Measuring the impact of subtitles on cognitive load

Digital Humanities Colloquium
14 September 2022

Faculty of Humanities

#DiscoverNWU
Overview

• DH & Subtitles
• Subtitle characteristics
• Benefits of subtitles
• Measurements with subtitles
• Eye-Tracking equipment
• Eye-Tracking measurements and paradigms
• Measurements of CL
• How to measure subtitles with ET
• Results
• Conclusion
About Myself…

• Dr Gordon Matthew
• Research Technologist
• School of Languages
• North-West University, Vanderbijlpark
• Eye-Tracking Lab Manager

PhD Thesis
• Measuring the impact of subtitles on cognitive load in an educational context
DH & Subtitles

• *Digital Humanities (DH)*

“...form a bridge between the **traditional practices** of research and the **opportunities** afforded by **technology**, providing scholars with **new ways of looking at old problems**, and the **methods, tools and frameworks** to support them in **novel avenues of enquiry**.”

• Subtitles:
  • Follows long history of instructional material: Audiovisual Aids for learning
  • Converts speech into text on a screen
  • Provides access to information in any language group
Subtitle Characteristics

Three types of subtitle presentations

1. **Bimodal or intralingual** (the dialogue and subtitles = the same language);
2. **Standard or interlingual** (English dialogue and mother tongue subtitles)
3. **Reversed** (mother tongue dialogue and English subtitles)

- Mostly used for entertainment
- Recently used for education
Subtitle Characteristics

- Text in-sync with dialogue
- Different from reading **static texts**
- Standardized / Automatic (SADiLaR project)
- Visible only a short period of time (dynamic)
- Must compete for their share of cognitive resources (audio and visual)
- Optimal speed is 120 wpm (10-20 cps)
- Max onscreen visibility: 6 seconds - 2 lines
- Max characters per line: 37 (incl. spaces)
Benefits of subtitles

• Research focus
  • Language Acquisition
  • Vocabulary Learning
  • Comprehension / Retention of Information

• Can be translated to any language

• More cost-effective than other language transfer methods
  • (e.g. dubbing, voice-over and re-speaking)

• Can help with accessibility to information for lesser-known languages

• E-learning environments
Measuring of subtitles

• Are the subtitles even processed?
Measuring of subtitle processing

• Measuring techniques
  • Comprehension / Retention test
    • Content of video

• Other technique
  • Eye tracking
    • Eye movement on video
    • Attention on objects
    • Reading of subtitles
Eye-tracking measurements

- **Fixation** = circles
  - Bigger circle = longer fixation duration
  - Processing of information
    - Eye-mind hypothesis

- **Saccades** = lines (movement of eyes)

- **Scan path** = combination of dots and lines (directional movement)
Eye-tracking measurements

- **Attention** to objects can be measured:
  - How many focus points on object (**Fixation Count**)?
  - How long those focus points were (**Mean Fixation Duration**)?
  - How a person moved their attention to objects (**Scan path**)?
  - How long did the person look at the object (**Dwell Time**)?
- **Transition Matrix** – movement between AOIs
- **Reading speed** (words per minute)
- **Pupilometrics / pupil dilation** (bigger = more CL)
- **Blink rate** (less blinks = More CL)
Eye-tracking Research

• Assistive technologies
  • For people with complex physical disabilities
  • Screen tracks your eye movements

• Hardware and Software of eye trackers

• Academic Research
  • Reading (static)
  • Subtitles (dynamic reading)
  • Editing
  • Translation
  • Usability of interfaces
  • Comprehension
  • Cognitive Load Theory
Eye-tracking paradigms

1. Visual search (Comprehension)
2. Reading (Static or Dynamic)
3. Scene-perception (Pictures vs. text)
4. Usability (interactive study guide)
Cognitive load

“is mainly concerned with the learning of complex cognitive tasks ...” and “... the relationship between working (short-term) and long-term memory and the effect of their relationship on learning and problem solving ...”

Types of memory

• **Working memory**: Does all the processing
• **Long-Term Memory**: Unlimited repository

Types of cognitive load

• **Intrinsic cognitive load (ICL)**- task-participant interaction
• **Extraneous cognitive load (ECL)** - presentation format of the task
Cognitive load

Measurements of cognitive load
- Subjective / self-reported rating scales
- Physiological measurements
- Psychological measurements
- Dual-task performance

- Eye tracking measures- Physiological
  - Fixation count
  - Average fixation duration
Measuring the effect of subtitles on CL

Problem:
- Inconclusive evidence for effect of subtitles on CL

<table>
<thead>
<tr>
<th></th>
<th>Native Language</th>
<th>Foreign Language</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Effect</strong></td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td><strong>Language acquisition</strong></td>
<td>Kvitnes (2013)</td>
<td>Miterre &amp; McQueen (2009); Rokni &amp; Atatee (2014)</td>
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<td></td>
<td></td>
<td>Kvitnes (2013); D’Ydewalle &amp; van der Poel (1999)</td>
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<td></td>
<td></td>
<td>Etemadi (2012)</td>
</tr>
<tr>
<td><strong>Comprehension / Retention</strong></td>
<td>Kvitnes (2013); Entemadi (2012)</td>
<td>Kvitnes (2013); Zarei (2009); Entemadi (2012); Hyathi &amp; Mohmedi (2014); Markham (1999); Hwang &amp; Huang (2011)</td>
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<td></td>
<td>Miler &amp; Levine (1952)</td>
<td>Maker, Lee &amp; Peebles (2014); Chan, Kruger &amp; Doherty (2019); Matthew (2020)</td>
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<td>Harji et al. (2010); Kruger et al. (2014); Kruger &amp; Steyn (2014); Mayer, Lee &amp; Peebles (2014); Kruger &amp; Steyn (2014); Mayer, Lee &amp; Peebles (2014); Chan, Kruger &amp; Doherty (2019); Matthew (2020)</td>
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Measuring the effect of subtitles on CL

Experimental setup
• Participants: n=23,
• L2 English speakers
• 4 Groups – 4 Videos
• Randomized order of presentation
• Self perceived CL questionnaire
• Comprehension test (20)
Measuring the effect of subtitles on CL

- Material
  - Self-reported CL Questionnaire
  - Comprehension Test

- Subtitles
  - English (Intralingual)
  - Standardized + Automatic generated

- Videos
  - English dialogue

- Research Questions
  - Effect of PM on CL
  - Effect of CL on subtitles
Results

• Between all presentation modes
  • No significance (Comp, ICL & ECL)

• But: Sig. difference for ECL - two subtitled PMs
  • Format of presentation is the same
    • Higher ECL measurement
  • Sig. lower comprehension
  • -10% for automatic subtitles

• What could be the cause?

|                | Estimate | Std. Error | t value | Pr(>|t|) |
|----------------|----------|------------|---------|----------|
| (Intercept)    | 3.17     | 0.53       | 5.99    | 1.42E-07*** |
| PMAV           | 0.54     | 0.80       | 0.68    | 0.49     |
| Automatic      | 0.86     | 0.70       | 1.23    | 0.22     |
| Standardized   | 0.58     | 0.81       | 0.72    | 0.48     |
## Results: Similarities

- Similarities

<table>
<thead>
<tr>
<th></th>
<th>Automatic</th>
<th>Standardised</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of subtitles per video</td>
<td>229</td>
<td>214</td>
</tr>
<tr>
<td>Average number of word per subtitle</td>
<td>6,97</td>
<td>7,29</td>
</tr>
<tr>
<td>The average speed of the subtitles</td>
<td>14,20</td>
<td>14,4</td>
</tr>
<tr>
<td>Subtitles skipped</td>
<td>33%</td>
<td>34%</td>
</tr>
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</table>
Results: Differences

- 0 to 5
- 5 to 10
- 10 to 15
- 15 to 20
- 20 to 25
- 25+

Automatic
Standardized
Results: Differences

![Graph showing differences between Automatic and Standardized data.](#)
Conclusion

• Subtitles can help with accessibility of information
• Also in other languages
• Subtitles = no significant influence on comp or CL
• However, higher ECL for the automatic subtitles
• AND significantly lower comprehension score (-10%)

• Automated subtitles = more cost-effective to produce
  • Negative consequence for generating automatic subtitles
  • AND various other aspects of subtitles need to be controlled for

Standardised subtitles = More costly + time consuming
• Have more control over presentation speed
• More effective for information accessibility
THANK YOU