Physical and Virtual Objects

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ThinkSpatial Brown Bag
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Thank you!

- Mary Hegarty
- Rich Mayer
- Russ Revlin
- Jack Loomis
- Bonnie Dixon
- Mike Stieff

- Trevor Barrett
- Bailey Bonura
- Jana Ormsbee
- Taylor Davis
Physical and Virtual Objects

Research:

- Multimedia learning
  - How do we design instructional material that promote meaningful learning?

- Small-scale spatial cognition
  - How does spatial ability affect learning with objects?

- Human-computer interactions
  - How do we design productive interactions?
Physical and Virtual Objects

Studies:

- Physical objects
  - Chemistry models and representational translation
  - When used as an intermediary, models are helpful

- Virtual objects
  - Anatomy learning and orientation references
  - Salient visual cues help to resolve disorientation

Future Directions

- Cognitive and perceptual differences
- Design of the interface matters
Physical Objects

- Our hand is an interface to the world.

- Action performed in the world can help us think.
  
Chemistry Models

Draw a Dash-Wedge diagram.
Chemistry Models

Are models helpful?
How?

Dash-Wedge  Newman  Fischer

Task: Translate one to another
IV: Model vs. No Model
Models vs. No Models

- Participants – 64 organic chemistry undergrads (35 female)

- Stimuli & Task – 3 diagrams and 1 model (18 trials)

- Design: Between subjects (Models vs. No Models)
  - Models group
    - models provided and use was encouraged
    - models not aligned with starting diagram
  - No Models group did not receive models

- Measures:
  - Drawing accuracy
  - Model use behaviors
  - Spatial ability (MRT)
  - Experience

- Trials recorded on video for later coding

- Groups did not differ on spatial ability or organic chemistry experience.
Models vs. No Models

- People with models drew more accurate translations than people without models.
  - $F(1,62) = 5.04$, $p = .028^*$, $d = 0.56$

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Drawing accuracy M (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Models</td>
<td>32</td>
<td>.40 (.05)</td>
</tr>
<tr>
<td>No Models</td>
<td>32</td>
<td>.26 (.04)</td>
</tr>
</tbody>
</table>

- Groups did not differ on spatial ability or experience.
Models vs. No Models

• Encouraged use of models
  • 87% of Ps (28 of 32 Ps) used the models
  • 4 Ps used the model on every trial

• Types of model use
  • move (any) (28 Ps, 44% of trials)
    – align to start (26 Ps, 24% of trials)
    – align to target (24 Ps, 35% of trials)
    – reconfigure (15 Ps, 22% of trials)

• Classification of people as users or non-users
Models vs. No Models

- **Drawing accuracy**
  - $F(2,61) = 18.59, p < .01^*$
  - *Users vs. No Model*
    - $t(61) = 5.65, p < .01^*, d = 1.52$
  - *Users vs. Non-users*
    - $t(61) = 5.47, p < .01^*, d = 1.69$
  - *Non-users vs. No Model*
    - $t(61) = 0.41, p < 1.0$

- Users and Non-users were divided by 50% align to target.

- Groups did not different on spatial ability or experience.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Drawing accuracy M (SE)</th>
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</thead>
<tbody>
<tr>
<td>Models (all)</td>
<td>32</td>
<td>.40 (.05)</td>
</tr>
<tr>
<td>User</td>
<td>13</td>
<td>.66 (.06)</td>
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<tr>
<td>Non-user</td>
<td>19</td>
<td>.23 (.05)</td>
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<tr>
<td>No Models</td>
<td>32</td>
<td>.26 (.04)</td>
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Models vs. No Models

<table>
<thead>
<tr>
<th>Parts</th>
<th>Centers</th>
<th>Order</th>
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</thead>
<tbody>
<tr>
<td>Level 0</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Level 1</td>
<td>√</td>
<td>X</td>
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<tr>
<td>Level 2</td>
<td>√</td>
<td>√</td>
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<tr>
<td>Level 2.5</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Level 3</td>
<td>√</td>
<td>√</td>
</tr>
</tbody>
</table>
Models vs. No Models

- Proportion of people performing 66.7% at level or better

Most level 3 Ps were model users
Models vs. No Models

Correlations

- Accuracy is correlated with spatial ability
  - \( r = .32, p = .01^* \)

- Model use is correlated with accuracy
  - move (any) \( r = .74, p < .01^* \)
    - align to start \( r = .54, p < .01^* \)
    - align to target \( r = .84, p < .01^* \)
    - reconfigure \( r = .66, p < .01^* \)

- Model use is correlated with spatial ability
  - move (any) \( r = .33, p = .03^* \)
    - align to start \( r = .27, p = .07 \)
    - align to target \( r = .33, p = .03^* \)
    - reconfigure \( r = .40, p = .01^* \)
Models vs. No Models

• Together, spatial ability, align start, align target, and reconfigure explain 72% of variance in drawing accuracy
  • $R = .85; F(4,27) = 16.90, p < .01^*$

• Partial regression coefficients:
  • spatial ability: $\beta = .01, p = .92, sr^2 < .01$
  • align to start: $\beta = -.16, p = .32, sr^2 = .01$
  • align to target: $\beta = .82, p < .01^*, sr^2 = .27$
  • reconfigure: $\beta = .17, p = .32, sr^2 = .01$

➢ Only Align to Target uniquely predicted accuracy after controlling for the other variables.
Also

• Providing models aligned to the given diagram is not helpful
• Training students to relate the model to the given diagram is not helpful
• Having students “discover” that they are wrong when not using the model is helpful
Physical Objects

Summary

• Students should use the models.
  – Most don’t without encouragement.
• When wrong, most students are close.
• Spatial ability is a predictor of accuracy.
• Model use may compensate for spatial ability.
Virtual Objects

Technology is rapidly replacing traditional material.

Low-spatial individuals may be especially burdened. (Garg, Norman, Eva, Spero, & Sharan, 2002)

Disorientation is common for some people when they use virtual objects (Cohen & Hegarty, 2007; Keehner et al., 2008)
Virtual Objects

Same or Different?
Virtual Objects

Procedure

Spatial Ability Measure

Training & Practice

Object Manipulation

error & efficiency

Anatomy Posttest

feature recognition
(learning measure)
Virtual Objects

Training (5 min)
- anatomy of bone
- 2-page paper booklet
- 5 anatomical features

Practice (3 min)
- interface practice
- review anatomy on 3D computer model
Virtual Objects

Object Manipulation (orientation matching)

Orientation References vs. Control

Start ➔ Target
Virtual Objects

When interacting with virtual objects, learners are frequently disoriented.

Do orientation references reduce disorientation?
Do they improve learning?
How do these factors interact with a learner’s spatial ability?

Stull, Hegarty, & Mayer, 2009
Virtual Objects

- Design: Between subjects
  - Orientation References (38) vs. Control (37)
  - High Spatial (36) vs. Low Spatial (39)

- Measures:
  - **Object Manipulation**:
    - error (deg) – success
    - directness (deg x sec) – efficiency
  - **Anatomy Posttest**:
    - feature recognition (prop correct)

- Groups did not differ on spatial ability or organic chemistry experience.
Virtual Objects

Manual: error (deg)

Participants who used ORs were more accurate.  
\[ F(1, 71) = 7.62, p = .01^*, d = 0.63 \]

Spatial ability significantly predicted accuracy.  
\[ F(1,71) = 5.32, p = .02^*, d = 0.46 \]

lower is better
Virtual Objects

Manual: directness (deg x sec)

Participants who used ORs were more direct.
\[ F(1, 71) = 20.02, p < .001^*, d = 0.86 \]

Spatial ability significantly predicted directness.
\[ F(1, 71) = 24.50, p < .001^*, d = 0.79 \]

lower is better
Virtual Objects

Learning: feature recognition (prop correct)

High spatial Ps learned well with or without ORs.

\[ OR \times SA: F(1,71) = 5.92, p = .02^* \]

Low spatial Ps who used ORs learned more with than without ORs.

\[ F(1,71) = 6.27, p = .02^*, d = 0.76 \]

higher is better
Virtual Objects

The shape of the object may hurt performance

Are learners making a symmetry error?

Example of a symmetry error (error >120°)
Virtual Objects

Manual: Symmetry Errors

- Symmetry errors were significantly more common for the control group (74% of errors >120° are symmetry errors).
  \[ F(1,73) = 7.16, \ p < .01^* \]

- ORs may have helped to disambiguate the shape of the object.

- All trials for all Ps are represented.
Virtual Objects

Same/Different decision:

- 2 images can be the same (0°) or vary by 30°, 60°, or 180°
- 80 trials (20 orient. x 4 angles)
- 0°/180° is the key comparison
- Record eye gaze information
- Record accuracy of decision
Virtual Objects

Accurate (10 best Ps) vs. Inaccurate (10 worst Ps)
Error and eye fixation by angle of disparity.
Virtual Objects

Summary

• Some people are easily disoriented with virtual objects.
• Strong visual cues (ORs) reduce disorientation when manipulating virtual objects.
  • Stereo depth cues are also helpful
• High spatial Ps do well with or without visual cues
• Learning interacts with spatial ability.
  • Low spatial learners are particularly helped by ORs
Interacting with Virtual Objects

When working with computers, including virtual reality, our primary interface (hand) is filtered by a secondary interface.

How does this physical “filter” of the interface affect user performance?

What are the important cognitive and perceptual factors?
Physical and Virtual Objects

Chemical models

- VR system designed to match the physical experience
  - Stereo glasses
  - Co-located interface

- Interface allows for important interactions
  - Object rotation
  - Bond rotation

The virtual model image and the interface were co-located
Physical and Virtual Objects

• **Current:**
  – Comparing use of VR models to Physical models
    • May be seeing a facilitation from using VR
    • Constrained interaction

• **Future:**
  – Evaluate
    • Co-location of the interface and image
    • Stereo depth cues
    • Size and shape of the interface
    • Types of interaction
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