Hand-Held Cognition: Does Learning Suffer When an External Representation Interface Style Is Used?

Keith A. Beatty
Outline

• Introduction
• Literature Review
• Methodology
• Results
• Discussion
• Conclusion
Definitions

- Internal Representation
- External Representation
- External Cognition
External Representations in Software

- Use of recognition in place of recall (Nielsen, 2005)
- This is done via disabling menu items, wizards, etc.
External Representation Example

This is information on my page
External Representation Example

This is information on my page
External Representation Example

This is information on my
Literature Review
Zhang & Norman (1994)

- Distributed Representation

(image Zhang & Norman, 1994, p. 90)
Zhang & Norman (1994)

- Study of several versions of the Towers of Hanoi logic game

**Results**

- External Representations
  - Memory aids
  - Anchor structure
  - Anchor learning behavior
  - May change nature of task
- External representations can be internalized
  - Not needed, if external representations always available

- Mayes, Draper, McGregor & Oatley (1988)
  - Effect of recall using MacWrite, a GUI based word processing program
  - Skill range: novice – skilled
  - All subject were able to use MacWrite menu’s to format letters correctly
- Payne (1991)
  - Effect of recall using character and GUI based word processing programs
  - Subjects answered common questions on the word processing package that they used most
Nimwegen, Oostendorp, Tabchneck-Schijf (2004)

- Study on learning
- Created a new game based on the rules of the Missionaries and Cannibals logic game
- **Rules**
  - 3 cannibals / 3 missionaries / 1 boat holds 1 or 2 people
  - Cannibals will eat any missionaries when missionaries are outnumbered
  - Goal of the game to get all missionaries and cannibals to the opposite side of the river
Nimwegen, Oostendorp, Tabchneck-Schijf (2004)

- This study used 5 people, instead of the traditional 3.
- 9 trials
- Post test questionnaire, 7 procedural, 1 declarative knowledge questions about the game
- Neither time nor procedural knowledge had a significant difference
- Declarative knowledge was significantly different, where the internal representation interface style was better
- Eight months later, the originals were re-tested with a different missionaries and cannibals isomorph, with similar results as the main study
Research Hypothesis

• On a hand-held device, participants that use the internal representation interface style will have significantly more declarative knowledge than those who use the external representation interface style.
Methodology
Participants

- 31 people took part in the study
  - 19 men, 12 women
  - Age: 19 to 48, mean: 31.7
  - All had some experience with hand-held device, digital camera cited most often
- 21 people completed all four sessions
  - 13 men, 8 women
  - Age: 19 to 48, mean: 31.0
  - 12 assigned to internal representation interface type
  - 9 assigned to external representation interface type
Design

- Between subjects
- Participant assigned to a group: representation interface style
- New game that used the Missionaries and Cannibals game rules on a smart phone
- 4 sessions, 6 to 8 days apart
  - 1st session, 6 trials: trial 1 & 2 are used to train, 4 remaining trials are “normal”
  - 2, 3 and 4 sessions – 4 trials
Implementation - Game

Comparison between interface styles

- Internal Representation
- External Representation
Implementation - Game

Instructional video given to the participants
Statistical Tests

- Non-parametric tests used, because of range of data
- Pearson’s Chi-squared Test for Independence used for categorical types:
  - Declarative
  - Procedural
- Mann-Whitney U test — non-parametric version of the Student $t$ test
- Significance level of .05 or less is considered a significant result
Results
Results – Declarative Knowledge
Results – Procedural Knowledge
Discussion

• Declarative / Procedural Chi-Squared Results
• Declarative Results
• Procedural Results
• Qualitative Results
• Summary Count Mann Whitney U Selected Results
Post-Survey Qualitative and Quantitative Chi-Squared

- Contingency tables for Declarative and Procedural knowledge questions had cells that did not total up to 5, so that the Chi-square result would be unreliable.
- Declarative and Procedural results are reviewed using Means and Standard Deviations
<table>
<thead>
<tr>
<th>Group</th>
<th>Declarative Knowledge</th>
<th>Procedural Knowledge</th>
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<tr>
<td></td>
<td>M</td>
<td>SD</td>
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<tr>
<td>Internal Session 1</td>
<td>1.50</td>
<td>1.00</td>
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<td>External Session 1</td>
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## Summary Count Mann-Whitney U Results, Session 1

<table>
<thead>
<tr>
<th>Grouping</th>
<th>Time</th>
<th>Non-Object Moves</th>
<th>Invalid Moves</th>
<th>Object Moves</th>
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<tbody>
<tr>
<td></td>
<td>U</td>
<td>Exact Sig.</td>
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<td></td>
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<tr>
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<td>32.00</td>
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<td>Session 1 – w/o 2X outliers</td>
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<tr>
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<tr>
<td>Trial 5</td>
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<td>27.00</td>
<td>0.06</td>
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<tr>
<td>Trial 6</td>
<td>22.50</td>
<td>0.04</td>
<td>25.00</td>
<td>0.06</td>
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Summary Count Mann-Whitney U Results, Session 1 Screens

Trial 3

Trial 5

Trial 6
Summary Count Mann-Whitney U Results, Session 1, Trial 5, 6 - Object

- With Outliers
- With 2X Outliers removed

[Graphs showing data distribution for different interface types and session sessions with and without outliers.]
Summary Count Mann-Whitney U
Results, Session 1, Trial 6 - Time

Has two times standard deviation outliers removed
Summary Count Mann-Whitney U
Results, Session 1, Trial 6 - Invalid

Has two times standard deviation outliers removed
# Summary Count Mann-Whitney U Results, Session 2

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<tr>
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<td>29.50</td>
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</tbody>
</table>
Summary Count Mann-Whitney U Results, Session 2, Trial 3 - Object

- Trial Screen for session 2, trial 3 & session 3, trial 3
Summary Count Mann-Whitney U Results, Session 2, Trial 3 - Object

Has two times standard deviation outliers removed
Summary Count Mann-Whitney U Results, Sessions 3

<table>
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<th>Non-Object Moves</th>
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Summary Count Mann-Whitney U Results, Session 3, Trial 3 – Invalid

Has two times standard deviation outliers removed
Conclusion

• Study Limitations
• Future Research
Study Limitations

- Low number of participants
  - Longitudinal nature of study limited participation
  - Required interaction with a proctor
  - Length of study
  - Budget
Future Research

• Larger budget to recruit more participants
• Change program to record individual movements
• Change program to vary objects (5 / 4 / 3 )
• Use newer / easier to use smart phones – iPhone, Google Android based G-1
References

Questions?