Effects of Visual Cueing on Beginner Problem Solvers in Physics
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Motivation

- Multimedia in science education
- Guide students’ attention
- Activate prior knowledge
- Create deeper conceptual understanding
Research Question

- Does visual cueing influence problem-solving ability?
- Does visual cueing activate prior knowledge?
- Do students reason differently after visual cueing?
- Does visual cueing affect students’ eye movements?

Previous Research (1)

Attentional Cueing

- Visual cues on animation of cardiovascular system enhanced comprehension and transfer performance.\(^1\)
- Participants whose eyes were guided while solving Duncker’s radiation problem solved more quickly.\(^2\)

1. B. Koning et al. (2007)
2. L. Thomas & A. Lleras (2007)
Visual Attention Differences

- Participants who responded correctly visually attended to the diagram differently.\textsuperscript{[3]}

The motion of two objects is represented in the graph below. When are the two objects moving with the same speed?

<table>
<thead>
<tr>
<th>Relevant Area</th>
<th>Percentage of Time Spent in Viewing Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct</td>
<td>30%</td>
</tr>
<tr>
<td>Incorrect</td>
<td>19%</td>
</tr>
<tr>
<td>Salient Area</td>
<td>Correct: 13%</td>
</tr>
<tr>
<td></td>
<td>Incorrect: 28%</td>
</tr>
</tbody>
</table>

3. Carmichael et. al. (2010)

Visual Cueing

- Can we guide novices' attention to relevant parts of a diagram using visual cues to help activate correct prior knowledge and answer correctly?

If frictional effects can be ignored, how does the final speed of roller coaster car A compare to the final speed of roller coaster car B, if the mass of the carts is the same and they both start at rest?

- The cart A is moving faster at the final position
- The cart B is moving faster at the final position
- Carts A and B have the same speed at the final position
- There is not enough information to decide

Rank the changes in potential energy during the skier's descent down each slope from greatest to least.

- $\Delta E_C > \Delta E_B > \Delta E_A$
- $\Delta E_B > \Delta E_A > \Delta E_C$
- $\Delta E_A = \Delta E_B = \Delta E_C$
Participants

- N=15 participants (8 cued, 7 non-cued)
- Students had taken at least one physics course
- Prior course taken varied between students
- Varying scientific backgrounds, different majors

Experimental Design

Cued Group

Initial Problem → Correct Explanation? (no) → Transfer Problem

1st Cued Problem → Correct Explanation? (yes) → 2nd Cued Problem

2nd Cued Problem → Correct Explanation? (yes) → 3rd Cued Problem

3rd Cued Problem → Correct Explanation? (yes)
Experimental Design

Non-Cued Group

- Initial Problem
  - Correct Explanation?
    - yes → Transfer Problem
    - no → 1st Similar Problem
  - Correct Explanation?
    - yes
    - no → 2nd Similar Problem
    - Correct Explanation?
      - yes
      - no → 3rd Similar Problem
      - Correct Explanation?
        - yes
        - no

Similar problems
- same concept, similar surface features

If frictional effects can be ignored, how does the final speed of roller coaster cart A compare to the final speed of roller coaster cart B, if the mass of the carts is the same and they both start at rest?

1. The cart A is moving faster at the final position
2. The cart B is moving faster at the final position
3. Carts A and B have the same speed at the final position
4. There is not enough information to decide
Example Cues

If frictional effects can be ignored, how does the final speed of roller coaster cart A compare to the final speed of roller coaster cart B, if the mass of the carts is the same and they both start at rest?

1. The cart A is moving faster at the final position
2. The cart B is moving faster at the final position
3. Carts A and B have the same speed at the final position
4. There is not enough information to decide

Experimental Design

Initial Problem

- Rank the changes in potential energy during the skier's descent down each slope from greatest to least.

1. $\Delta P_{E_A} > \Delta P_{E_C} > \Delta P_{E_B}$
2. $\Delta P_{E_A} > \Delta P_{E_B} > \Delta P_{E_C}$
3. $\Delta P_{E_B} = \Delta P_{E_C} = \Delta P_{E_A}$

Transfer Problem

- A ball is thrown upward from the ground. Ignoring the effects of air resistance, compare the change in potential energy in each segment of the ball's flight path.

1. $\Delta P_{E_A} > \Delta P_{E_C} > \Delta P_{E_B}$
2. $\Delta P_{E_A} > \Delta P_{E_B} > \Delta P_{E_C}$
3. $\Delta P_{E_B} = \Delta P_{E_C} = \Delta P_{E_A}$

- Same concept, different surface features.
Comparisons between cued vs. non-cued groups:
- Transfer problem responses
- Number of similar problems needed
- Changes in verbal explanation
- Eye-Movements on initial/transfer problems
Students who correctly moved to the transfer problem after a given number of similar problems

<table>
<thead>
<tr>
<th></th>
<th>1st Similar Problem</th>
<th>2nd Similar Problem</th>
<th>3rd Similar Problem</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cued Group</strong></td>
<td>4 (of 25)</td>
<td>0 (of 21)</td>
<td>2 (of 21)</td>
</tr>
<tr>
<td><strong>Non-cued Group</strong></td>
<td>3 (of 19)</td>
<td>0 (of 16)</td>
<td>0 (of 16)</td>
</tr>
</tbody>
</table>

Categorized participants verbal explanations to analyze changes in conceptual reasoning.

"The hill was steeper in A, so it will be going faster."

"There are less bumps in A, so it will be going faster."
Results

Eye Movements:

Rollercoaster Transfer Problem:

If frictional effects are ignored, how does the final speed of roller coaster cart A compare to the final speed of roller cart B? The theme of the events is the same. Choose one option below:

1. The cart A is moving faster at the final position.
2. The cart B is moving faster at the final position.
3. Cart A and B have the same speed at the final position.
4. There is not enough information to decide.

<table>
<thead>
<tr>
<th>Transition from Track A to Track B</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cued</td>
<td>8.71</td>
</tr>
<tr>
<td>Non-cued</td>
<td>6.25</td>
</tr>
</tbody>
</table>

Average # of Changes in Explanation per Student

Changes in Verbal Explanation

Problem Set 1
Problem Set 2
Problem Set 3
Problem Set 4

Cued Group
Non-Cued Group
Conclusions

- Some transfer problem improvement, overall cueing effect on transfer problem accuracy.
- No notable difference in number of similar problems.
- Differences in verbal explanation changes in Problem Sets 2 and 4.
- Cueing causes similar eye-movements on transfer problems.

Note: Due to small sample size, Mann-Whitney test shows no significant difference in transfer problem responses and changes in explanation.

Future Research

- Repeat with more students.
- Vary cue type.
- Increase cue duration.
- Increase number of similar problems.
- Control more precisely for differences in prior knowledge.
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Further questions?

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References