Short-Term Effects of Animated versus Static Visualisation of Operations on Program Perception

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Outline

- Background
- Visualization and Cognition
- Previous work
- Experiment
- Discussion
- Conclusion
Background

- Numerous visualization and animation tools to assist teaching of computer programming

- Empirical evaluation of visualization tools based mostly on long-term effects, ignoring immediate effects of visualizations

- A series of experiments studying immediate and short-term effects and their relation to long-term effects based on our model of cognitive phenomena that take place during viewing
• Locations of participant's gaze (visual attention)
  • Gathered with eye-tracking equipment
Cognitive Phenomena behind Visualizations

- Locations of participant's gaze (**visual attention**)  
  - Gathered with eye-tracking equipment

- Knowledge of variable roles (**programming knowledge**)  
  - Measured with post-tests (Stützle and Sajaniemi 2005)

- Summaries of studied programs (**program knowledge**)  
  - Analyzed with Good's scheme (Good 1999)
Cognitive Phenomena behind Visualizations

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PlanAni Visualization Tool (Sajaniemi and Kuittinen 2005)

• Visualizes variable roles
• Role of a variable = behavior of a variable, e.g.,
  – Stepper = a variable stepping through a systematic, predictable succession of values
  – Gatherer = a variable accumulating the effect of individual values
• Facilitates learning introductory programming
• Eleven roles cover 99% of all variables in novice-level programs
• Role image represents the salient stereotypical features of variable’s behavior
• Role image also used for the animation of operations on a variable
Previous Work on Roles of Variables

• Beneficial long-term effects on programming skills (Byckling and Sajaniemi 2006, Sajaniemi and Kuittinen 2005)

• Use of original role images enhanced learning of roles when compared to neutral control images (Stützle and Sajaniemi 2005)

• PlanAni compared to Turbo Pascal debugger (Nevalainen and Sajaniemi 2005):
  • Use of PlanAni $\rightarrow$ increase in targeting of visual attention on variable visualizations
  • Increase of visual attention to variables $\rightarrow$
    increase of high-level information,
    and decrease of low-level code-related information in program summaries
Experiment: Design

• Between-subject design

• Independent variable: version of PlanAni (smoothly animated (“animation group”) or immediate update ("static group"))

• Dependent variables:
  • Locations of participant's gaze
  • Participant's post-test score on role knowledge
  • Program summary provided by the participant

• Participants:
  • Eleven male and five female (n=16)
  • Had taken a first-year programming course in last eighteen months and continued their studies thereafter
**Experiment: Procedure**

- A video presentation introducing roles
- Pre-test on role knowledge
- A practice program with PlanAni
- An actual program with PlanAni
- Post-test on role knowledge
- Tool evaluation form
Results: Role Knowledge and Visual Attention

- Post-test scores on role knowledge (max score 13)
  - Animation group: 12.00
  - Static group: 11.25  Difference N.S.

- Mean proportions of viewing times on different areas of the screen (difference between the groups significant in viewing code and I/O areas):
Results: Program Summaries

- Good’s program summary analysis scheme (Good 1999) was applied to participants' program summaries.

- Information types divided into high-level and low-level types:

<table>
<thead>
<tr>
<th>Code</th>
<th>Information Type</th>
<th>Group</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Animation</td>
<td>Static</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
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<tr>
<td>HIG</td>
<td>FUN+ACT+SHI+DAT</td>
<td>76.09</td>
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<tr>
<td>LOW</td>
<td>OPE+SLO+CON</td>
<td>15.58</td>
<td>8.09</td>
<td>15.20</td>
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<tr>
<td>OTH</td>
<td>100-HIG-LOW</td>
<td>8.30</td>
<td>9.07</td>
<td>7.49</td>
</tr>
<tr>
<td>HIP</td>
<td>HIG / (HIG+LOW) * 100</td>
<td>82.81</td>
<td>8.97</td>
<td>83.84</td>
</tr>
</tbody>
</table>

Differences N.S.

- Object description categories:

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<thead>
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<th>Object Description Category</th>
<th>Group</th>
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<td>Static</td>
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<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
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<td>UNO</td>
<td>Unclear</td>
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</table>

Differences
Discussion: Visual Attention

- Variation in the graphics, location and size of variable visualizations $\rightarrow$ clear influence on the distribution of visual attention (Nevalainen and Sajaniemi 2005)

- Presence or absence of a smooth animation $\rightarrow$ only subtle differences on the distribution of visual attention

- Even participants provided with rich pictorial information resorted heavily to the textual cues
Discussion: Role Knowledge

• Variation in the images of PlanAni → significant differences in development of role knowledge found in (Stützle and Sajaniemi 2005)

• Presence or absence of a smooth animation → differences non-significant

• One explanation: the role images, not the role animation, play central role in the development of role knowledge when PlanAni is used
Discussion: Program Summaries

- PlanAni has been found to have long-term effects on programming knowledge, that results in differences in program summaries (Sajaniemi and Kuittinen 2005)

- The effects do not seem to manifest themselves in program summaries collected after viewing visualization (Nevalainen and Sajaniemi 2005, this experiment)
Conclusions

• Research focus: how a person viewing visualizations targets her visual attention and what kind of a mental model she constructs concerning a computer program

• Research based on a model of cognitive phenomena that take place during viewing

<table>
<thead>
<tr>
<th>Experiments on visualizing variable roles</th>
<th>Dependent Variables:</th>
<th>Visual attention on visualization</th>
<th>Programming knowledge</th>
<th>Program knowledge</th>
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<tbody>
<tr>
<td>Varied factors:</td>
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<td>Content of images used in visualization</td>
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<td>Significant differences</td>
<td>Not measured</td>
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<td>(Stützle &amp; Sajaniemi 2005)</td>
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<td>Graphics, location, and size of visualization (Nevalainen &amp; Sajaniemi 2005)</td>
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<td>Significant differences</td>
<td>Not measured</td>
<td>No significant differences</td>
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<td>Animation style used in visualization (Nevalainen &amp; Sajaniemi 2006)</td>
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<td>No significant differences</td>
<td>No significant differences</td>
<td>No significant differences</td>
</tr>
</tbody>
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• Future experiments: use of style of engagement as a varied factor.