How much exposure is needed for learners to pay attention? Lessons from an eye-tracking study

Bimali Indrarathne
Michael Ratajczak
Judit Kormos
Lancaster University
Contextual grammar learning from written input

**Reading processes:** (Perfetti & Stafura, 2014; Reichle et al., 1998)
- word-form decoding
- word-to-text integration
- syntactic parsing
- meaning extraction

**Attentional processing:** (Chun, Golomb and Turk-Browne 2011; Lamme, 2003)
- selective
- With our without awareness

**Learning:** (Davis & Gaskell, 2009; Ellis, 2006; van der Ven et al., 2015)
- Creating memory traces
- Strengthening and refining memory traces
- Consolidation of form-meaning associations
Attention decrease with time

Attention to repeated and familiar stimuli

Attention to novel stimuli

Habituation
Reaching optimal level
More fluent processing

How much exposure is necessary?

**Implicit input:** input flood

No impact: 13 to 60 exposures
Significant impact: 4 to 18 exposures
Denhovska et al. (2016): 3 types and 3 tokens better than higher types and higher tokens

**Implicit input:** textual enhancement

No impact: 28 to 150 exposures
Significant impact: 12 to 36 exposures

**Explicit input:** asking to pay attention

No impact: 36 exposures
Significant impact: 10 to 150 exposures

**Vocabulary research:**
Godfroid et al. (2017), Elgort et al. (2017): 1-10 exposures for word form, 7-10 exposures form-meaning link
Pellicer-Sánchez (2016): form-meaning link after 3 exposures
Research design

- **Control group**
- **Enhanced + instructions**
- **PPT - explicit explanation**
- **Enhanced only**
- **Unenhanced**

**Pretest**
- A: Enhanced + instructions
- B: Enhanced + instructions
- C: Enhanced only
- D: Unenhanced

**Posttest**
- A: Enhanced + instructions
- B: Enhanced + instructions
- C: Enhanced only
- D: Unenhanced
To investigate....

1. **Differences** in cognitive processing across instructional conditions and sessions

2. **Changes** in cognitive processing of a target syntactic construction across exposures

3. **Changes** in cognitive processing across sessions in explicit and implicit learning conditions

4. **Relationship** between cognitive processing and learning gains
Participants

- 100 undergraduates at a Sri Lankan university
- Age between 18-22
- First language Sinhala speakers
- Had been learning English as an L2
- B1/low B2 level of proficiency
- 20 in a group
Input

- Three stories
  - Controlled for length, word frequency, syntactic complexity, readability
  - Target construction – causative ‘had’ – E.g. I had my car repaired (BNC)
  - 7 examplars in each story – 21 in total
  - Every other day for one week (3 times)
Eye-tracking

- Tobii X2-60 portable eye tracker fixed to a laptop
- Slides were prepared on PowerPoint first: 24-point, double-spaced Calibri
- Areas of Interest (AOI) - example of the target structure
- All words of the AOI placed in one line
- 80 participants eye-tracked, 20 control group
Data analysis

- Eye-tracking data
  - Total fixation duration on AOIs (TFD)
- Pre/post test data (Timed aural grammaticality judgement and sentence transformation)

For more information on research design see Indrarathne and Kormos (2016) in SSLA
Statistical analysis

- Linear Mixed-Effects Modelling with higher-order polynomials, also known as Growth Curve Analysis (Mirman, 2014), was used to analyze the effects of exposure to a target syntactic construction causative had on fixations durations.
  - Orthogonal polynomials
  - The fixed effects: Group and Session on all exposure terms
  - The random effects: random intercept of participants; random slopes of exposure and session.
  
  \[
  \text{lmer(\text{logTFD} \sim (\text{exposure}+\text{exposure}^2+\text{exposure}^3)^*\text{Group}*\text{Session} + (\text{Session} + \text{exposure}+\text{exposure}^2+\text{exposure}^3+1 | \text{Participant})
  \]

- 1309 observations (308 excluded)
- 77 participants (three excluded)
### Results - RQ1

#### Multiple comparisons; main effects.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Estimate</th>
<th>Standard Error</th>
<th>z-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>En_Instr vs. Unenhanced</td>
<td>.99</td>
<td>.16</td>
<td>6.14</td>
<td>***</td>
</tr>
<tr>
<td>En_Instr_Expl vs. Unenhanced</td>
<td>.97</td>
<td>.16</td>
<td>6.06</td>
<td>***</td>
</tr>
<tr>
<td>Enhanced vs. Unenhanced</td>
<td>.40</td>
<td>.16</td>
<td>2.40</td>
<td>.08</td>
</tr>
<tr>
<td>En_Instr_Expl vs. En_Instr</td>
<td>-.02</td>
<td>.14</td>
<td>-.15</td>
<td>1.00</td>
</tr>
<tr>
<td>Enhanced vs. En_Instr</td>
<td>-.59</td>
<td>.15</td>
<td>-3.95</td>
<td>***</td>
</tr>
<tr>
<td>Enhanced vs. En_Instr_Expl</td>
<td>-.57</td>
<td>.15</td>
<td>-3.85</td>
<td>***</td>
</tr>
<tr>
<td><strong>Session</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Session 2 vs. Session 1</td>
<td>-.13</td>
<td>.12</td>
<td>-1.04</td>
<td>.54</td>
</tr>
<tr>
<td>Session 3 vs. Session 1</td>
<td>-.22</td>
<td>.15</td>
<td>-1.51</td>
<td>.28</td>
</tr>
<tr>
<td>Session 3 vs. Session 2</td>
<td>-.10</td>
<td>.11</td>
<td>-.86</td>
<td>.66</td>
</tr>
</tbody>
</table>

*Note.* * = p < .05; ** = p < .01; *** = p < .001.
## Results - RQ1

### Multiple comparisons: Group by Session.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Estimate</th>
<th>Standard Error</th>
<th>z-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>En_Instr x Session 2</code> vs. <code>En_Instr x Session 1</code></td>
<td>-.05</td>
<td>.10</td>
<td>-.47</td>
<td>.88</td>
</tr>
<tr>
<td><code>En_Instr x Session 3</code> vs. <code>En_Instr x Session 1</code></td>
<td>-.37</td>
<td>.15</td>
<td>-2.51</td>
<td>*</td>
</tr>
<tr>
<td><code>En_Instr x Session 3</code> vs. <code>En_Instr x Session 2</code></td>
<td>-.32</td>
<td>.13</td>
<td>-2.57</td>
<td>*</td>
</tr>
<tr>
<td><code>En_Instr_Expln x Session 2</code> vs. <code>En_Instr_Expln x Session 1</code></td>
<td>.37</td>
<td>.10</td>
<td>3.74</td>
<td>***</td>
</tr>
<tr>
<td><code>En_Instr_Expln x Session 3</code> vs. <code>En_Instr_Expln x Session 1</code></td>
<td>.10</td>
<td>.13</td>
<td>.78</td>
<td>.68</td>
</tr>
<tr>
<td><code>En_Instr_Expln x Session 3</code> vs. <code>En_Instr_Expln x Session 2</code></td>
<td>-.26</td>
<td>.11</td>
<td>-2.39</td>
<td>*</td>
</tr>
<tr>
<td><code>Enhanced x Session 2</code> vs. <code>Enhanced x Session 1</code></td>
<td>.24</td>
<td>.10</td>
<td>2.30</td>
<td>.05</td>
</tr>
<tr>
<td><code>Enhanced x Session 3</code> vs. <code>Enhanced x Session 1</code></td>
<td>.20</td>
<td>.14</td>
<td>1.45</td>
<td>.31</td>
</tr>
<tr>
<td><code>Enhanced x Session 3</code> vs. <code>Enhanced x Session 2</code></td>
<td>-.04</td>
<td>.11</td>
<td>-.38</td>
<td>.92</td>
</tr>
<tr>
<td><code>Unenhanced x Session 2</code> vs. <code>Unenhanced x Session 1</code></td>
<td>-.13</td>
<td>.12</td>
<td>-1.04</td>
<td>.54</td>
</tr>
<tr>
<td><code>Unenhanced x Session 3</code> vs. <code>Unenhanced x Session 1</code></td>
<td>-.22</td>
<td>.15</td>
<td>-1.51</td>
<td>.28</td>
</tr>
<tr>
<td><code>Unenhanced x Session 3</code> vs. <code>Unenhanced x Session 2</code></td>
<td>-.10</td>
<td>.11</td>
<td>-.86</td>
<td>.66</td>
</tr>
</tbody>
</table>

*Note.* * = p < .05; ** = p < .01; *** = p < .001.
Figure 1. The effects of Exposure on TFDs averaged across Groups and Sessions.
Figure 2. TFDs by Exposure, Group, and Session.
RQ1: Differences across groups

- Unenhanced = Enhanced < Enhanced + Instructions = Enhanced + Instructions + Explanations
- Low levels of attention in input flood and visual enhancement – working memory limitations, externally induced salience might not correspond with learner generated salience
- Instruction to pay attention: raises expectancy and value (Wickens’ 2007 SEEV model of attention) – increased top-down and bottom-up attentional control (Koch & Tsuchia, 2006)

For more detailed explanation see Indrarathne and Kormos (2016) in SSLA
RQ1: Differences between groups across sessions

- Explanation provided raises attention level in Session 2 in the group that received prior metalinguistic explanation.
- Processing efficiency increases in Session 3 in the rule-search condition.
# Relationship between eye-tracking measures and learning

<table>
<thead>
<tr>
<th>Correlation between TFD &amp; learning gain</th>
<th>Correlation between ΔTFD &amp; learning gain</th>
<th>Attention decrease or increase in processing efficiency?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong and positive</td>
<td>Positive</td>
<td>Attention decrease</td>
</tr>
<tr>
<td>Strong and negative</td>
<td>Positive</td>
<td>Increase in processing efficiency</td>
</tr>
<tr>
<td>Weak to moderate and positive</td>
<td>Strong positive</td>
<td>Attention decrease and increase in processing efficiency</td>
</tr>
<tr>
<td>Strong and positive</td>
<td>Negative</td>
<td>Attention maintenance</td>
</tr>
</tbody>
</table>
## Relationship between TFD and gain scores

- Total sample: SR gain & TFD \( \rho = .636 \) GJ gain & TFD \( \rho = .524 \) \( p < .001 \)
- SR gain & \( \Delta \) TFD \( \rho = .644 \) GJ gain & \( \Delta \) TFD \( \rho = .536 \) \( p < .001 \)

<table>
<thead>
<tr>
<th>Eye tracking measurement</th>
<th>Group</th>
<th>SR Gain</th>
<th>GJ Gain</th>
<th>Attention area</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TFD</strong></td>
<td><strong>enhanced+ instr</strong></td>
<td>.583*</td>
<td>.281</td>
<td>Attention+ efficiency</td>
</tr>
<tr>
<td></td>
<td><strong>enhanced+ instr+ expl</strong></td>
<td>.793**</td>
<td>.761**</td>
<td>Attention decrease</td>
</tr>
<tr>
<td></td>
<td><strong>enhanced only</strong></td>
<td>.612*</td>
<td>.654*</td>
<td>Attention maintenance</td>
</tr>
<tr>
<td></td>
<td><strong>unenhanced</strong></td>
<td>-.242</td>
<td>-.272</td>
<td>Neither</td>
</tr>
<tr>
<td><strong>( \Delta )TFD (TFD1-TFD7)</strong></td>
<td><strong>enhanced+ instr</strong></td>
<td>.647*</td>
<td>.798**</td>
<td>Attention+ efficiency</td>
</tr>
<tr>
<td></td>
<td><strong>enhanced+ instr+ expl</strong></td>
<td>.521</td>
<td>.530</td>
<td>Attention decrease</td>
</tr>
<tr>
<td></td>
<td><strong>enhanced only</strong></td>
<td>-.256</td>
<td>-.040</td>
<td>Attention maintenance</td>
</tr>
</tbody>
</table>
RQ2: Change in cognitive processing across exposures

- S-curved change seems to suggest a relatively quick form-recognition, followed by a consolidation phase and increase in processing efficiency.


![Graph](image)
Changes in cognitive processing in the unenhanced group

- Fluctuations reflecting reading processes – initially slightly higher attention paid to first two items
- No learning effects when compared to control group and low non-significant correlations between learning gains and TFD (rho SR = -.242; rho GJ = -.272), no significant correlations between ΔTFDs and gains
Changes in cognitive processing in the enhanced group

- Some level of attentional processing – significant positive correlation between learning gains and TFD
- Somewhat higher attentional processing initially in Session 1 $\Delta$TFDinitial in Text 1, ($\text{rho SR } = -0.503^{**}; \text{ rho GJ } = 0.331$)
- Maintaining attention in Session 2: $\Delta$TFDtotal in Text 2, ($\text{rho SR } = -0.538^{*}; \text{ rho GJ } = 0.038$)
- Significant learning gain compared to control only in GJ task
Changes in cognitive processing in the enhanced+instructions group

- High initial attention in all three sessions - significant and positive correlation between learning gain in SR and TFD (rho SR = .583*) but not in GJ task (rho GJ=.281)
- Sudden increase in processing efficiency in Session 3 $\Delta$TFDlate in Session 3, (rho SR = .869**; rho GJ=.824**)
- Significant learning effects in both tasks
Changes in cognitive processing in the enhanced+instructions+explanation group

- High initial attention in all three sessions - high significant and positive correlation between learning gains and TFD (rho SR = .793; rho GJ = -.761)

- Increase in attentional processing early in Task 2

\[ \Delta \text{TFD}_{\text{total}} \text{ in Text 2}, \quad (\text{rho SR} = .831*; \text{rho GJ} = .557*) \]

\[ \Delta \text{TFD}_{\text{initial}} \text{ in Text 2}, \quad (\text{rho SR} = .717*; \text{rho GJ} = .598* ) \]
How much exposure is necessary?

**Input flood**
A lot more than $3 \times 7$
(SR task-10%, GJ: 56.1%)

**Textual enhancement**
A lot more than $3 \times 7$
(SR task-6%, GJ: 57.5%)

**Rule-search**
Processing efficiency starts to develop towards the end of the $3 \times 7$ exposure but more exposure is needed
(SR task-28%, GJ: 60.5%)

**Metalinguistic explanation**
Form-meaning link integration might take place after explanation but for processing efficiency more exposure is needed
(SR task-36%, GJ: 68.3%)
Thank you


