Why Some Problems are Harder: Analysis of Illegal Moves

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Introduction

Illegal moves are actions that violate the rules of a problem. They often comprise a large portion of problem-solving activity. Reducing illegal moves is important because they will never lead to a correct solution and thus are just wasted effort, and may have serious consequences.

Prior Research on Reducing Illegal Moves

- Rule Representation (Zhang & Norman, 1994)
- Externalizing rules reduced illegal moves
- Information Availability (Kotovsky & Simon, 1990)
- Presenting legal alternatives decreased illegal moves

Illegal Move Framework

- Based on Illegal Move Filter (Jeffries et al., 1977)

We investigated a possible new way of reducing illegal moves – by imposing a penalty or “time out” for making illegal moves. After an illegal move participants rated words for pleasantness (cost)

If it works, where in the framework?

Experiment I

Purpose: determine if a “time out” cost manipulation could reduce illegal moves

- 64 UF students who solved Hobbits & Orcs
- Design: 2 Verbalization (silent vs. aloud) x 2 Cost (cost vs. control)
- Verbalization: Participants “thought aloud” and stated any move they were considering.
- No main effect of verbalization and no interactions with verbalization, all Fs < 1.
- Regression

<table>
<thead>
<tr>
<th>Legal Moves (L)</th>
<th>1.14</th>
<th>17.56</th>
<th>.55</th>
</tr>
</thead>
<tbody>
<tr>
<td>Considered Moves (C)</td>
<td>1.13</td>
<td>15.01</td>
<td>.24</td>
</tr>
</tbody>
</table>

\[ t = \frac{(1.14 - 1.13) - (17.56 - 15.01)}{1.97} \] (I = Illegal Moves)

Making more legal moves resulted in more illegal moves (generation-rate). However, after controlling for legal moves checking the rules more frequently resulted in fewer illegal moves (caution).

Would cost reduce illegal moves?

Experiment I Conclusions

- Cost reduced illegal but not legal moves
- Evidence for illegal move reduction at multiple stages
- Verbal protocols did not affect performance

Experiment II

Purpose: determine if the benefits of cost would be sustained on a subsequent problem

- 81 UF students solved the Hobbits & Orcs problem twice
- Cost Group: Cost \( \rightarrow \) No-Cost
- Control Group: No-Cost \( \rightarrow \) No-Cost

Did the benefits of cost remain on the second solution attempt when the cost was removed?

Experiment II Conclusions

- Replicated findings of Exp I: cost reduced illegal moves without affecting legal moves
- Control group had fewer illegal moves on second solution, replicating Reed, Ernst & Banerji (1974)
- Illegal moves remain low after removal of cost

Experiment III

Purpose: determine if caution or rule-verifications is responsible for illegal move reduction

- 77 UF students solved both Titration and Hobbits & Orcs (20 minutes each)

Titrating: Very different looking isomorphic threat of the Hobbits & Orcs problem with different rules

Would sustained benefits from cost transfer to novel problems?

Experiment III Conclusions

- People in the cost condition continued to make fewer illegal moves on a novel problem even when the cost was removed. However, unlike Exp II there was no transfer in the control group replicating Reed et al. (1974) and suggesting caution rather than rule-specific transfer as the source of the benefit of cost.

Working Memory Assessment

- OSPAN given after every experiment

<table>
<thead>
<tr>
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<th>Cost (N = 96)</th>
<th>Control (N = 172)</th>
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<tbody>
<tr>
<td>Legal Moves</td>
<td>( r = .013 )</td>
<td>( r = .025 )</td>
</tr>
<tr>
<td>Illegal Moves</td>
<td>( r = .167 )</td>
<td>( r = .132 )</td>
</tr>
</tbody>
</table>

Note: all correlations \( p > .05 \)

Conclusions

- Caution (stage II) caused illegal move reduction and legal moves remained unaffected
- Benefits of Cost remain after Cost is removed
- Size of sustained benefits same for novel \( \eta^2 = .094 \) (Exp III) or same problems \( \eta^2 = .096 \) (Exp II)
- Framework applicable to many problems
- WM had little affect on illegal move selection

References


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