

Chapter I

Individual Differences Among Users: Implications for the Design of 3D Medical Visualizations

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ABSTRACT

This chapter examines human factors associated with using interactive three-dimensional (3D) visualizations. Virtual representations of anatomical structure and function, often with sophisticated user control capabilities, are growing in popularity in medicine for education, training, and simulation. This chapter reviews the cognitive science literature and introduces issues such as theoretical ideas related to using interactive visualizations, different types and levels of interactivity, effects of different kinds of control interfaces, and potential cognitive benefits of these tools. The authors raise the question of whether all individuals are equally capable of using 3D visualizations effectively, focusing particularly on two variables: (1) individual differences in spatial abilities, and (2) individual differences in interactive behavior. The chapter draws together findings from the authors' own studies and from the wider literature, exploring recent insights into how individual differences among users can impact the effectiveness of different types of external visualizations for different kinds of tasks. The chapter offers recommendations for design, such as providing transparent affordances to support users' meta-cognitive understanding, and employing personalization to complement the capabilities of different individuals. Finally, the authors suggest future directions and approaches for research, including the use of methodology such as needs analysis and contextual enquiry to better understand the cognitive processes and capacities of different kinds of users.

INTRODUCTION

The study of anatomy is a core component of medical training. With developments in computer graphics, interactive three-dimensional (3D) visualizations of anatomical structure and function are becoming increasingly prevalent in medicine for education, training, and simulation purposes. This chapter examines human factors relating to the use of these tools. We examine individual differences among users, discuss how these may impact the usefulness of medical visualizations, and suggest some implications for the design of these tools. We focus particularly on two variables that differ among individuals and that are especially relevant to using interactive 3D visualizations effectively. These are: 1) individual differences in spatial abilities, which affect a user's internal representation of the information presented; and 2) individual differences in interactive behavior, which affect how the user manipulates and interacts with the external visualization. We draw together findings on these issues from our own studies and from the wider literature, in order to make recommendations for design and suggest future directions and approaches for research on this topic.

BACKGROUND

The study of anatomical structure and function is a fundamental part of medical training. At some level, the goal of anatomy education is to provide students with high quality spatial mental models of human anatomy that they can use in medical practice. Resources such as diagrams, bench-top models, and cadaver dissection laboratories have long been used to provide students with an understanding of the 3D relationships among different anatomical structures. But compared with today's technologies, these traditional learning materials have a number of limitations. Printed diagrams are unavoidably restricted to two dimensions,

generally entail only cardinal views, and bear little resemblance to real anatomy. Bench-top models are often useable only once as they are of little value once they have been "dissected." Cadavers, although the most naturalistic of these materials, are rare commodities, whose use in medical schools is becoming increasingly restricted due to the expense of maintaining dissection laboratories. For teaching purposes, they also have the drawbacks of being opaque, restricting the learner's view of internal structures, and of being idiosyncratic, making standardization difficult.

With developments in medical informatics (Collen, 1995; De Dombal, 1996, van Bommel & Musen, 1997), the medical establishment has begun to explore 3D visualizations as potential alternatives to traditional learning resources. Unlike physical teaching materials, computer visualizations are flexible, permitting designers and users to alter parameters such as anatomical variability, disease-state, or viewpoint perspective. They can also be easily reused with little cost and can be widely disseminated, allowing access outside the traditional constraints of the classroom. As a result, medical education has begun a dramatic shift towards introducing digital representations into its learning programs.

Medical educators are enthusiastically embracing the potential of these resources. The Association of American Medical Colleges (AAMC) foresees a future in which these tools play a central role in teaching, learning, evaluation, continuing education and certification within medicine and the allied health professions. They advocate the development of new core digital resources such as virtual patients, simulations, 2D and 3D images, and interactive cases, and recommend that these become an integral part of future medical education programs (Florance & Masys, 2002; Florance & Moller, 2002). Optimism about the educational potential of new technology is not limited to the medical domain. Researchers in the cognitive and learning sciences have seen visualizations as external aids that can "enhance"

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