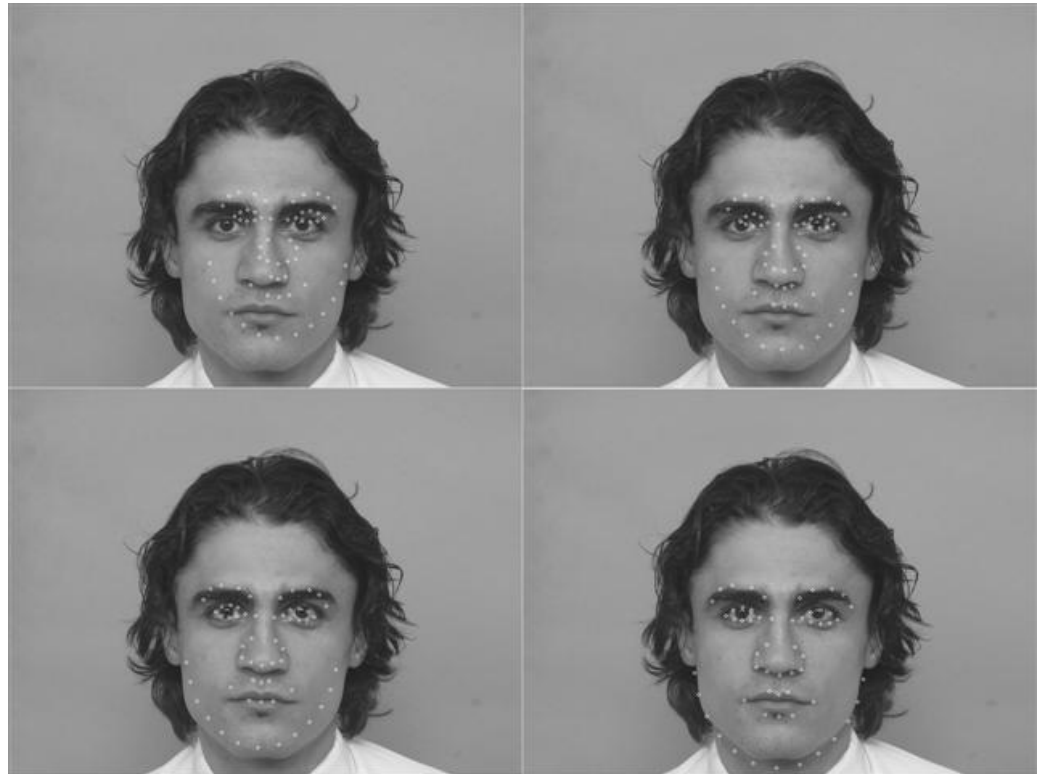
Eye Tracking with Artificial Neural Networks

- Input
 - retinal image
- Output
 - gaussian distribution of the x and y coordinates of the gaze vector
- 3 layer network
- standard backpropagation algorithm



Eye Tracking with Active Appearance Models

- image interpretation
using statistical models



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Pupil Size

1.5 mm
bright light



5 mm
standard



8 mm
dim light

- factors that cause change in pupil size

alcohol

drugs

illness

brightness

likes/dislikes

emotions

mental
workload

physical
activity

age

Basic Principles of Pupillometry

- observation I:

Brightness has the biggest influence on pupil size.

- observation II:

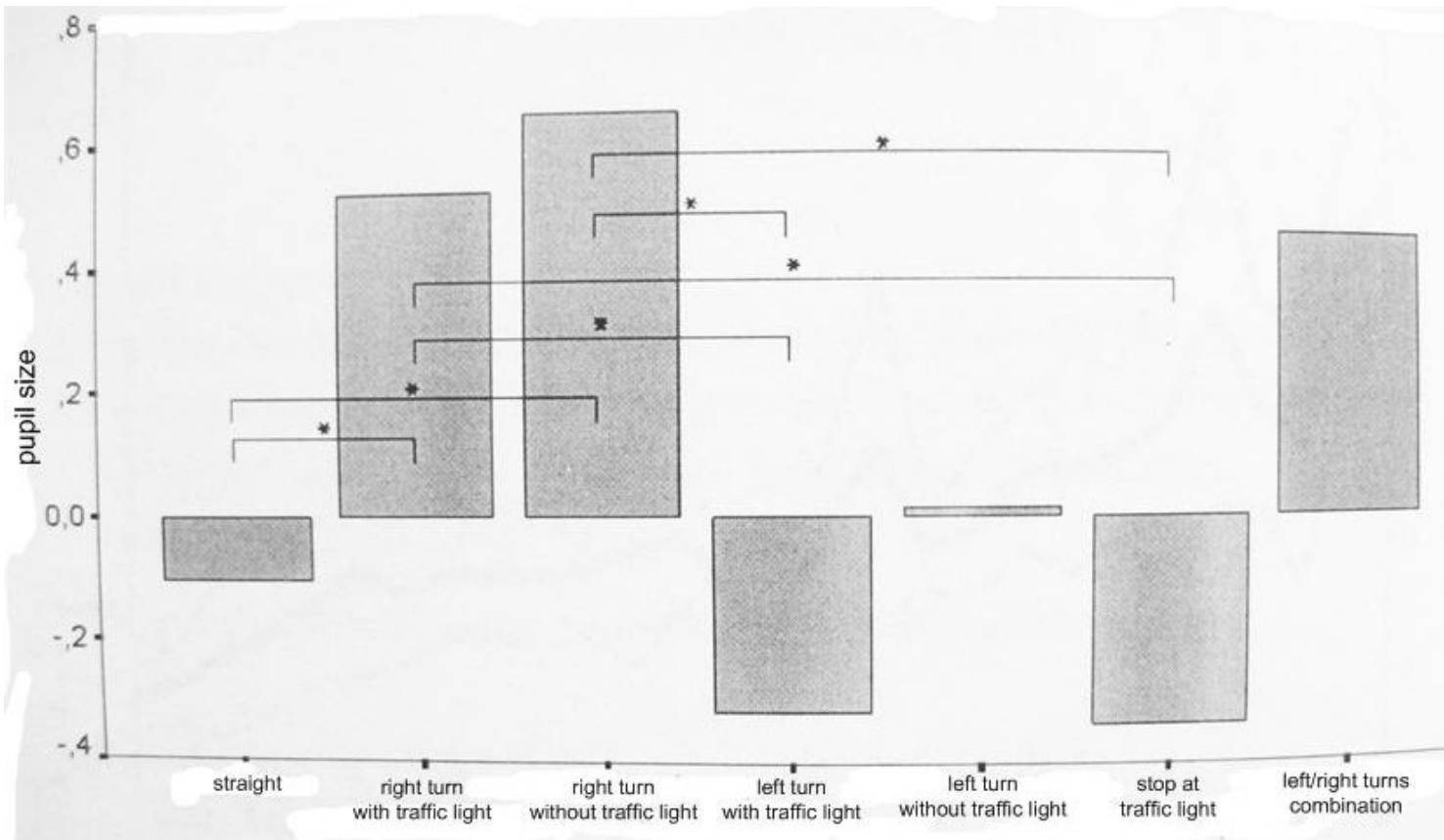
Every change in pupil size occurs independently from other changes. (linear combination of changes)

- observation III:

Pupil size increases proportionally to the difficulty level of the task to be solved.

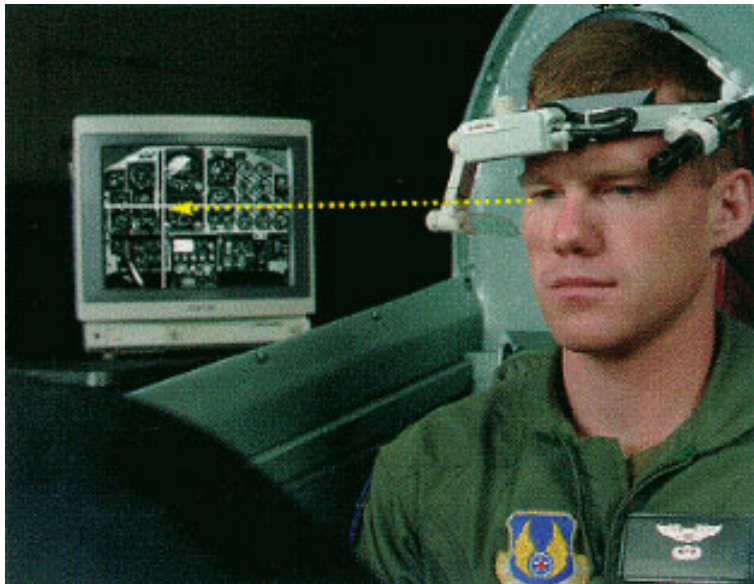
Experimental Results

- pupil size in different driving situations



picture taken from Rößger

Eye Tracking and Time-critical Tasks



evaluation of pilots



driving

Other Application Areas



marketing research

car design



Conclusion

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Thank you for your attention!