

## The Brachial Plexus: Development and Assessment of a Computer Based Learning Tool

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**Abstract** - The objective of the present study is to evaluate the use of multimedia technology to simplify study of the brachial plexus. A combination of newly-rendered illustrations, animations, explanatory text, and a set of printable sample questions were combined into a program to provide a tutorial for the brachial plexus. One aspect of the program is an animation showing the development of the brachial plexus from its developmental origins that illustrates limb rotation and the resulting adult anatomy and dermatomal arrangement. The cross-platform program requires Quicktime 3.0 and is packaged on CD-ROM. Student evaluation of the program highlights its ease of use and intuitive navigation. User evaluation provides validation that the use of illustrations and animations is beneficial to user's understanding and retention of the material. Future plans involve incorporation of pathologic images in order to enhance the clinical relevance of the product.

**Keywords:** computer program, anatomy, development, embryology, animation, CD-ROM

### Introduction

Anatomy laboratories across the country are faced with continually increasing pressures. These pressures include ever-larger numbers of students needing a gross anatomy laboratory experience and a decreasing number of faculty qualified to teach human gross anatomy, the latter primarily being a result of life science PhD recipients being routed into careers in bench research<sup>1</sup> (National Research Council, 1998). In 1995 the 141 U.S. medical schools enrolled 18,090 allopathic and osteopathic students.<sup>2</sup> The total population of health-science professional students is even higher when factoring in all other first year health professions students across the country that are required to take human anatomy (ie. nursing, physical therapy, occupational therapy, dentistry, pharmacy, etc.).

The numbers of faculty who are qualified to teach gross anatomy at the professional level are proportionally shrinking every year when considering the ever increasing ratio of research oriented Ph.D.'s awarded and available academic positions to the steadily increasing number of students.<sup>1</sup> The problem involving the lack of anatomy instructors is exacerbated by the fact that most life science Ph.D. recipients, including those from anatomy departments, can spend up to an average of five years in postdoctoral positions learning research techniques while

their instructional expertise and interests slowly fade.<sup>1</sup> Thus there is a need for an alternative to the traditional gross anatomy experience.

One approach towards solving the problem may be to use new technologies combined with using the relationships between basic science courses in order to integrate, consolidate, and simplify difficult areas in courses. Technologically enhanced course integration may be able to increase the overall efficiency of basic science knowledge transfer and increase the quality of the limited contact time between student and instructor by illustrating many difficult concepts in advance. Using developmental anatomy as a basis for learning adult anatomy may be an appropriate place to apply technology in order to efficiently integrate the subjects. Many schools across the country already incorporate development into the gross anatomy course, but it is still treated as a separate entity. Traditionally difficult topics in both subjects, such as the nervous system, have a natural relationship which, when studied together, illustrate a continuity that is otherwise unachievable. The melding of the two topics, anatomy and development, could be accomplished by incorporation of multimedia instructional programs into the curriculum. Such programs could lessen the demands on overburdened laboratories by allowing for more independent learning in both areas.

The purpose of the present study is to determine the efficacy of an adult and developmental anatomy multimedia CD-ROM. The goals of the program being evaluated were to: 1) render difficult topics in an animated two-dimensional form, 2) ease the burden on overcrowded and overused anatomy labs, and 3) make use of the beneficial aspects of computers which have been shown to increase the ability of students to learn, comprehend and retain information.<sup>3,4,5</sup> An interactive, multimedia CD-ROM with a self-examination element was developed for use by health professions students at the University of Kentucky. A voluntary student survey was used to assess satisfaction and the overall effectiveness of the product.

### Development and Design

The primary goal was to augment current gross anatomy and development lectures and laboratories dealing with the brachial plexus. Newly-rendered, two-dimensional illustrations of the motor and cutaneous innervation patterns of the terminal branches of the brachial plexus, combined with a Quicktime<sup>®</sup> animation showing the derivation of the adult dermatomes are packaged on a CD-ROM. The self-contained nature of the current brachial plexus module makes it easily accessible to computer users regardless of Internet accessibility.

Instructional designers and medical illustrators from the University of Kentucky's Chandler Medical Center department of Medical Arts and Photography provided design guidance, programming expertise, and professional medical illustrations. The animation, also developed by Medical Arts and Photography, was created using Macromedia Director<sup>®</sup> software. Additionally, colleagues in the Department of Anatomy and Neurobiology provided valuable insight and advice. Overall project supervision and direction as well as all content was provided by the author.

Important considerations for the design of this project included; 1) ease of navigation, 2) efficient and realistic testing element, 3) logical and organized arrangement of information, and perhaps most important 4) the use of new technologies must have some benefit over the existing system for teaching the morphology and formation of the brachial plexus. A further benefit of the current program is that it seeks to enhance the educational process while developing student's basic computer and information retrieval skills.

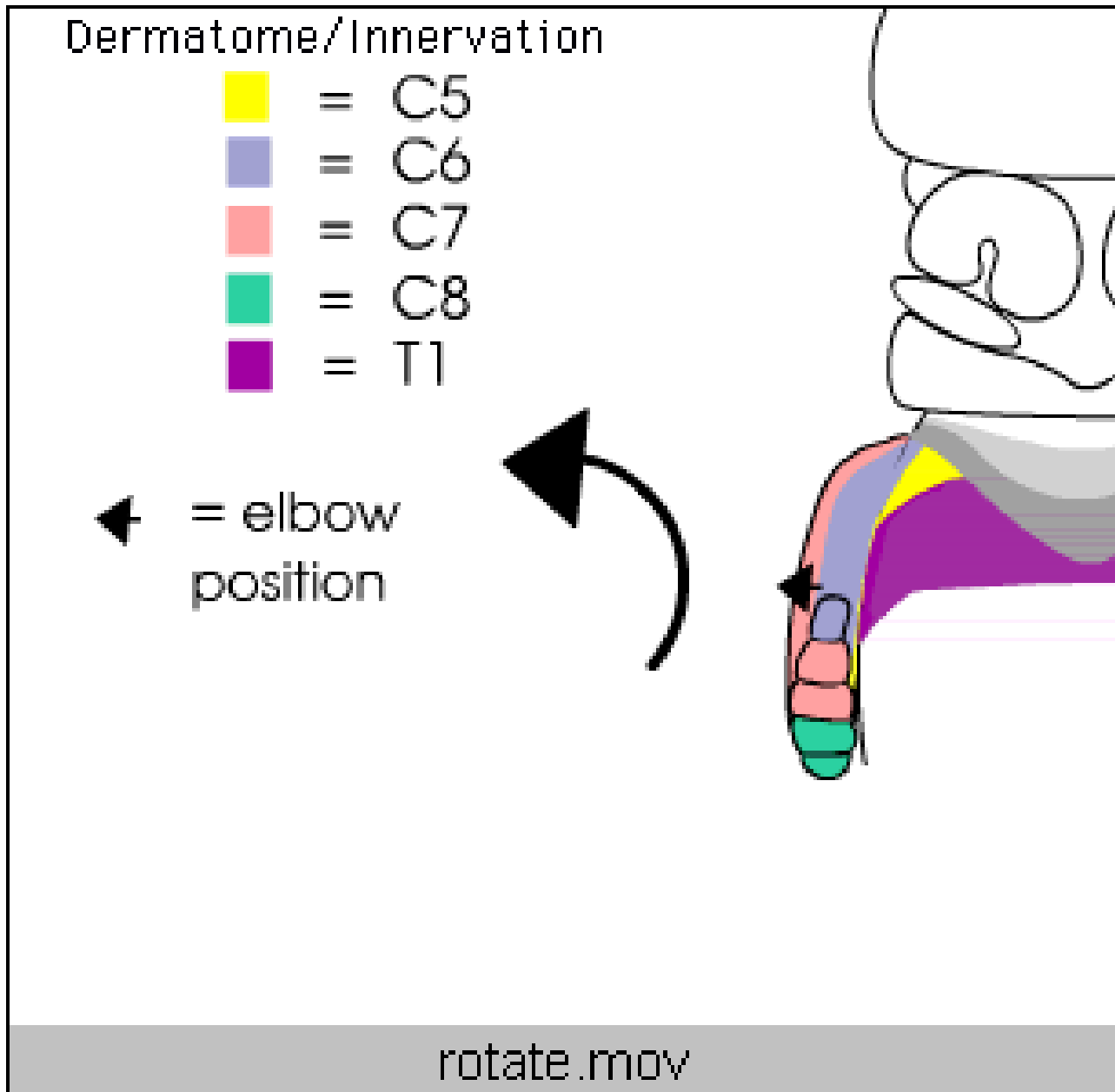
**Ease of Navigation** - It is necessary for any software program that may be used away from instructional support be easily navigable. The quantity and complexity of the material necessitated a logical interface and intuitive system of navigation to create a successful learning tool. Users should be able to proceed forward in a logical fashion, jump ahead to desired information, back up in a step-by-step way, or jump back to the area of interest. Navigation is made logical by having a semi-linear pathway for the user to follow. Possible navigation choices are indicated by *Rollover Hotspots*, which consist of text that becomes highlighted as the cursor is dragged over it.

**Printable Testing Element** - Self-evaluation is a valuable learning tool and is made possible in the current program in the form of a printable sample question bank. Thirty questions of varying degrees of difficulty and depth are presented on three printable pages of ten questions each. Answers are not provided in order to encourage the user to actively find the correct answer. In future versions of the program, a computerized testing element may be developed, which would allow for statistical analysis of the questions.

**Beneficial Use of Technology** - Beneficial use of technology means using technology to mimic what can be seen in an actual laboratory but also to present things that can not be presented any other way. In the present study animation is used to show developmental limb rotation. The adult relationships and dermatomal patterns are much easier to understand after you have witnessed their evolution from an early form.

A Quicktime 3.0<sup>®</sup> movie depicts a six-eight week old embryo with the dermatomes of the upper limb (C5-T1) color coded in a pre-rotational state (Figure 1). The seven-second animation shows the limb rotation that occurs during this time period as a result of forces generated by the developing elbow joint. Facial features of the embryo are also animated in order to provide a more realistic picture of the embryo at this time. In addition, a simple black arrowhead is used to designate the changing orientation of the elbow joint throughout the animation. The animation ends with the color coded dermatomes, elbow joint, and facial features of the embryo as they appear after the ninety-degree external limb rotation is complete.

Macromedia Director 7.0<sup>®</sup> was used to create novel illustrations that show the right upper limb outlined in a transparent form with the brachial plexus roots, trunks, divisions, and terminal branches



**Figure 1** Beginning image of animation showing developmental limb rotation. The colored key corresponds to dermatomes on the embryo. The black arrow indicates approximate orientation of limb position.

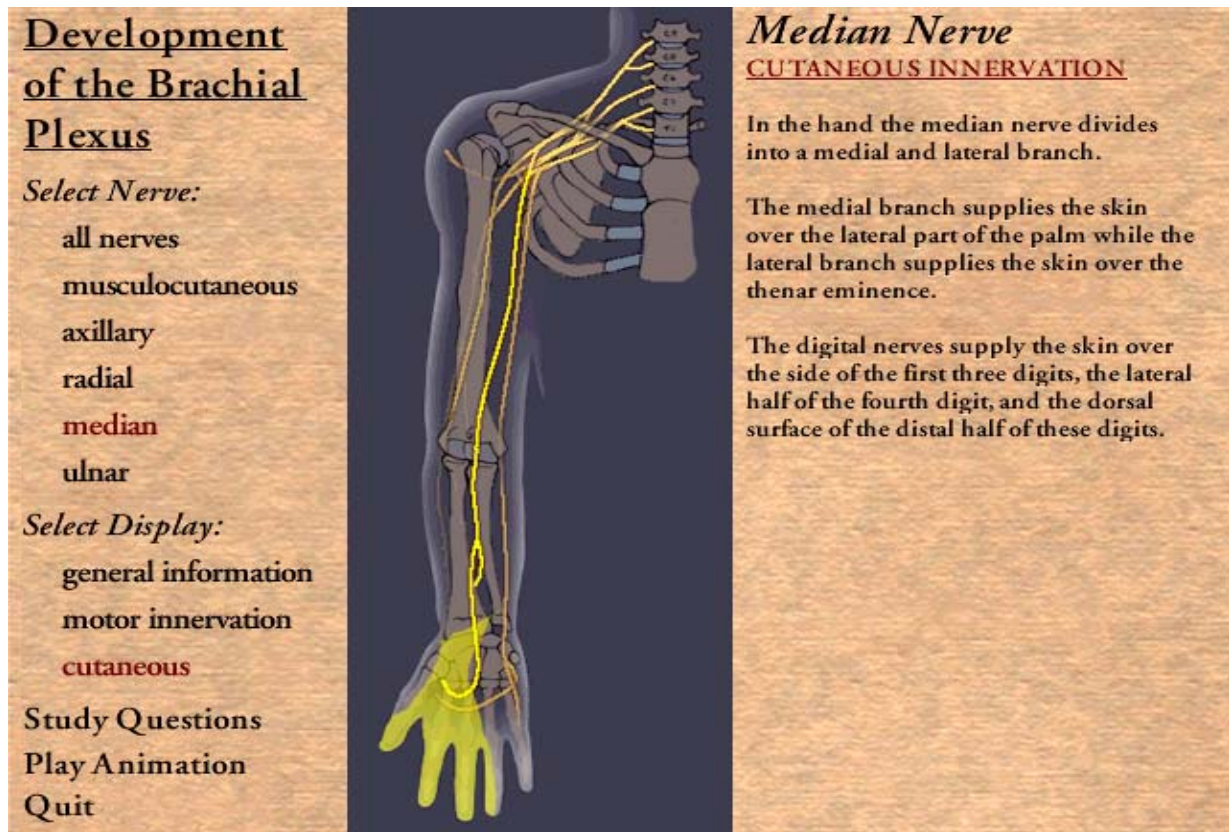
of the plexus drawn *in situ* (Figure 2). Each of the five terminal branches can be selected individually or all five can be displayed as a group. After a terminal branch is selected its course through the upper limb is highlighted and described. Information on its pattern of cutaneous or motor innervation can then be selected and is also described and highlighted in the illustration.

### Methods of Analysis

**Questionnaire** - A ten-item questionnaire was used to assess the effectiveness of the current program. Subjects (n=23) voluntarily agreed to anonymously use and evaluate the CD during the nervous system unit in their respective graduate level human gross anatomy course. The subject group was comprised of first year professional students from the

Physician Assistant & Physical Therapy program (n=12), Dental program (n=1), and Medicine (n=10).

as the current one developed/available for their use, and indicated a desire for the inclusion of more clinically relevant information. Some of the other, more



**Figure 2** Screen illustrating/describing the cutaneous pattern of innervation of the median nerve. Note the navigation choices available on the left side of the image.

Subjects were asked to evaluate the program by responding to questionnaire items using a scale from 1-5 (1=strongly disagree, 2=disagree, 3=no opinion, 4=agree, 5=strongly agree) (Table 1). In addition, written comments were invited regarding how users would change the CD if they could. The average scores of all 23 users are reported in Table 1.

**Written Comments** - Student users provided written feedback (n=17) in accordance with the following statement; what would you change about the CD if you could? The written feedback can be grouped and summarized into comments pertaining to the testing element and comments pertaining to the content. There were no written comments regarding the navigation and overall structural format of the program. The overall theme of the written comments regarded student desire to have more programs such

common, written comments are summarized as follows:

#### Testing Element Comments

- Provide the answers to items in the sample question bank
- Provide information as to why an answer is wrong if user answers it incorrectly

#### Content Comments

- Include arteries to show relationship to nerves
- More animations and more detail
- Use a wider variety of colors
- Make the illustrations printable

**Discussion**

The results of the presents study reveal that: 1) student users felt strongly that the text included in the

ferring to print text whenever possible. Therefore an attempt was made when writing the essential textual information in the current program to limit it to concise summaries in order to minimize the amount of

item #	question/comment	average rating
1	The CD was easily navigated and required no extra tutoring. The buttons and prompts did what you thought they should.	4.6
2	No help was necessary in order to get the CD started.	4.0
3	The animation was easy to activate, backup, or step through.	4.7
4	The animation and diagrams were helpful in illustrating the concepts.	4.2
5	This CD helped you to gain a deeper understanding of the Brachial Plexus and will aid in your retention of the material.	4.3
6	You would like to see more programs similar to this developed for use by students?	4.7
7	The text was helpful, clear, and informative.	4.7
8	I would pay for this CD is it were not provided free for my use.	2.7
9	The staff, hours, and location of the computer center were to my satisfaction.	4.3
10	Overall rating of the CD.	4.3

**Table 1 Student Survey**

Questionnaire, n=23 Scale from 1-5 (1=strongly disagree, 2=disagree, 3=no opinion, 4=agree, 5=strongly agree)

current program was helpful and informative, 2) animations of development aided students in learning and retaining information regarding the adult morphology of the brachial plexus, 3) users were pleased with the organization, ease of use, and intuitive navigation of the current program, and 4) students were unwilling to pay for the current version of the CD. Moreover, the results of the present study indicate the strong desire of students to have more programs similar to this one made available for their use. Written comments on student evaluations also indicate users liked the added convenience of having a high-quality, comprehensive learning tool such as the current CD available for use outside of the classroom and they recognize the benefits of using computers for their education.

Textual information is easily incorporated into multimedia products. However, computers users are not inclined to read text from a computer screen, pre-

non-interactive reading of material. Student users gave an average rating of a 4.7 regarding the level of helpfulness, clarity, and informative properties of the text (Table 1). Above all, text must be accurate, other important considerations included: organization, font size, brevity, and clarity.

Integration of the basic sciences is already a reality in many professional health curriculums across the country. At the University of Kentucky, first year medical gross anatomy and embryology have been combined into one course. Students felt using the animation (Figure 1) aided them in learning and retaining information regarding the adult morphology of the brachial plexus. Users gave this aspect of the current program an average rating of 4.2 (Table 1). Integration of the basic science courses provides a continuity and synthesis of knowledge that is unachievable when information is presented separately, often during separate semesters. Integration is not

only a historically sound idea for learning and retention of concepts but it also makes sense as time becomes increasingly scarce in curricula where the solution to many problems is simply to add courses and/or topics to the already demanding first year schedule.

Users were pleased with the organization, ease of use, and intuitive navigation of the current program. Several items on the survey were designed to assess these aspects of the current program (Table 1). Other questions were devoted to the technical and structural issues of the program. If there is a flaw in one of these elements the user will be less likely to use the program to its fullest potential or critically evaluate the content and other features of the CD. Individuals using the current program may often be places that have no technical assistance available, such as at home or in the library. Relatedly, the program should be easy to start; this aspect of the current project only received an average score of 4.0. Some computers students were using did not have Quicktime 3.0<sup>®</sup> installed on them. Subsequent versions of the program will have Quicktime 3.0<sup>®</sup> installation instructions included on the cover insert.

Students were unwilling to pay for the current version of the CD. The average user rating of this item, 2.7, was the lowest of any of the items on the survey (Table 1). It is believed that students, generally with limited financial resources, would be unwilling to pay for the current program because of the limited scope of this preliminary version. The item will be eliminated from future assessments, as the purpose of the current survey is to receive feedback regarding design and content, not to serve as a market analysis, which can be conducted more fully after a more complete version is developed.

Written comments from students emphasized the testing element of the current program. Students like the ability to print the 30-question test bank. Many comments indicated that users wanted the correct answers to the sample questions provided for them, indications/prompts on where in the program to look for information regarding answers, and information on why their incorrect answers were wrong. In addition, students indicated their desire for a more realistic testing element rather than a listing of sample questions. Most written anatomy exams are multiple choice exams and it is not hard to design such a testing element for inclusion in multimedia programs. Although, it is somewhat beyond the scope of for the preliminary version of the program, a timed multiple choice exam will be developed and included in future versions.

Additionally, written comments indicate that users desire incorporation of clinically relevant information into future versions of the program. Gross and developmental anatomy courses have taken on a progressively more clinical orientation at many institutions across the country. An updated version of the program is currently being created which incorporates clinical nerve lesion photographs of patients, with an accompanying description of the injury and the results of the injury.

Users gave an average rating of 4.3 in regards to the hours and location of the computer center (Table 1). Considerations for future versions of this and similar programs will need to include the accessibility of the program to users. User access to the program should be carefully planned, especially if the program is not intended for individual sale, such as the current one. Present considerations included class size, hours of availability, and equipment necessary to run the program.

Overall the program received an average rating of 4.3. Users felt that it was useful in helping them gain a deeper understanding of the brachial plexus and in retention of the material, average rating 4.3. Since helping students understand and retain material, or learn material, is the overarching goal of any educational product, the current program was deemed a success. The encouraging average rating of a 4.7 on whether students would like to see more programs of this type developed for their use, reinforces the idea that students will use this type of multimedia product if they feel it is useful and will help them in their studies

Many faculty members across the country are developing multimedia learning tools such as the one presented here for their own use, as evidenced by the numerous journals, conferences, and organizations devoted to academic multimedia development. As more of these programs are put into use and incorporated into the curriculum the evaluation of new technology driven products is becoming increasingly essential. Users have not adequately evaluated the majority of the many technology-rich multimedia teaching products currently in use.<sup>4</sup> The evaluation of the current, preliminary version of the teaching tool described here will guide further development of such products at the University of Kentucky. Only after a finished version has been incorporated into the curriculum can its true effect on user retention and understanding of the material, effectiveness of integration of the basic sciences of embryology and anat

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omy, and impact on reducing laboratory overcrowding and overuse be more fully assessed.

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