Mental model training wheels: Scaffolding mental imagery with partial sensory support

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Abstract: Inspired by blindfold chess, laparoscopic surgery and field-stripping of rifles, this study investigated whether partial sensory support can scaffold mental imagery. Will interacting with skeletal 3D virtual shapes without key identifying marks, stimulate people to imagine key portions? This study hypothesized that participants who first trained with such skeletal shapes would perform differently and better on a post-test. The study used an online game, CopyCat, involving rotating and stamping a 3D cube on a 2D pattern. Half the participants encountered occasional “blanking levels”, where the cube turned white on all six sides at the first rotation, thereby eliminating any visual feedback on sequences of rotations. Preliminary results indicate undergraduate women benefited more from the blanking than did their male counterparts.

Introduction

The current study investigated whether partial sensory support can scaffold mental imagery. Will interacting with skeletal versions of three-dimensional virtual shapes, with the key identifying marks removed, stimulate people to imagine those key portions? Skeletal versions can provide as scaffolding, minimal shapes without colors or other identifying marks which would otherwise verify the orientation of shapes as students turned them. This study hypothesized that participants who first trained with such skeletal shapes would perform differently and perhaps better on a post-test, i.e., they would use mental imagery more, plan more and find more parsimonious solutions. Working with partial visual information may help people: a) memorize the shape and then visualize the memorized object, b) cultivate a more patient mind-set for "spatial planning", as opposed to an impulsive "click-first and explore" mind-set.

With virtual shapes, students can be provided with more or less sensory information at different times. Organic chemistry could be used to illustrate the concept. If students first familiarize themselves with the shapes of molecules by interacting with computer models that show complete information, perhaps they will later better learn to mentally visualize the molecules by working with “skeletal” models with the key information removed – sort of mental model training wheels.

Investigating pedagogies for teaching and learning complex spatial skills is very important because:

a) Spatial skills are vital to a variety of educational and vocation fields such as mathematics, the sciences and engineering.

b) Women often do less well in spatial tasks (Scali, Brownlow, Hicks, 2000). This is a potential blocking point for entering the sciences and engineering. Any new information that will help them learn these skills is valuable.
   The research may point to a pedagogy of spatial skills which will help people learn material with high spatial content in a variety of fields.

Background

This research is inspired by several phenomena of blindfold chess (Saariluoma, 2001), laparoscopic surgery and the field-stripping of rifles.

Chess experts first spend countless hours visualizing chess combinations over the board before attempting to visualize an entire chess position "blindfolded." A chess board is a scaffolding for visualizing entire chess positions. As a player decides on a move, they often imagine the position several moves in advance. They do not have to represent with mental imagery all the pieces of the position, only those pieces which would be moved from their current positions.

Laparoscopic surgery is a minimally invasive technique by which doctors operate through a small hole in the abdomen wall while looking at a two-dimensional television image produced by a miniature video camera. Surgeons claim that laparoscopic surgery requires additional planning and spatial skill because of the limited visual information. The two-dimensional visual image can be thought of a scaffolding for visualizing the three-dimensional situation.

In the military, soldiers are often required to field-strip and reassemble their rifles blind-folded. The motivation is that they may be required to do similar manipulations under harsh night-time combat conditions. Such blindfold training also presumably helps soldiers build a mental model of the mechanical workings of the rifle. Blindfold field-stripping of a rifle is a scaffolding for mentally visualizing the parts of a rifle. Tactile sensory information is provided, but not visual. The soldier substitutes a mental model for visual feedback. Blindfold field-stripping is an intermediary step between: a) assembling a rifle with eyes open, and b) field stripping a rifle entirely in one's mind's eye.

Blindfold chess, laparoscopic surgery and blindfold field stripping are "real-world" examples of partial sensory support for scaffolding of mental imagery. The goal of this research was to empirically investigate the effectiveness of this sort of scaffolding that has evolved in the everyday world.

Method

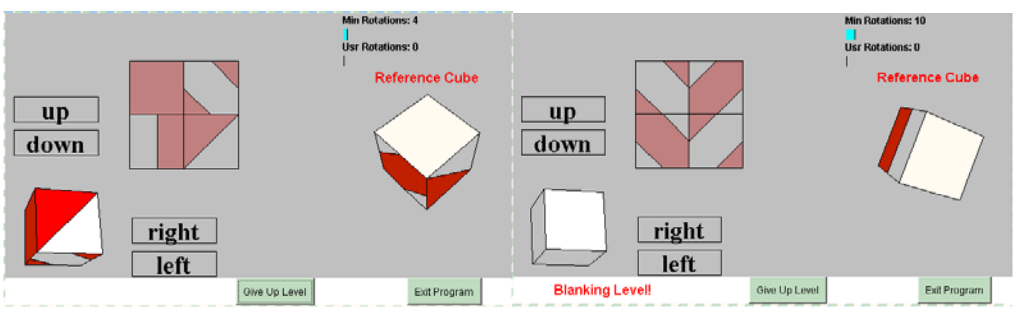
In order to investigate some of these ideas, we modified an online Java-based interactive mathematical game called CopyCat, which is based on group theory. The original version of CopyCat was developed by Jim Morey, a doctoral student at the University of Western Ontario in Canada. CopyCat revolves around replicating a picture created by several patterned faces of a cube. See Figure 1a. Using the up, down, left and right buttons, the player can rotate the cube on the left until the upper face of the cube matches a pattern on the flat tile. At which point, the player clicks on that tile of the target pattern. If there is a match, the patterned face is dropped in the appropriate position on pattern and the colors of that tile brighten to indicate a match. In Figure 1a, the upper face of the cube matches the pattern on the lower right tile and could deposited there by clicking on the lower right tile.

To help the player become familiar with the cube, there is a rotating copy to the right known as the reference cube. As well as observing it, the player may also click and drag the reference cube to rotate it.

The game is not as easy as it seems because it often requires a combination of two different directions of rotation to match the pattern on a tile.

For the study, we created a modified version of the game, with some "blanking levels", the cube turned white on all six sides at the first rotation, thereby eliminating any visual feedback when doing a sequence of rotations. See Figure 1b. Only when the player clicked on the target tile would the cube replay the sequence of rotations with full visual feedback showing the patterns on the cube as it rotated. The idea was that the player would have to plan, imagine and keep track of the cube as it was rotated. The replaying of the sequence of rotations provided feedback.

In a two session experiment, half of the participants played the game in its original form, half with occasional "blanking levels." Participants were college undergraduate students, participating voluntarily. Each group participated in two separate sessions, one week apart. Each session had a total of eight unique levels. A legend was observable on the screen during the game, which showed the minimum number of rotations possible to solve the puzzle as well as each student's rotations on that puzzle.



Figures 1a and 1b: The CopyCat game in normal and in blanking modes.

Both groups had exactly the same puzzles, the only difference being one group had occasional "blanking levels". However no "blanking levels" were used in the last four levels the second session, which were considered to be a post-test comparing the two groups. The last four levels of session two (post-test) were considered to be a test of "near transfer" and as such they had a slightly different task. See figure 2. The four post-test levels had only two rotations buttons, up and down, instead of up, down, left and right. This required longer sequences of rotations. Secondly the upper face of the cube did not just drop "as is" on the target tile. It stamped in the more realistic manner of a hand-held stamp. In other words, it requires a *reflection* to match. In Figure 2, the upper face of the cube matches the pattern on the lower left tile and could deposited there by clicking on the lower left tile. Note that the upper face of the cube and the lower left tile are reflections of each other.

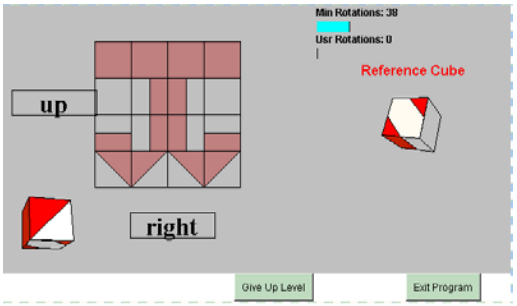


Figure 2: The post-test of near transfer.

As student played the game a variety of data was sent directly back to a database on a server where it was easily retrieved for statistical analysis.

Preliminary results

As of this writing, the experiment has been conducted with roughly half the number of subjects needed to properly investigate the research questions. So far there are 50 participants with 26 men and 24 women. Since men often perform better on spatial tasks and since it appears that women and men react quite differently to the CopyCat task, men and women should be considered distinct populations. With two treatment groups and two separate populations, at least 80 participants (20 in each group) are needed to realistically evaluate the hypotheses. That being said, preliminary results indicate that undergraduate women who did spatial exercises with less visual information solved post-test spatial puzzles more parsimoniously (than other women who did spatial exercises with full visual information). This difference was not quite statistically significant.

The opposite was true for men. The blanking group did worse on the post-test. Again this was not quite significant.

During the coming months, we plan to run more subjects. Secondly we plan to develop a different post-test which tests far transfer and perhaps more accurately measures the differences in the effects of the true training situations.

References

Saariluoma, P. (2001). Chess and content-oriented psychology of thinking. Psicológica, 22, 143-164.

Scali, M., Brownlow, S. & Hicks, J. (2000). Gender differences in spatial task performance as a function of speed or accuracy orientation, Sex Roles, 43(5/6), 359-76.