Metacognitive Sophistication about Desirable Difficulty: Implications for Learning Complex Material  
Matthew J. Hays, Lindsey E. Richland, and Robert A. Bjork  
University of California, Los Angeles

Abstract

<table>
<thead>
<tr>
<th>Investigated</th>
<th>Found</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Whether three “desirable difficulties” (Bjork, 1994) remained desirable when applied to learning typical classroom material.</td>
<td>Interleaving (between) - No effect. Contextual Interference (between) - No effect. Teaching by Testing (within) - Material tested during learning was better retained.</td>
</tr>
<tr>
<td>(2) Students’ awareness and understanding of desirable difficulties</td>
<td>Students’ awareness and understanding of desirable difficulties Only 31% of participants reported that they normally use tests as learning tools.</td>
</tr>
<tr>
<td>(3) Whether (2) predicted students’ retention of educational materials.</td>
<td>The above participants’ retention was superior.</td>
</tr>
</tbody>
</table>

Conclusion (3): potential positive relationship between metacognitive sophistication and cognitive ability.

Are Desirable Difficulties Relevant to Classroom Material?

**Materials:**
12 paragraphs in each of 2 topics (Star formation and Planet formation) presented via the Web-based Inquiry Science Environment.
10 Embedded Assessment Protocols (EAPs), which consisted of a fill-in-blank question and two judgment of learning (JOL) questions (designed to assess metacognition).

**Design:** 2x2x2 mixed design.  - Between-subjects: (Blocked | Interleaved)  - Between-subjects: (Greater CI | Less CI)  - Within-subjects: whether a presented concept was tested during learning.

The set of 10 concepts tested during learning was counterbalanced across participants randomly within each combination of the two between-subjects factors, to which participants (71 UCLA undergraduates) were also randomly assigned.

**Procedure and Measures:**

<table>
<thead>
<tr>
<th>TIME</th>
<th>Session 1 Part 1</th>
<th>Session 1 Part 2</th>
<th>Delay</th>
<th>Session 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Immediate Recall</td>
<td>Delayed Recall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blocked</td>
<td>S,S,S,P,P,P,P,P,P</td>
<td>better</td>
<td>worse</td>
<td></td>
</tr>
<tr>
<td>Interleaved</td>
<td>S,P,S,P,S,P,S,P,P</td>
<td>worse</td>
<td>better</td>
<td></td>
</tr>
</tbody>
</table>

**Results**

Interleaving: No effect. Contextual Interference: No effect.

Tested material was better retained. F(1,1392) = 63.4, p < .05

**Discussion**

The retention advantage enjoyed by tested material indicates that pop quizzes should be used for instruction. The superior performance of participants who use tests as learning events suggests a positive relationship between metacognitive sophistication and overall cognitive ability.

At first glance, our results portray interleaving as neither difficult nor desirable. However, in making our paradigm more educationally relevant, we diverged from traditional desirable difficulties investigations, which have presented verbatim repetitions of already-studied material. Importantly, because all participants received 10 EAPs, this manipulation does not detract from our finding of a positive relationship between memory and metacognitive sophistication about desirable difficulty.

**References**


Thank you: Dan Fink, Jason Finley, Nate Kornell, and Matthew Makel.