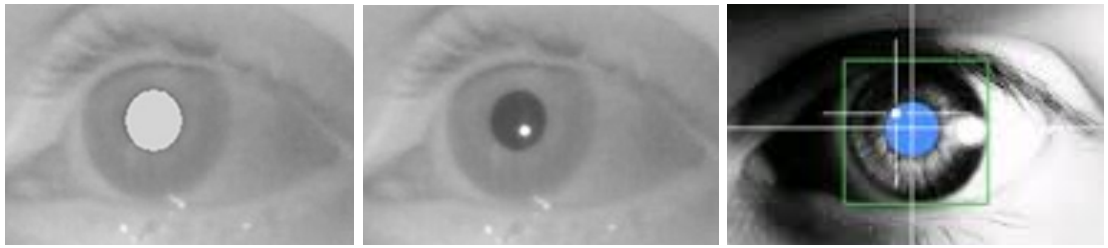
Eye-Tracking

Provides detailed gaze information – Where and for how long participant looks

- Video-camera(s) and infra-red light source record eye-movements and pupil dilatation
- Maps eye movements onto precise locations in space using relationship between pupil and corneal reflection
- Has high temporal resolution (250-1000 Hz)



Eye Movements in Reading

The eyes do not move continuously while reading

Fixations

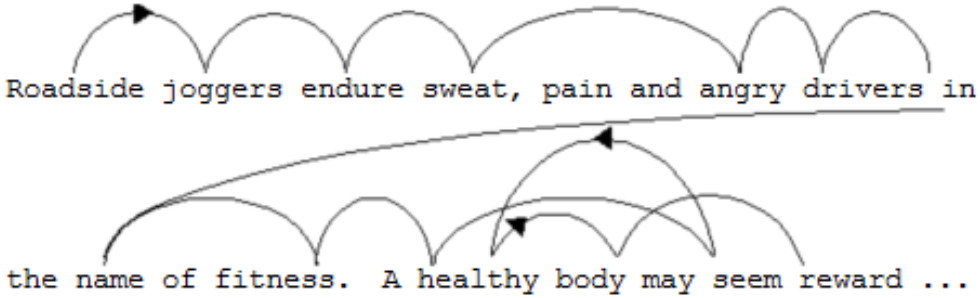
- Information extraction
- Mean = 225-250 ms

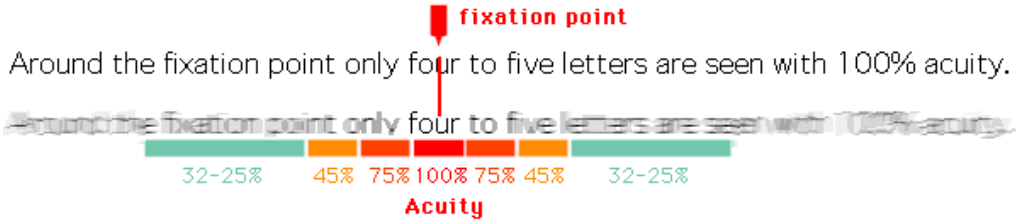
Saccades – quick jumps

- 20-30 ms in duration
- Move 7-9 characters
- Vision is suppressed

Regressions

- 10-20% of saccades





Eye-Tracking in Reading

Stimuli

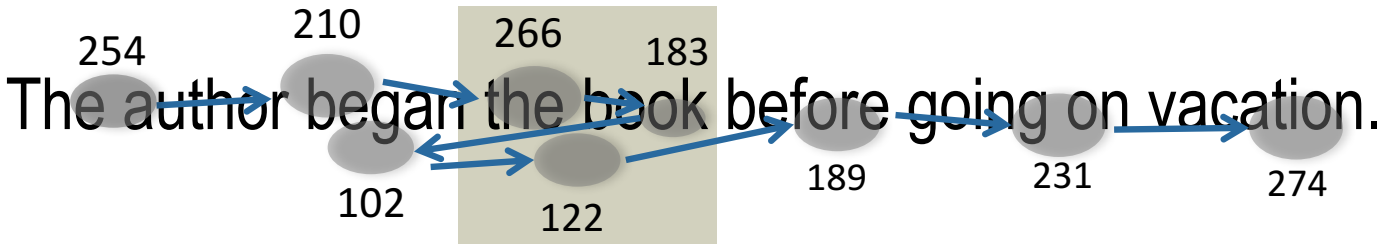
- Whole sentences, entire texts, webpages, etc.

Task: Usually just reading

- Additional (offline) tasks can include plausibility judgments, comprehension questions, etc.

DVs: Eye-movement measures

Eye-Tracking in Reading



Eye-movement measures

First fixation duration = 266 ms

First-pass duration = 266 + 183 ms

Regression path duration = 266 + 183 + 102 + 122 ms

Second-pass duration = 122 ms

Total time = 266 + 183 + 122 ms

Regressions out = 1 regression

Eye-Movement Measures

Measure	Description
First fixation duration	Duration of first fixation in a region
First-pass duration	Time spent in a region before moving on or looking back
Regression path duration	Time from first entering a region until eyes move beyond that region, including regression time
Second-pass duration	Duration of re-fixations
Total time	Sum of all fixations in a region
Regressions out	Proportion of regressions out of a region following first-pass fixations

Linking Hypothesis 1

There is a close relationship between what the eyes are fixating and what the brain is processing

Eye-Mind Hypothesis (Just & Carpenter, 1980)

- There is no appreciable lag between what is fixated and what is processed
- Readers retain fixation on a word until processing is completed

Eye-Mind Hypothesis

Question

- Do we perform word recognition, syntactic parsing, semantic integration, referential integration and discourse processes before moving eyes to the next word?

Subsequent Results

- The effects of a manipulation are often visible after the critical word or region (***spill-over effects***)
- Suggests that processing of word X continues while fixating word X+1, and possibly while fixating word X+2, etc.

→ The eye-mind assumption is too strong

Linking Hypothesis 2

The eyes do not leave a word until it has been syntactically integrated (tree building) (Boland 2004)

- "Early" measures (first-fixation, first-pass reading time, regressions out) reflect lexical access and constraints on structure-building
- "Later "measures (e.g., regression path duration, total reading times) are sensitive to higher-level processes like semantic integration, reference integration, and discourse processes

Eye-Tracking vs Self-Paced Reading

Eye-tracking	Self-paced reading
Relatively natural	Relatively unnatural (may lead to task-induced effects)
Some words are skipped	No words are skipped (measurement for each word)
Dealing with blinks can be problematic	Blinking not problematic
Often difficult to interpret various reading measures	Simple and easy to implement and analyze
High temporal resolution	RTs include processing of target and programming button press (slow RTs)

Behavioral Methods

Common methods used in language comprehension:

- Lexical Decision
- Priming techniques

Investigate the mental lexicon

- Self-paced reading
- Eye-tracking

Investigate syntactic, semantic, and/or pragmatic processing

- Pupillometry

Complexity, cognitive load

Pupillometry

Detect changes in the **pupil size**, using Eye-tracker

Link these changes to (increased) underlying neural activity -> Cognitive Load

- Pupil diameter (Just & Carpenter 1993)
- Pupil jitter (Marshall, 2002)

Pupil diameter

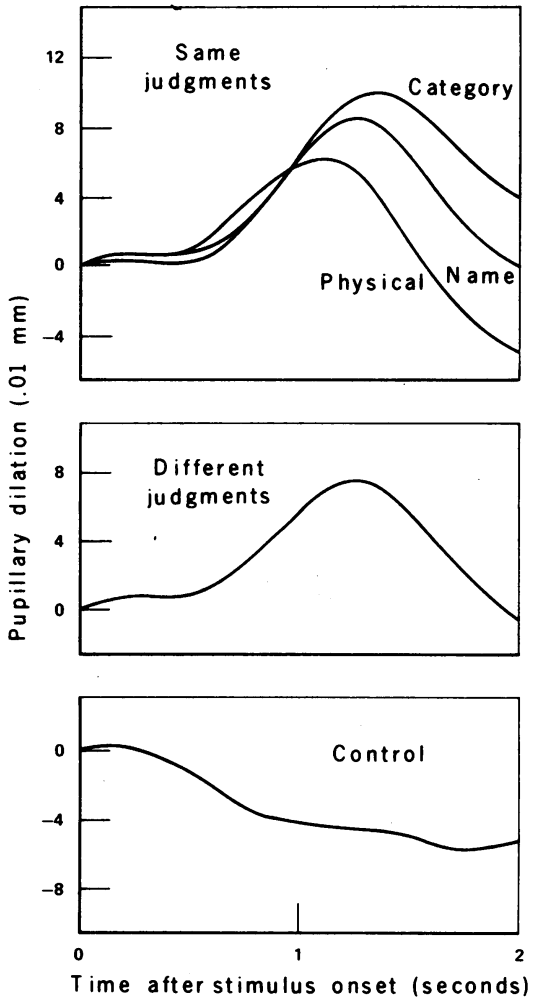
Pupil diameter is “index of automatic activity in psychophysiological research” (Goldwater, 1972)

Dilation corresponds to “central nervous system arousal” (Beatty & Wagoner, 1977)

- **Linking Hypothesis:** Hierarchically organized processes require increased activity –> greater pupil dilation

Letter Matching:

- Physical : A A
- Name: A a
- Category: a i



Pupil diameter

Just & Carpenter (1993): **Complexity in sentence-processing**

- Reading Object relative clause vs subject relative clause

Min

0 **“**The new media like to cover political events extensively.”

1a “The reporter that the senator attacked admitted the error publicly.”

1b “The reporter that attacked the senator admitted the error publicly.”

Max

2 “The reporter attacked the senator” TRUE or FALSE?

- Reading time + Button press + Pupil diameter (max change) !

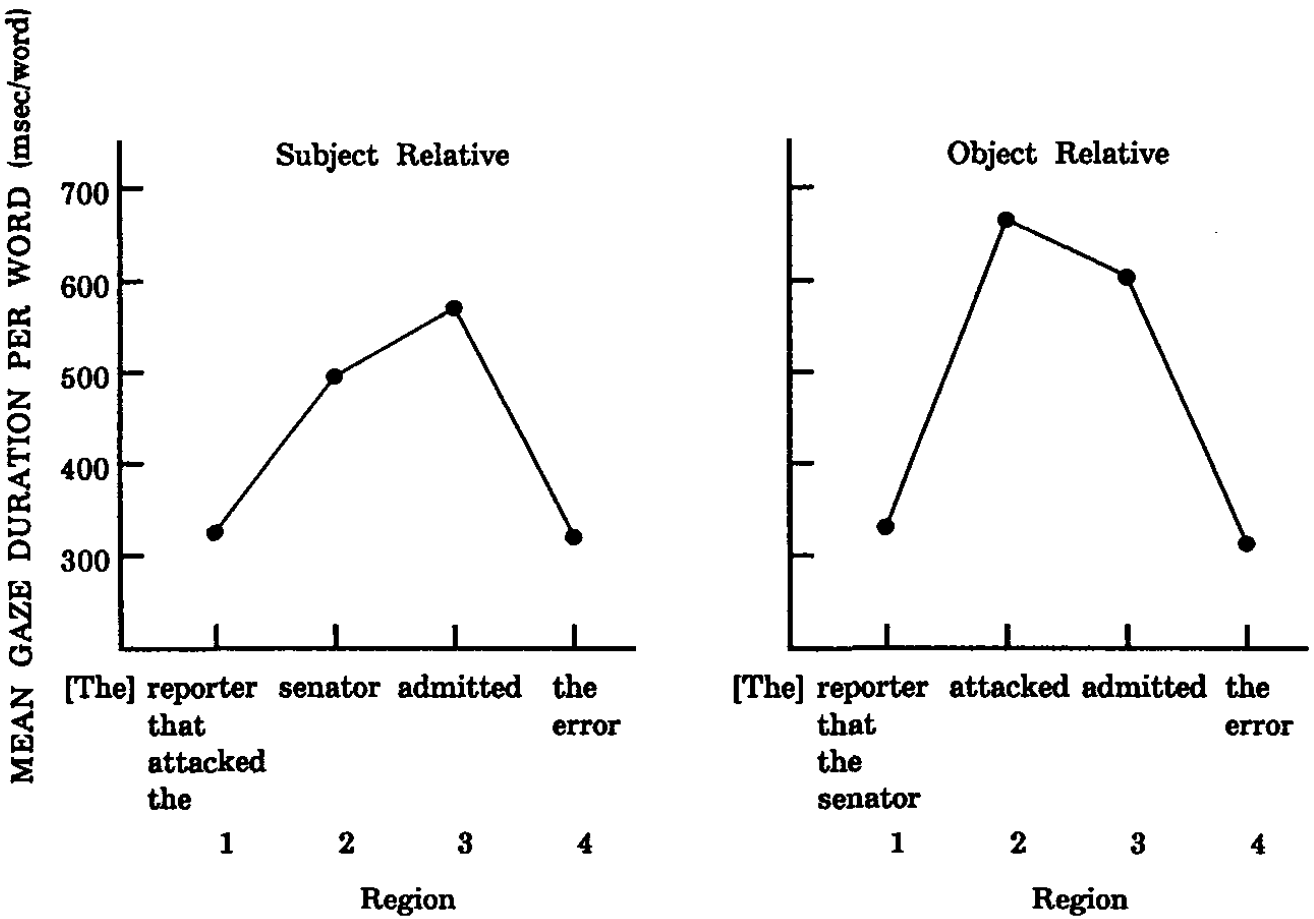
Pupil diameter

Just & Carpenter (1993):

Error rate: Object relative = 21% vs subject relative = 11%

Pupil diameter:

Reading time:



Pupil “jitter” - ICA

The Index of Cognitive Activity (Marshall, 2000)

Separate light reflex from dilation reflex

Light reflex – slow oscillation of pupil diameter in response to light

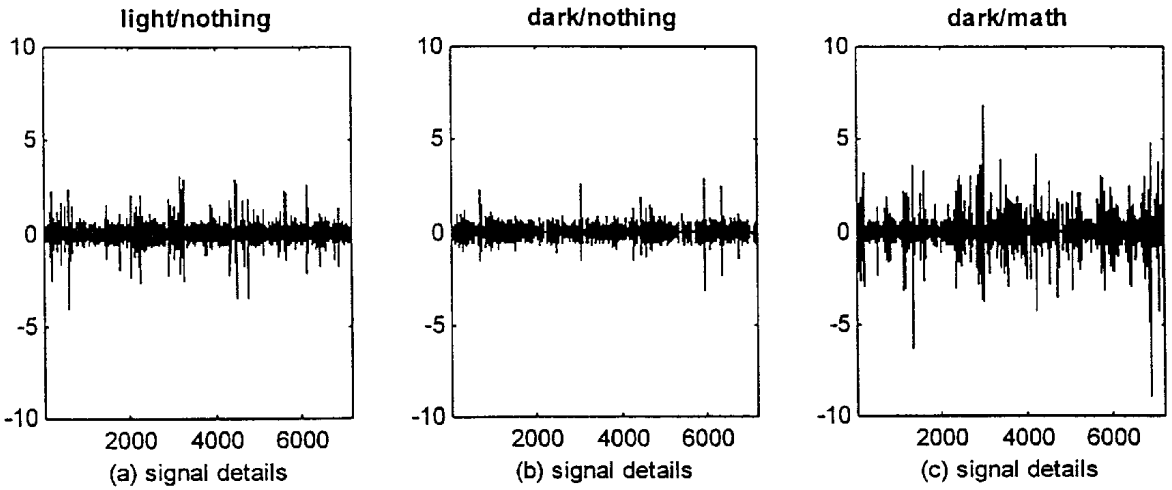
Dilation reflex – brief but great dilation in response to cognitive activity

Wavelet analysis extracts sudden and sharp changes in pupil dilation and ignores smooth, gradual changes in pupil diameter

- Preserves size and number of sharp dilations

Pupil “jitter” - ICA

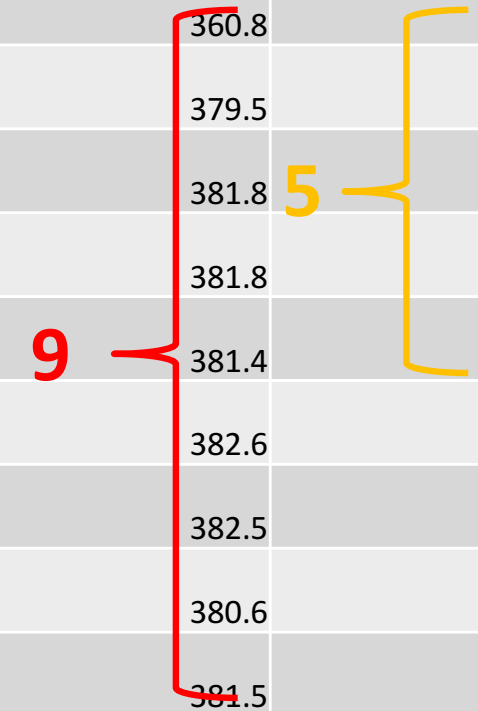
The Index of Cognitive Activity (Marshall, 2000)



Obtaining ICA values

- Binocular eye-tracking during stimulus presentation
- Extracting ICA values from eye movement results file
- Collect number of dilations/events per 100ms
- Align to stimulus presentation!
- Analyze no of ICA events in critical time region

Display	X Pos	Y Pos	Time (secs)
1	539.6	363.5	1.316
1	539.8	363.2	1.348
1	539.2	357.7	1.516
1	539.2	359	1.58
1	551.1	360.8	1.6
1	644.3	379.5	1.616
1	751.5	381.8	1.648
1	749.8	381.8	1.664
1	749.9	381.4	1.68
1	749.5	382.6	1.7
1	749.2	382.5	1.716
1	748.3	380.6	1.748
1	747.5	381.5	1.8
1	605	380.5	3.364



Pupillometry - Comparison

Pupil diameter	Jitter - ICA
“Free”	Patented
Light sensitive	Only sensitive to cognitive load
Slow	Fast
Well-researched and understood, linking hypothesis	Under-researched - physiological basis? - do all types of “cognitive load” affect ICA?

Course Experiment

What open questions remain after van Berkum et al. (2008)?

Manipulation: Could the speaker-inconsistency effect interact with addressee knowledge?

- Imagine an addressee who knows something about the “unusual” speaker

Measures: Could these results extend to reading?

- Imagine getting an email from someone that you either know or don’t know

Could such speaker inconsistencies be reflected in ICA?

Homework: Read student paper from last semester **(S16_final_paper.pdf)**

- What were the Stimuli, Task, DV and Linking Hypothesis?
- Can you think of any confounds that were missed?
- Problems with the stimuli or procedure? Ideas for fixing?

Agenda

Next Monday

- Read: Student paper for our course experiment
- Discussion of course experiment

Next Wednesday

- Read: Demberg & Sayeed (2016)
- ICA and self-paced reading combined
- Apply to course experiment