Tangible User Interface for 3D Navigation of Human Anatomy

Introduction,Evaluation Plan and Prototype

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1 INTRODUCTION

Spatial cognition is associated with how humans encode spatial information, that is, information about the position, orientation, and movement of objects in the environment. It also involves how this information is perceived in memory and manipulated internally [7]. Spatial cognition is one of the core components of understanding medical images. Surgery, in particular, is heavily reliant on internal representations and transformations of spatial information. The surgeon must develop a mental model of internal three-dimensional anatomy based on medical images, essentially two-dimensional slices of three-dimensional objects [4]. Efficient performance of surgical tasks involves a wide range of spatial processes to plan and navigate (i.e., recognizing landmarks provided by distinctive structures and avoiding sensitive tissues such as large blood vessels). Although spatial cognition is a fundamental component of medical study, researchers have found that medical students frequently have an inadequate spatial understanding of three-dimensional (3D) anatomy [1]. Research has suggested that the deficiency of anatomical knowledge results in errors during surgeries[3].

The primary reason for the decline in anatomical knowledge is traditional study methods in learning anatomy. Numerous websites are dedicated to anatomy images, lectures, oral presentations, and cadaveric dissection used to learn anatomy. For learning anatomy, cadaver dissection is widely recommended by experts [5]. Cadaverics are, however, in short supply and costly to obtain and maintain. Additionally, lectures and oral presentations help gain a theoretical understanding of the subject matter, but visualization element is required to grasp the spatial information better. The commonly used visual element is the 2D images found in the anatomy book and the internet. Students have difficulty mentally rotating static, 2D illustrations. Moreover, in the anatomy textbooks, the pictures differ from the natural anatomical structures because pictures in the book have unusual angles [4].Therefore, it is necessary to introduce different study methods to learn/teach anatomy. For example, computer assisted study, as a vast majority of research outcomes favor computer-assisted technology for learning anatomy[4].

Research has shown that tangible interfaces can benefit non-expert users to learn and make 3D navigation easier [2]. More research has been conducted to determine how Tangible User Interfaces affect spatial cognition (TUIs). According to research, a TUI helps students learn more efficiently in a variety of situations[6] (e.g., anesthesia). We propose an interactive tabletop tangible interface for 3D navigation of the human body. We believe that our proposed system can help students visualize human anatomy better than existing 2D images. Furthermore, we firmly believe that better

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visualization will help better understand the subject matter.Our study intends to see whether TUIs have an impact on medical students' learning of spatial cognition of the human body. Our research will focus on the domain of human anatomy.

2 METHODOLOGY

Our research intends to create a tabletop tangible interface for 3D human body navigation, allowing students to learn about human's internal body components through physical interaction with the interface. The results showed if students can understand the subject matter that they learned from the interface. The target user group of our study is the first-year medical college students in anatomy class. We aim to answer our research question and justify our claim by conducting experimental studies on students. The experimental studies evaluated the student's understanding of the subject matter by using the traditional method and the proposed TUI model. To evaluate this, we divided our experiment into two phases where we divided two groups of students where one group used the traditional model and the other used the proposed model, and finally, we conducted a cognitive test and written test on all the students to evaluate our research question. In the subsequent sections, we will delve into the participants, materials, design, and procedure of our evaluation plan.

2.1 Participants

Our target users for this experiment are first-year medical students attending Baylor College of Medicine. We performed our experiment in an anatomy class where there was a total of forty students. All of the students were first-year medical students taking anatomy classes at their medical school.

2.2 Materials

We developed an interactive visualization screen in a table structure that includes a tangible interface for 3D navigation of the human body. On a custom-built table, we used a 55-inch MultiTactionTM Cell positioned horizontally like a tabletop. A physical ring-shaped magnifying spectacle was used here to navigate the tabletop interface. Individuals could see through the invisible fiducial and glass because an infrared-reflective fiducial marker was inserted in the glass of the ring. When a student placed the tangible ring in a certain body portion of the tabletop surface, the internal body organs could be seen through the magnifying ring. Students were able to effortlessly move the ring from one location to another, simulating the human body organs and their connections.

2.3 Design

This study utilized a between-subject design in which we divided the students into two groups where each group contained twenty students. We exclusively focused on the human heart segment and its related arteries for the experimental study. One group learned their subject matter by using the traditional 2D image of the human heart and vessels whereas the other group interacted with our proposed prototype with tangible interfaces for 3D navigation of the human heart with related arteries. After interacting with traditional and proposed model we conducted a post-experiment evaluation by asking the participants to identify the components (vessel) from a sketch map of the environment(human heart). The complete timeframe of our experiment was estimated to be 30 minutes long, with 20 minutes allocated for variable interaction and 10 minutes for post-experimental evaluation. In addition, to find out whether TUIs have an impact on the spatial cognition of medical students, we conducted a cognitive test one day after the evaluation where both groups participated in the same test. The test consisted of short questions and multiple-choice questions from the theory of heart that they learned previously from both the 2d image and our proposed TUI which was a total of 15 minutes long.

The independent variable of our study is the proposed tabletop tangible interfaces for 3D navigation of the human body and the traditional 2d image of the human body. One student group used the traditional 2d image for understanding the concept and component of the human internal body part and the other group used the tabletop tangible interface that uses a physical lens to observe the human internal body part through a tangible magnifying ring. Understanding the spatial cognition of human anatomy is the dependent variable in this experiment.

2.4 Procedure

The procedure was carried out in an anatomy class at Baylor college of medicine in Houston, Texas. The study was divided into two parts: first, the individual group used their assigned variables where one group used 2D images and the other used our proposed TUI where after the experiment the students participated in a post-experiment evaluation. Finally, after 24 hours, we conducted a test consisting of short questions and multiple-choice questions, participated by all forty students.

2.4.1 Phase 1. After assigning two groups of students, we asked the students to utilize their model for learning about human internal body organs specifically the portion of heart and it's related vessels and positions. One group used the traditional 2D image for learning and another group used our proposed tangible interfaces where based on the 3d navigation of the human body, students learned about the subject matters. After interacting with model, we arranged a post-experimental evaluation test. Several studies in cognitive psychology research are used in experiments to assess a person's spatial abilities in general—for example, navigation of an environment (i.e., as in the sketch map study)[6]. We asked all the students to identify the components (vessel) from a sketch map of the environment(human heart). The test was graded on a point scale. Zero was the perfect score. An additional one point is added to the score every time participants fail to identify the vessels. The results guided us in evaluating comparisons between the overall spatial cognition of the human heart.

2.4.2 Phase 2. After 24 hours, we conducted a test in the same anatomy class consisting of all forty students. The purpose of this test was to assess abstract knowledge gained from the previous day of training. The test consisted of five short answers and five multiple-choice questions from the theory of human anatomy that they have learned from the previous investigation of their individual model. We graded the questions based on the correct answers. This grade was also used to assess students' spatial knowledge of the human heart.

3 PROTOTYPE

We have developed a pen and paper based prototype of our proposed model shown in figure1. Here,We used an interactive visualization screen in a table structure to construct our prototype of a tabletop tangible interface for 3D navigation of the human body. The 55-inch MultiTactionTM Cell is positioned horizontally like a tabletop on a custom-built table. This interactive graphic depicts the human body structure as well as the internal anatomy of the human body. The human body is seen as a collection of internal body components, including the connections between bodily organs. Students can look into various areas of the body and observe the internal organs of that section using a tangible device. The physical item to observe the organs inside the human body is shaped like a ring. The ring represents the properties of magnifying spectacles. An infrared-reflective fiducial marker was embedded in the glass of the ring so that individuals could see through the invisible fiducial and glass shown in figure2. Students can move the ring from one location to another and pause it to examine the human body's internal organs. Students will be able to observe a 3D image of human inside body organs for each body part with the help of this ring.

Fig. 1. Tabletop tangible interface for 3D navigation of the human body

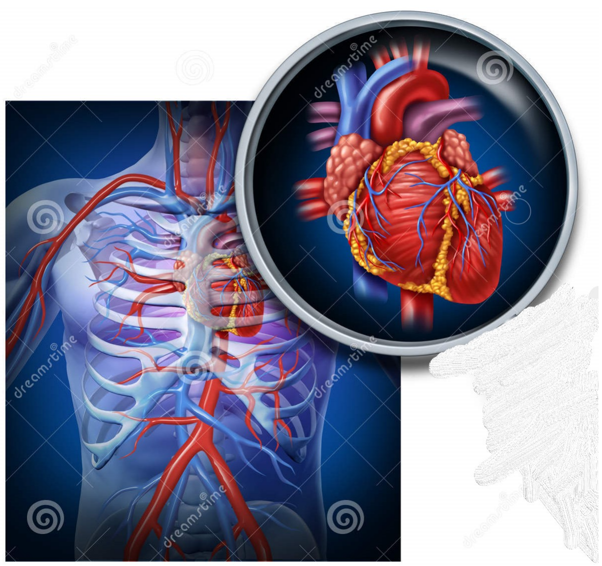

Fig. 2. Tangible ring shaped magnifying spectacles that help to visualize the D representation of human internal body parts.

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