**Teaching Geoscience with Visualizations:**
**Using Images, Animations, and Models Effectively**
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# My Interests and Research in Scientific Visualizations

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I am a geographer and psychologist, with research interests in many aspects of spatial and geographic perception, cognition, and behavior. My particular interest is in space and place at scales larger than the human body, including both built and natural spaces such as buildings, campuses, parks, cities, wilderness areas, states, countries, and the globe. These spaces include features and landscapes of direct interest to earth scientists, including physical geographers, geologists, oceanographers, climatologists, and ecologists. I am interested in knowledge acquisition, reasoning, problem solving, and communication via a variety of modalities, including direct sensorimotor apprehension, maps and other graphics, language, and virtual representations. Thus, while my major interest is in the psychology of (near) earth surface space, I am interested in the space of pictures and objects because they are a common means by which people interact with information about larger spaces—sometimes the only way.

I believe that many of my research activities over the past two decades have at least an indirect relevance to the study, creation, and use of scientific visualizations. In particular, I have collaborated on various research projects, and written several reviews of research, that have examined perceptual and cognitive aspects of cartographic and virtual information displays, including their role in information acquisition and knowledge development, and their similarities and differences from other modes of knowledge acquisition such as direct sensorimotor experience in the environment (Montello, 1998, 2002; Montello et al., 1994, 2004; Montello & Freundschuh, 1995; Pick et al., 1995; Slocum et al., 2001). Two ongoing lines of research are directly relevant to scientific visualization.

First is research being conducted with primary collaborators Drs. Sara Fabrikant and David Mark. This project investigates how users of information spatializations interpret spatial and nonspatial graphical variables as representing similarity relationships among documents represented in the display. "Information spatializations" are computer visualizations in which nonspatial information is depicted spatially. For example, a "point-display spatialization" depicts documents (or other information-bearing entities) as collections (clouds) of points in 2- or 3-dimensional space. Common examples include point displays, network displays, region displays, natural land surfaces, urban land surfaces, and more (http://www.kartoo.com, http://www.touchgraph.com, see Links at http://www.geog.ucsb.edu/~sara/html/research/spacecast/spacecast.html). Spatializations of large databases commonly use distance as a metaphor to depict semantic (nonspatial) similarities among data items. We call this the *Distance-Similarity Metaphor*.

Our results so far show that this metaphor operates differently depending on the type of graphical metaphor (e.g., points vs. regions) and whether nonspatial visual variables (such as color hue or value) are manipulated. For example, straight-line distance in point displays is equated quantitatively with similarity when the display is a fairly homogeneous field of points (Montello et al., 2003). In heterogeneous fields in which points are more aggregated, people perceive emergent linear or cluster features that induce judgments of greater similarity for documents within a common emergent feature. In network displays, similarity is spontaneously judged as equivalent to metric distance along network links, not to straight-line distance across the links or to nonmetric distance, such as node counts (Fabrikant et al., in preparation). Link hue, value, and width all moderate this relationship, however. For example, homogeneously hued links are seen to connect more similar documents than are heterogeneously hued links. We also have data on region displays. Currently, we are designing studies of 3-D dynamic and interactive displays (such as “clouds of points”).

As part of this research project, we have recently begun to investigate the use of spatializations that appear more like natural or urban landscape surfaces. In our first study, we had participants view what appeared to be a hilly or mountainous landscape surface surrounded by water. Half the participants were told they were looking at a landscape surface; the other half were told they were looking at an information visualization designed to appear like a landscape. Qualitative responses to these displays suggest some interesting things about how lay people interpret geomorphologic surfaces (“common-sense geomorphology”) and about how they interpret such surfaces to represent information about the semantic content and similarity of documents. A specific example: The role of denudation is rarely considered by lay people to play as important a role as it does in “creating” what appear to be mountainous surfaces, such as those found in many mature plateau areas around the world. An urban version of this study is under way.

A second line of research in which I am involved, and that is relevant to scientific visualization, involves the use of visualizations in medical education, including both laparoscopic surgery and dentistry. My collaborators on this research are Drs. Mary Hegarty, Madeleine Keehner, and Frank Tendick. As part of its interest in medical informatics, the medical establishment is increasingly turning to computer-supported interactive visualizations (virtual technology) for training purposes. But there have been few systematic studies of how people interact with and learn from 3-D computer visualizations. Initial studies in the medical domain, including some of our own, suggest that rather than augmenting cognition for all learners, 3-D interactive models may actually be disadvantageous to some individuals.

Our overall goal in this research is to explore issues relating to the use of 3-D computer visualizations in teaching anatomy. Our research has three main objectives. The first is to explore the correlation between spatial ability and anatomy learning. In the initial phase of our research, we have examined how this correlation is modulated by the use of interactive computer visualizations. The second objective is to test the effectiveness of different aspects of computer visualizations for learning anatomy. Here we plan to manipulate variables relating to the computer visualization itself, such as depth cues (monoscopic vs. stereoscopic), interactivity (active vs. passive control), and haptic cues (a hand held manipulation device vs. a traditional interface), to see whether they affect learning. The third objective is to apply our findings to medical education by developing and testing training methodologies that incorporate the types of simulations that we show to be most effective.

While computer visualizations are often conceived as having the potential to enhance or support cognition, it is not known whether these hypothesized benefits are equal for all learners, or whether they differ for individuals with varying levels of spatial ability. Interactive computer visualizations might "augment" cognition equally for high-spatial and low-spatial individuals, or they might act as a type of "prosthetic" for those with poor internal visualization ability, so that interacting with them improves the performance of low-spatial learners more than that of high-spatial learners. Alternatively, however, it is possible that some minimum level of spatial ability is a necessary prerequisite for learning from these types of representations, that is, effective *internal* representations are needed to support the comprehension of *external* visual representations. If spatial ability proves to mediate the comprehension of 3-D computer visualizations in critical ways, understanding this mediation and exploring potential ways of supporting low-spatial learners or classes of learners will be important.

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