EYE-TRACKING WORKSHOP
MORNING SESSION 1

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2nd International Connect‘M Conference
University of Reading, Malaysia
16th – 19th July, 2018
EYE-TRACKING WORKSHOP:
SCHEDULE

Morning Session 1 (9.00am – 10.30am)
➢ Introduction to eye-tracking and different commercially available eye-trackers

Morning Session 2 (11.00am – 12.30pm)
➢ Indepth look at eye-tracking during reading and eye-tracking during listening

Afternoon Session 1 (2.00pm – 3.30pm)
➢ Research design in eye-tracking during reading and eye-tracking during listening

Afternoon Session 2 (4.00pm – 5.30pm)
➢ Practical session with Tobii eye-tracker and data analysis
EYE-TRACKING WORKSHOP: MORNING SESSION 1

What is eye-tracking?
- Introduce eye-tracking and how it can be used to investigate language

Eye-tracking in language research
- Introduce different paradigms that investigate eye-tracking during reading and eye-tracking during listening
- Discuss linking hypotheses between eye-movements and language understanding

Which eye-tracker?
- Discuss some of the different options available for eye-tracking research
‘The eye is thought to give researchers a window into the mind’

Conklin & Pellicer-Sánchez (2016)

➢ What does this mean?
EYE-TRACKING DURING LANGUAGE COMPREHENSION

Eye-Tracking During Reading
- Investigate moment-to-moment processes involved in reading
- Investigate language comprehension at word, sentence and discourse level

Eye-Tracking During Listening
- Investigate moment-to-moment processes involved in listening, and how they interact with the visual environment around us
- Particularly useful for individuals who may not have adequate reading ability (e.g. young children)
After the boy spoke to the man in the shop, he decided to go home.
After the boy spoke to the man by the till in the shop, he decided to go back home.
Eye-tracking during reading and listening provide complimentary ways to use eye-movements to study language comprehension
 They are different methods, with their own advantages and disadvantages

Do not assume that you can easily do the same study with both methods
 Studies need to be adequately adapted to the particular method that you wish to use
 Which method to use depends on your research aims and hypotheses
It is tempting to think that eye movements in each of these tasks would be controlled by the same mechanisms, and that the same principles, with respect to eye movements, should hold across the three tasks. After all, the neural circuitry for controlling eye movements is the same across the tasks.

However, it is actually somewhat hazardous to generalize across these tasks in terms of eye movement behaviour. Presumably, the cognitive mechanisms involved in the different tasks, and how the cognitive system interacts with the oculomotor system, differ as a function of the task.

Rayner (2009, p.1459)
EYE-TRACKING DURING READING OR LISTENING?

Think about why **you** would like to use eye-tracking

(1) What would you want to use eye-tracking to study?

(2) Do you think eye-tracking during reading or listening is more appropriate?

(3) Why do you think eye-tracking during reading or listening would be more appropriate?
WHAT IS EYE-TRACKING?

Eye-tracking monitors where a participant‘s eyes move as they view a visual display or read some text

- Most commercial eye-trackers use infrared light and high-speed cameras to record gaze position across a display at multiple points in time

An eye-tracker will typically record gaze position in X/Y co-ordinates (or pixels) every X milliseconds

- The speed at which an eye-tracker samples gaze position depends on the sampling rate in Hertz
  e.g. 250Hz = one sample every 4 milliseconds
WHAT IS EYE-TRACKING?

Eye-trackers will then typically convert these X/Y coordinates over time into different eye-movement events

- **Fixations** are periods of time when the eyes are relatively still (typically ~ 250ms)
- **Saccades** are periods of time when the eyes are moving (typically much shorter, ~20ms)

New visual information is normally only acquired during fixations

- The brain suppresses processing of visual information during saccades
- This is known as *saccadic suppression*
Language researchers are typically interested in *fixation-based* measures

- Length of time participants look at a particular part of a visual display (either pictures or words)
- Other dependent measures may include saccade time, saccade length, or pupil dilation

The sampling speed of an eye-tracker will affect how dependent measures can be calculated

- 60Hz+ is typically sufficient for eye-tracking during listening
- 500Hz (or 1000Hz) is sufficient for eye-tracking during reading
LINKING HYPOTHESES BETWEEN EYE-MOVEMENTS AND LANGUAGE

To understand what eye-movements tell us about language we need a linking hypothesis to relate eye-movement behavior to cognitive function.

In eye-tracking during reading, one linking hypothesis is that fixation durations index cognitive effort:
- Longer fixation durations = more difficulty/more cognitive effort required.

In eye-tracking during listening, one linking hypothesis is that fixations index how the sentence is being interpreted:
- Gaze towards a particular region of a display indexes how the sentence is being interpreted.
EYE-TRACKING DURING READING

**Linking hypothesis**
- Longer fixation durations index = more difficulty

(1) John said that the boy accidently hurt himself yesterday.
(2) John said that the girl accidently hurt himself yesterday.

How does our *linking hypothesis* relate to eye-movements of sentences like (1) and (2)?
- Longer fixation durations predicted at *himself* in (2) than (1)
EYE-TRACKING DURING LISTENING

Linking hypothesis
➢ Fixations index how the sentence is being interpreted

(1) After the boy spoke to the man by the till, he went home

How does our *linking hypothesis* relate to eye-movements in a sentence like (1)?
➢ Looks to either *the boy* or *the man* at *he* index how the pronoun is interpreted
EYE-TRACKING AND
LANGUAGE RESEARCH

We need clear linking hypotheses to understand what eye-
movements tell us about language comprehension

- Different eye-tracking methods have different linking
  hypotheses
- We need to carefully consider which linking hypothesis is
  appropriate when designing an experiment

The different eye-tracking paradigms can be used to
investigate different aspects of language processing

- Briefly overview three key paradigms in language research
EYE-TRACKING METHODS: LOOKING WHILE LISTENING

Typically used in infant research
➢ Also known as the ‘preferential looking‘ paradigm

Child listens to a sentence while viewing two displays
➢ A (video) camera records which of the two displays the child looks at as they hear the sentence
EYE-TRACKING METHODS: LOOKING WHILE LISTENING SETUP
EYE-TRACKING METHODS: VISUAL WORLD PARADIGM

Used to study child and adult language
➢ Similar to ‘looking while listening‘ but can involve more complex visual displays

‘Put the frog on the napkin in the box‘
(Tanenhaus et al., 1995; Trueswell et al., 1999)
EYE-TRACKING METHODS: VISUAL WORLD PARADIGM

Used to study child and adult language
- Similarly to ‘looking while listening‘ but can involve more complex visual displays

‘The man will ride the motorbike‘
(Kamide et al., 2003)
EYE-TRACKING METHODS: READING

Used to study child and adult language

- Participants must obviously have adequate reading abilities
- Typically involves comparing reading times of an ‘easy’ baseline condition to a more ‘difficult’ condition

(1) Ambiguous Condition
The scientist proved the theory was wrong yesterday.

(2) Unambiguous Control Condition
The scientist proved that the theory was wrong yesterday.

(Rayner & Frazier, 1987)
WHICH EYE-TRACKER?
WHICH EYE-TRACKER?
WHICH EYE-TRACKER IS APPROPRIATE?

Eye-tracker hardware and set-up
- Head-free vs. head-mounted
- Head stabilization (chin rest, bite bar)
- Portability

Sampling rate and accuracy
- Sampling rate in Hertz (e.g. 250Hz = one datapoint every 4ms)
- Accuracy in degrees of visual angle

Software
- What experiment design and analysis software, and what software support, is available?
DIGITAL VIDEO CAMERA
(‘POOR MAN’S EYE-TRACKER’)

Can be used for looking while listening

- Typically can only have two regions of interest

Not suitable for complex displays in the visual world paradigm or to study reading

Sampling rate is slow and restricted to camera speed

- Typically 24 fps (i.e. one datapoint every 42ms)
- Sampling accuracy largely restricted to ‘left/right’ or ‘top/bottom’ of screen
DIGITAL VIDEO CAMERA
(‘POOR MAN’S EYE-TRACKER’)

Can be used for looking while listening
➢ Typically can only have two regions of interest

Typically the hardware is comparatively cheap and portable

No software for experiment design or analysis
➢ Need separate experiment software (e.g. EPrime)
➢ Each frame needs to be manually coded in the analysis
➢ Data analysis is very slow and labour intensive
TOBII EYE-TRACKING SOLUTIONS

Tobii provide several eye-trackers

- The Tobii X-60 and X-120 are good, widely used eye-trackers that are easily portable

Good for eye-tracking during listening in the visual world paradigm

- X-60/120 may not be accurate enough or have a high enough sampling rate for reading
- Newer ‘Tobii Pro Spectrum system‘ provides accurate tracking up to 1200Hz
Tobii ‘Extensions for EPrime‘ can be used to create experiments in EPrime

- EPrime data analysis tools not particularly sophisticated
TOBII EYE-TRACKING SOLUTIONS

Tobii have also developed their own software suite for experiment design and analysis

- Tobii Pro Studio and Tobii Pro Lab provide software for experiment design and data analysis
SR Research Eyelink 1000 is a state-of-the-art system
- 1000Hz (or 2000Hz) tracking with extremely high accuracy
- Suitable for eye-tracking during listening and reading

Typical Eyelink 1000 setup is not very portable
- Two desktop PCs, two monitors, eye-tracker and head-rest
- Newer ‘Eyelink Portable Duo‘ is a more portable system
SR Research provide a software suite for experiment design and analysis

- *Experimental Builder* provides a graphical user interface for designing different eye-tracking experiments.
SR RESEARCH EYELINK

SR Research provide a software suite for experiment design and analysis

- *Data Viewer* provides a tool to visualise, filter and analyse eye-movement data
SR Research provide a software suite for experiment design and analysis

» SR Research Forums provide quick online support
Eye-tracking provides a way of investigating language comprehension in real-time

- Eye-tracking during reading and eye-tracking during listening tap different aspects of language processing.

Understanding of the *linking hypothesis* between eye-movements and language processing is crucial in deciding which method you wish to use.

Different eye-trackers are available, but some are more suitable for some paradigms than others.
REFERENCES:

USEFUL BOOKS


REFERENCES:
OVERVIEW PAPERS AND CHAPTERS


REFERENCES:
RESEARCH PAPERS


EYE-TRACKING WORKSHOP
MORNING SESSION 2

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EYE-TRACKING WORKSHOP: MORNING SESSION 2

Eye-tracking during reading and listening
- Introduce eye-tracking during reading and listening in more depth

Analysis of eye-tracking data
- Discuss how eye-tracking during reading data is typically analysed
- Discuss how eye-tracking during listening data can be analysed

Eye-tracking in language research
- Discuss some papers as case studies of how eye-tracking during reading and listening can be used
EYE-TRACKING DURING READING AND LISTENING

Eye-tracking during reading and listening
- In eye-tracking during reading we are interested in how long individuals read portions of text
- In eye-tracking during listening we are interested in which portions of a visual display people look at

We typically identify specific regions of interest that are important for our research questions
- In eye-tracking during reading, regions of interest will typically be portions of text
- In eye-tracking during listening, regions of interest will typically be a part of the visual display
EYE-TRACKING DURING READING: REGIONS OF INTEREST

A region of interest in eye-tracking during reading refers to a piece of text that you are particularly interested in:
- It could be a word, phrase or sentence
- Or some other linguistic unit (e.g. morpheme)

Region size influences how often it will be fixated:
- Smaller regions will be fixated less and may be skipped entirely
- But with larger regions you learn less about time-course

You should carefully consider your regions of interest when designing an eye-tracking during reading study:
- It may be too late if you leave it until the analysis
EYE-TRACKING DURING READING: REGIONS OF INTEREST

Typically a researcher will identify a critical region
- This will be where you expect your experimental manipulation to first affect reading

It’s also typical to analyse a spillover region (or regions)
- This is the text that follows the critical region

Spillover regions are analysed because the effects of an experimental manipulation are not constrained to individual words
- They spillover to subsequent regions of text
- This can especially be true with some reader populations (e.g. children, non-native speakers)
EYE-TRACKING DURING READING: REGIONS OF INTEREST

What would be the critical and spillover region in an experiment with two conditions as below?
(1) The boy accidentally injured himself yesterday morning.
(2) The girl accidently injured himself yesterday morning.

The reflexive himself would be the critical region
➢ The spillover region could be yesterday or it could be yesterday morning

Ideally you should decide before doing the analysis
➢ Consider skipping rates and increase the size of the region if you think it will be frequently skipped
EYE-TRACKING DURING READING: READING TIME MEASURES

*First fixation duration* refers to the duration of the first fixation within a region of interest.

*First pass time (or gaze duration)* sums fixations from when a region is first fixated, up until it is exited to the left or right.

*Regression path time (or go-past time)* sums all fixations, starting when a region is first entered, up until but not including the first fixation in a region to the right.

These ‘first pass‘ measures are typically only calculated if a region is entered from the left.

- Regions that are initially skipped are treated as missing data.
EYE-TRACKING DURING READING: READING TIME MEASURES

‘First pass‘ measures index relatively earlier stages of processing
➢ Other measures include ‘later‘ stages of processing and include fixations if a reader looks back at piece of text

Second pass time (or rereading time) sums all fixations in a region after it has been exited for the first time

Total viewing time is the sum of all fixations on a region, irrespective of when these occur
EYE-TRACKING DURING READING: EXAMPLES

The girl injured himself yesterday morning.

(1) → (2) → (3) → (4)
(5) → (6) → (7)
(8) → (9) → (10)

Reading times at himself

- First fixation duration = (4)
- First pass time = (4)
- Regression path time = (4) + (5) + (6)
- Second pass time = (6) + (8)
- Total viewing time = (4) + (6) + (8)
EYE-TRACKING DURING READING: EXAMPLES

The old man pondered about the problem.

(1) → (2) → (3) → (4) → (5) → (6) → (7)

Reading times at *pondered*

- First fixation duration = (3)
- First pass time = (3) + (4)
- Regression path time = (3) + (4)
- Second pass time = 0
- Total viewing time = (3) + (4)
EYE-TRACKING DURING READING: EXAMPLES

The young boy said that she hated homework.

(1) → (2) → (3) → (4) → (5) → (6)

(7) → (8) → (9)

Reading times at she

- First fixation duration = N/A
- First pass time = N/A
- Regression path time = N/A
- Second pass time = (7)
- Total viewing time = (7)
EYE-TRACKING DURING LISTENING: REGIONS OF INTEREST

A region of interest in eye-tracking during listening will typically be a portion of a visual display

- It may depict a particular object
- It may depict a particular scene

Regions of interest can be of different sizes (depending on your research question and also equipment)

- They need to be depictable
e.g. how would you depict truth?

As in eye-tracing during reading, you should consider your regions of interest when designing your study

- It may be too late if you leave it until the analysis
After the boy spoke to the man by the till, he decided to go back home for lunch.
EYE-TRACKING DURING LISTENING: REGIONS OF INTEREST

Which cow is pushing the goat?
(Contemori et al., 2018)
EYE-TRACKING DURING LISTENING: TIME WINDOWS

In addition to regions of interest, we also need to have periods of interest

➤ These are typically called time windows

A time window is a period of time where we are particularly interested in where participants look

➤ Participant gaze will typically be time-locked to the onset of a critical word in the sentence

Participant gaze will then be measured for a specified period of time after that time window

➤ This may differ, but is typically ~ 1-2 seconds after the onset of a critical word
After the boy spoke to the man by the till, he decided to go back home for lunch.
EYE-TRACKING DURING LISTENING: TIME WINDOWS

Which cow is pushing the goat?

(1 second)
EYE-TRACKING DURING LISTENING: DATA ANALYSIS

Once *regions of interest* and *time windows* are decided, the data can then be analysed

- There are different ways of analysing visual world eye-tracking data
- No clear ‘best practice‘ in how to analyse the data

Typically researchers calculate proportions of looks to the different regions of interest over time

- Often we may have a *target* region of interest and a *distractor*

The researcher is interested in how looks to both the *target* and *distractor* change over time
After the boy spoke to the lady by the till, he decided to go back home for lunch.

(1200ms)
After the boy spoke to the lady by the till, he decided to go back home for lunch.
Eye-tracking during reading and listening have been widely used to investigate language processing in different populations of speakers

- Widely used to examine comprehension in typical monolingual children and adults
- Also widely used to investigate bilingual processing, non-native acquisition, and language in impaired populations

Two case studies to illustrate how eye-tracking can be used to investigate non-native language comprehension

- Eye-tracking during reading (Felser & Cunnings, 2012)
- Eye-tracking during listening (Cunnings et al., 2017)
Felser and Cunnings (2012) examined L2 acquisition of reflexives

(1) John said that the boy hurt himself yesterday.

In English, reflexives must refer to a syntactically *local* antecedent

- Local antecedent = the boy ✓
- Nonlocal antecedent = John X

Can second language (L2) learners of English acquire and process this constraint in a nativelike way?
FELSER AND CUNNINGS 2012: STUDY DESIGN

Participants

- 28 L1 English speakers
- 25 L2 English learners with L1 German (intermediate – advanced)

Gender mismatch paradigm (Sturt, 2003)

- Longer reading times expected for gender mismatching reflexives
  
  (1a) The boy injured himself yesterday.
  (1b) The boy injured herself yesterday.

- Also occurs if the gender mismatch is stereotypical
  
  (2a) The soldier injured himself yesterday.
  (2b) The soldier injured herself yesterday.
(1a) Local Match, Nonlocal Match
James said that the soldier had hurt himself while on duty.

(1b) Local Match, Nonlocal Mismatch
Helen said that the soldier had hurt himself while on duty.

(2a) Local Mismatch, Nonlocal Match
Helen said that the soldier had hurt herself while on duty.

(2b) Local Mismatch, Nonlocal Match
James said that the soldier had hurt herself while on duty.
FELSER AND CUNNINGS 2012: DATA ANALYSIS

Reading times reported for the critical region

James/Helen said that the soldier had hurt...

Critical Region: himself

... while on duty

Two reading time measures
- First fixation duration
- Second pass reading time
FELSER AND CUNNINGS 2012: FIRST FIXATION DURATION

- **L1 Speakers:** ME of local antecedent
- **L2 Learners:** ME of nonlocal antecedent
Both groups: ME of local antecedent
L2 learners behaved differently to L1 speakers during early stages of processing
  - L2 speakers had longer reading times at the reflexive when it mismatched the nonlocal antecedent

L2 learners showed local antecedent gender mismatch effect in later measures
  - Also behaved like L1 speakers in an ‘offline‘ task that required explicit judgement of reflexive interpretation

L2 learners may have difficulty utilising knowledge of grammatical constraints on reflexives during processing
In English, subject pronouns typically refer to discourse salient antecedents
(1) After Peter spoke to Mr Smith at school, he went home.

Who does he refer to?
➢ Typically interpreted as referring to sentence subject

In languages with both null and overt pronouns, preferences differ
(2a) I jajá xerétise tin kopéla ótan Ø pernúse to drómo.
(2b) I jajá xerétise tin kopéla ótan aftí pernúse to drómo.
‘The old woman greets the girl when Ø/she crosses the street.’
CUNNINGS ET AL. (2017): STUDY DESIGN

Participants
- 35 L1 English Speakers
- 41 L2 Learners with L1 Greek
  (lower intermediate – very advanced)

Visual world paradigm study to investigate pronoun resolution during listening
- Can L2 learners interpret overt pronouns in English like L1 speakers, if their L1 has null and overt pronouns?
- Tested sentences with ambiguous and unambiguous pronouns
After Peter spoke to Mrs Jones by the till in the shop, he paid for the expensive ice-cream that looked tasty.
CUNNINGS ET AL. (2017): AMBIGUOUS EXAMPLE

After Peter spoke to Mr Smith by the till in the shop, he paid for the expensive ice-cream that looked tasty.
After Mr Smith spoke to Peter by the till in the shop, he paid for the expensive ice-cream that looked tasty.
CUNNINGS ET AL. (2017): MATERIALS

(1) **Subject Bias, Unambiguous**
After Peter spoke to Mrs Jones by the till in the shop, he paid for the expensive ice-cream that looked tasty.

(2) **Subject Bias, Ambiguous**
After Peter spoke to Mr Smith by the till in the shop, he paid for the expensive ice-cream that looked tasty.

(3) **Object Bias, Unambiguous**
After Mrs Jones spoke to Peter by the till in the shop, he paid for the expensive ice-cream that looked tasty.

(4) **Object Bias, Ambiguous**
After Mr Smith spoke to Peter by the till in the shop, he paid for the expensive ice-cream that looked tasty.
CUNNINGS ET AL. (2017): DATA ANALYSIS

Participant gaze measured following onset of the critical pronoun

- Proportion of looks to different regions of interest in the visual display calculated every 16ms (60Hz) for 1200ms following the onset of the pronoun

Proportion of gaze calculated to two different regions of interest

- Proportion of looks to the syntactic subject
- Proportion of looks to the syntactic object
CUNNINGS ET AL. (2017): LOOKS TO SYNTACTIC SUBJECT

Native Speakers

Non-Native Speakers

- Subject Bias Unambiguous
- Subject Bias Ambiguous
- Object Bias Unambiguous
- Object Bias Ambiguous
CUNNINGS ET AL. (2017): LOOKS TO SYNTAX TACTIC OBJECT

Native Speakers

Non-Native Speakers

Subject Bias Unambiguous

Subject Bias Ambiguous

Object Bias Unambiguous

Object Bias Ambiguous
L2 learners behaved similarly to L1 speakers in interpreting subject pronouns
- Both groups rapidly used gender in unambiguous conditions
- Both groups looked more to the sentence subject in ambiguous conditions

L2ers perhaps slightly delayed, but not qualitatively different
- Suggests L2ers, even from a null subject L1, can acquire and process subject pronouns in a nativelike way (cf. Roberts et al., 2008)
Eye-tracking during reading and listening

- Eye-tracking during reading and listening provide different implicit measures of language understanding.

Eye-tracking during reading

- Typically need a manipulation that you expect will alter reading times in some way to see if readers are sensitive to this manipulation.

Eye-tracking during listening

- Typically need a manipulation that may change how a sentence is interpreted.


EYE-TRACKING WORKSHOP
AFTERNOON SESSION 1

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Further applications
- Overview some further applications of eye-tracking during reading and eye-tracking during listening

Eye-tracking during reading
- Discuss study design and how to avoid potential confounds in eye-tracking during reading paradigms

Eye-tracking during listening
- Discuss study design and how to avoid potential confounds in eye-tracking during listening paradigms
FURTHER APPLICATIONS: EYE-TRACKING DURING READING

Word level processing

➢ Morphological processing (Juhasz et al. 2003)
  e.g. The lamplight was very bright in the evening.
    The starlight was very bright in the evening.

➢ Lexical ambiguity resolution (Duffy et al. 1998)
  e.g. The pen was abandoned because it was too dirty for the animals.
    The zoo was abandoned because it was too dirty for the animals.

➢ Incidental word learning (Joseph and Nation, 2018)
  e.g. Enough proof had accumulated so that the police arrested the robber.
FURTHER APPLICATIONS: EYE-TRACKING DURING READING

Sentence comprehension

- **Syntactic ambiguity** (Sturt, 2007)
  - e.g. The explorers found the South Pole was right at their feet. The explorers found the South Pole was impossible to reach.

- **Pronoun resolution** (Cunnings & Sturt, 2018)
  - e.g. The surgeon remembered that John had noticed him at work. The surgeon remembered that Jane had noticed him at work.

- **Dependencies and word order** (Staub et al. 2017)
  - e.g. The chef that distracted the waiter dropped the flour. The chef that the waiter distracted dropped the flour.
FURTHER APPLICATIONS: EYE-TRACKING DURING LISTENING

Spoken word recognition (Allopenna et al. 1998)

Pick up the beaker
FURTHER APPLICATIONS: EYE-TRACKING DURING LISTENING

Bilingual word recognition (Spivey and Marian, 1999)

Pick up the marker
FURTHER APPLICATIONS: EYE-TRACKING DURING LISTENING

Bilingual word recognition (Spivey and Marian, 1999)

Pick up the marker
FURTHER APPLICATIONS: EYE-TRACKING DURING LISTENING

Sentence comprehension (Tanenhaus et al. 1995)

(1) Put the apple on the napkin in the box
(2) Put the apple that’s on the napkin in the box
**FURTHER APPLICATIONS: EYE-TRACKING DURING LISTENING**

**Discourse comprehension** (Arnold et al. 2000)

Donald is bringing some mail to Minnie while a violent storm is beginning. He’s carrying an umbrella, and it looks like they’re both going to need it.
FURTHER APPLICATIONS: EYE-TRACKING DURING LISTENING

Anticipatory processing (Altmann and Kamide, 1999)

(1) The boy will eat the cake.
(2) The boy will move the cake.
EYE-TRACKING STUDY DESIGN: GENERAL ISSUES

In eye-tracking during reading and listening we typically test maximally similar words/sentences/texts in more than one condition
- Materials tested need to be carefully matched between conditions for any differences to be interpretable

Also need sufficient observations per condition for your study to have enough statistical power
- Typically need at least six observations per condition per participant
- Number of participants dependent on the effect size that you are examining
  - Recommend 40(+) for each group tested
EYE-TRACKING STUDY DESIGN: LATIN-SQUARE DESIGN

Many eye-tracking studies use a latin-square design
➢ Participants see multiple sentences in different conditions
  e.g.  
    (1a) The boy hurt himself yesterday.
    (1b) The girl hurt himself yesterday.
    (2a) The man emailed himself today.
    (2b) The lady emailed himself today.

But each participant will only see each sentence once
➢ This is to avoid confounds with reading otherwise identical material more than once
EYE-TRACKING STUDY DESIGN:
2-CONDITION LATIN-SQUARE DESIGN

(1a) The boy hurt himself yesterday afternoon.
(1b) The girl hurt himself yesterday afternoon.

(2a) The old man emailed himself by mistake.
(2b) The old lady emailed himself by mistake.

(3a) The girl introduced herself to the teacher.
(3b) The boy introduced herself to the teacher.

(4a) The old lady cut herself while making dinner.
(4b) The old man cut herself while making dinner.

...
EYE-TRACKING STUDY DESIGN: 2-CONDITION LATIN-SQUARE DESIGN

(1a) The boy hurt himself yesterday afternoon.
(1b) The girl hurt himself yesterday afternoon.
(2a) The old man emailed himself by mistake.
(2b) The old lady emailed himself by mistake.
(3a) The girl introduced herself to the teacher.
(3b) The boy introduced herself to the teacher.
(4a) The old lady cut herself while making dinner.
(4b) The old man cut herself while making dinner.

Participants see equal numbers of (a) and (b) sentences, but never the same item twice

- Participant 1 sees (1a), (2b), (3a), (4b) ...
- Participant 2 sees (1b), (2a), (3b), (4a) ...
- Participant 3 sees (1a), (2b), (3a), (4b) ...

...
EYE-TRACKING STUDY DESIGN: EXPERIMENTAL AND FILLER ITEMS

Participants will typically read a series of experimental items that you are interested in

- Also important to include fillers that you aren‘t interested in per se but which distract participants from what you are interested in
- To try and stop your manipulation becoming too obvious

Typically want at least 2x as many fillers as experimental items

- If you have 16 experimental items in 2 conditions
- You want at least 32 fillers
  - Fillers should be of a variety of different structures
EYE-TRACKING STUDY DESIGN:
EXAMPLE ITEMS

(Exp 1a) The boy hurt himself yesterday afternoon.
(Exp 1b) The girl hurt himself yesterday afternoon.
...
(Exp 16a) The old lady emailed herself by mistake.
(Exp 16b) The old man emailed herself by mistake.

(Filler 1) The boy emailed the teacher for some help.
(Filler 2) The lady introduced the man at the party.
...
(Filler 16) It was a really beautiful day to go swimming.
...
(Filler 32) After leaving work, John went for a drink.
EYE-TRACKING STUDY DESIGN: THE TASK

Although participants can read and listen to sentences naturally in eye-tracking during reading and listening you need a task to ensure participants pay attention.

In eye-tracking during reading, this is usually some sort of comprehension question:

- Carefully consider if you want the question to be in any way related to what you have manipulated.

(1) The old man said the boy hurt himself yesterday.

Who was hurt? The old man The boy
Was the man old? Yes No
EYE-TRACKING STUDY DESIGN:
THE TASK

Although participants can read and listen to sentences naturally in eye-tracking during reading and listening you need a task to ensure participants pay attention.

In eye-tracking during listening, this could also be a comprehension question or an instruction.

- Typically the participant responds by clicking on a part of the display.

(1) After the boy saw the man, he decided to go home.

Who went home?
EYE-TRACKING STUDY DESIGN: READING OR LISTENING?

Eye-tracking during reading is used to detect differences in processing ‘effort’ between different conditions

- Typically involves comparing relatively easy stimuli to some relatively more difficult stimuli

1. Unambiguous vs. Ambiguous
   The scientist proved (that) the theory was invalid.

2. Grammatical vs. Ungrammatical
   The (boy / girl) accidentally hurt himself yesterday.

3. Plausible vs. Implausible
   It was the (book / city) that the boy read in the library.

4. Sentences that otherwise differ in difficulty
   The boy (that helped the girl / that the girl helped).
Eye-tracking during listening cannot really be used to measure processing difficulty or effort

- It does however provide a more explicit measure of how the interpretation of a sentence develops over time
- Also don’t need to have manipulations that may lead to ‘odd‘ sentences (e.g. ungrammatical sentences)

Eye-tracking during listening also more appropriate for any population that may have difficulty reading

- Young children
- Some non-native speakers
- Heritage language users
STUDY DESIGN: EYE-TRACKING DURING READING

Various properties of words, phrases and sentences influence reading times

- Any potential confounds need to be dealt with
- Confounds include...
  - Word length and frequency
  - Phrase length (and frequency)

Consider active vs. passive sentences

1. The man ate the fish.
2. The fish was eaten by the man.

- Sentence (2) will likely be read more slowly than (1), but it’s difficult to be sure what is causing this here
STUDY DESIGN:
EYE-TRACKING DURING READING

You may be interested in length or frequency effects
➢ In which case sentences should be matched for all other variables except the one of interest
  ▪ For example length, frequency, grammaticality, plausibility...

(1a) Everyone thought the pen was really great.
(1b) Everyone thought the pun was really great.

(2a) The boy bought the pen at the store.
(2b) The boy bought the pencil at the store.
STUDY DESIGN:
EYE-TRACKING DURING READING

Conditions in an eye-tracking during reading experiments need to be maximally similar as possible

- Ideally your critical/spillover regions will be **identical** across conditions
- Some earlier part will be manipulated
  - (1a) The boy accidently injured himself at home.
  - (1b) The girl accidently injured himself at home.

**Beware spillover as a result of your manipulations**

- Differences before your critical region may spillover
  - (2a) The boys walk home every day.
  - (2b) The boy walk home every day.
STUDY DESIGN: EYE-TRACKING DURING READING

Sentence and trial ‘wrap-up‘ effects

- Reading times at the end of a sentence can be a bit ‘messy’
- One reason is because a reader may need to make a saccade to the next line of text
- Eye-movements at the end of the trial can also be a bit random

John said that the boy hurt himself. Luckily it was only a minor scratch.
STUDY DESIGN: EYE-TRACKING DURING READING

Sentence and trial ‘wrap-up‘ effects

- Best to ensure that your critical region is not at the end of the sentence
- Include some spillover text to avoid end-of-sentence effects influencing reading times
- Good to include a wrap up sentence so that any end-of-trial effects have a minimal effect on reading times of your critical sentence

John said that the boy hurt himself a few days ago. Luckily it was only a minor scratch.
STUDY DESIGN:
EYE-TRACKING DURING READING

With multi-line displays, it’s good to have some space between lines
➢ This helps ensure any drift in calibration doesn’t make it difficult to work out which line is being fixated

John said that the boy hurt himself a few days ago. Luckily it was only a minor scratch.

John said that the boy hurt himself a few days go.

Luckily it was only a minor scratch.
Think of a study that you could design using eye-tracking during reading

(1) What do you want to examine? What conditions will you need to test?

(2) How do your stimuli need to be matched? Write down some example stimuli from each condition.

(3) How many items and subjects do you think you will need to test?
STUDY DESIGN:
EYE-TRACKING DURING LISTENING

As in reading, you need to carefully consider your linguistic stimuli in eye-tracking during listening

- Your linguistic material must be imageable

An additional consideration is your auditory stimuli

- Consider the speech style and rate
- Be careful to minimise unwanted acoustic differences between conditions

(1) After the boy saw the lady in the shop, he went home.
(2) After the boy saw the man in the shop, he went home.
STUDY DESIGN: EYE-TRACKING DURING LISTENING

You need to be very careful in minimising acoustic differences between conditions
- One option is to *splice* your materials so they are as identical as possible
- But this can lead to unnatural stimuli if not careful

(1) After the boy saw the lady in the shop, he went home.
(2) After the boy saw the man in the shop, he went home.

*Prosody might be what your are interested in studying*
- Difficult to study in reading, but possible in eye-tracking during listening (e.g. Snedeker and Trueswell, 2003)
STUDY DESIGN: EYE-TRACKING DURING LISTENING

You also need to carefully consider the nature of your visual display

- How many regions of interest will you have?

What does each region consist of?

- An object or individual?
- An event?
- A written word?

What style of image will be used?

- Colour or black and white?
- Clipart, line-drawing or photo?
STUDY DESIGN:
EYE-TRACKING DURING LISTENING

Consider the orientation of your target and distractor regions

- Don’t always have the target on the left and always have the distractor on the right (or top and bottom)
- Ensure each region of interest is distributed across the visual display equally

Beware non-linguistic biases in your display that may confound your results

- Ensure no one region of interest is visually more salient than others
  - Many factors influence salience (size, animacy, colour, detail...)
After the boy spoke to the lady by the till, he decided to go back home for lunch.
After the boy spoke to the lady by the till, he decided to go back home for lunch.
After the boy spoke to the lady by the till, he decided to go back home for lunch.
STUDY DESIGN:
EYE-TRACKING DURING LISTENING

End of trial effects may also influence eye-movements during listening

➢ Consider having some amount of linguistic material after your critical time window to minimise end of trial effects

(1) After the boy saw the lady in the shop, he left.
(2) After the boy saw the lady in the shop, he decided to go back home.

Looks to parts of a visual display can also spillover and may make it difficult to interpret your results

➢ It’s best to divert participant gaze away from your regions of primary interest before your critical time window
After the boy spoke to the lady, he decided to go back home for lunch.
After the boy spoke to the lady in the shop, he decided to go back home for lunch.
After the boy spoke to the lady by the till, he decided to go back home for lunch.
EYE-TRACKING DURING LISTENING: EXERCISE

Think of a study that you could design using eye-tracking during listening

(1) What do you want to examine? How many conditions will you test?

(2) Create some stimuli. How do they need to be matched? What would your visual displays look like?

(3) How many items and subjects do you think you will need to test?
Eye-tracking during reading and listening
- Eye-tracking during reading and listening have a wide variety of (different) applications.

Eye-tracking during reading is best used when we expect differences in processing difficulty between conditions.
- Typically interested in differences in reading times between these conditions.

Eye-tracking during listening typically best when you want a measure of interpretation during processing.
- Can be used with populations (e.g. children) and some phenomena (e.g. prosody) difficult to study with reading.
REFERENCES: RESEARCH PAPERS


REFERENCES:
RESEARCH PAPERS


REFERENCES: RESEARCH PAPERS


EYE-TRACKING WORKSHOP
AFTERNOON SESSION 2

Ian Cunnings
(University of Reading)
i.cunnings@reading.ac.uk

2nd International Connect‘M Conference
University of Reading, Malaysia
16th – 19th July, 2018
EYE-TRACKING WORKSHOP: AFTERNOON SESSION 2

Running an eye-tracking experiment
- Brief introduction to the typical procedure of running an eye-tracking experiment

Practical with Tobii eye-tracker
- Practical demonstration of eye-tracking using the Tobii X2-60

Data analysis
- Discuss some things to consider when analysing data from eye-tracking during reading and listening studies
RUNNING AN EYE-TRACKING EXPERIMENT: SETUP, CALIBRATION AND VALIDATION

Initial setup involves ensuring the eye-tracking hardware can find the participant’s eyes
- Exact procedure depends on the system being used

Calibration
- Calibrate the eye-tracker to track the participant’s eyes
- Typically involves the participant following dots around the screen

Validation
- Check how accurately the eyes are being tracked
- If poor, redo calibration
RUNNING AN EYE-TRACKING EXPERIMENT: EYELINK SETUP
RUNNING AN EYE-TRACKING EXPERIMENT: TOBII SETUP
RUNNING AN EYE-TRACKING EXPERIMENT: CALIBRATION (9 POINT)
RUNNING AN EYE-TRACKING EXPERIMENT: EYELINK VALIDATION

Good Calibration

Poor Calibration
RUNNING AN EYE-TRACKING EXPERIMENT: TOBII VALIDATION
RUNNING AN EYE-TRACKING EXPERIMENT: THE EXPERIMENT

Participant can then begin the experiment

- You should check the calibration during the experiment
- For example, have the participant fixate on a marker before each trial begins

How to implement this depends on the hardware and software being used
EYE-TRACKING DURING READING: DATA ANALYSIS

Initially use analysis software to ensure the data is usable and to define regions of interest

- Export summaries of different regions time measures at different regions of interest
EYE-TRACKING DURING READING: DATA ANALYSIS

Output will be a file with different reading time measures at each region of interest for each participant

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**EYE-TRACKING DURING READING: DATA ANALYSIS**

Remember regions that are initially skipped are typically treated as missing data for first-pass measures

- Remove regions that are initially skipped from the analysis for first fixation, first pass and regression path

Very short and very long individual fixations are typically removed

- Less than 80ms or above 800ms

Consider other outlier removal criteria (?)

- Data points 3.5SDs away from participant mean (?)
Data can then be analysed using inferential statistics (t-test, ANOVA, mixed-effects models etc.)

- Are the assumptions of your statistical test met?
- Reading time data may not be normally distributed and may need an appropriate transformation
Data can then be analysed using inferential statistics (t-test, ANOVA, mixed-effects models etc.)

- Are the assumptions of your statistical test met?
- Reading time data may not be normally distributed and may need an appropriate transformation

Also be aware that when you analyse multiple reading time measures at multiple regions of interest you increase your false positive rate (von der Malsburg and Angele, 2017)

- Consider which comparisons are crucial to your hypothesis or consider adjustments for multiple comparisons
EYE-TRACKING DURING LISTENING: DATA ANALYSIS

Initially use analysis software to define regions of interest

➢ Typically then export summaries of fixation positions over time
EYE-TRACKING DURING READING: DATA ANALYSIS

Output will be a file with gaze position at every sample

➢ For example, one datapoint every 8ms (120Hz sampling)

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EYE-TRACKING DURING READING: DATA ANALYSIS

Time-lock the data to your time window of interest

- Visualise the data by calculating the proportion of looks for each sample over time

After the boy spoke to the lady by the till, he decided to go back home for lunch.
EYE-TRACKING DURING READING: DATA ANALYSIS

Consider which inferential statistics you want to conduct
- T-test, ANOVA, (generalised) mixed-effects models ...

Is further data aggregation into bins necessary?
- Do you want to aggregate data into, for example, 200ms bins? (0-200ms, 200-400ms, 400-600ms etc.)
- Do you want to analyse the unaggregated data over time?

What you choose to do depends on your research questions and hypotheses
EYE-TRACKING DURING READING: DATA ANALYSIS

Many researchers will aggregate the proportion of looks into different regions of interest in several bins

- Proportion of looks to the target (compared to other regions of interest) in 200ms bins (or 400ms, or larger)

Beware however that proportion data is often not normally distributed

- Data transformation will likely be necessary (e.g. empirical logit, see Barr, 2008)
- *However* even this may not be normally distributed

Also be wary of false positive rate when analysing multiple bins
EYE-TRACKING DURING READING: DATA ANALYSIS

Another option is to not aggregate data into bins

- Instead, analyse fixations for each sample over time
  - Growth-curve modelling

This is more complex and may be difficult to interpret

- The effect of time on fixation patterns over time is often not linear
- Need to include non-linear changes over time (e.g. quadratic time)
- These can be difficult to interpret (especially if you have higher order interactions)
Eye-tracking during reading and listening

- Carefully consider which method is most appropriate to your research questions and hypotheses
- Think about all stages of your study, from design to implementation to data collection and analysis, before you begin

Analysing eye-tracking data

- Carefully consider which analysis is most appropriate for your research questions and hypotheses
- Remember assumptions of your data analysis
- Consult the literature or seek help from experts
REFERENCES:

ANALYSIS (EYE-TRACKING AND GENERAL)


REFERENCES:
ANALYSIS (EYE-TRACKING AND GENERAL)

