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ABSTRACT

The traditional medical curriculum and internships must be supplemented by standardized teaching modalities, such as computer-assisted instruction using patient simulators. A patient simulator is defined as a representation of a clinical situation in which an individual conducts the diagnosis and management of a patient. Advantages include allowing students to have access to conditions which may not be routinely encountered in the clinical setting, posing no risk to an actual patient, providing an enhanced sense of reality, providing immediate feedback, and evaluating a student's response. Development of the patient simulator in this study included an analysis stage to determine users' requirements and to model knowledge, the design stage to encode the models of knowledge, and the implementation stage to evaluate effectiveness. Twelve students from various academic fields evaluated the patient simulator for ease of use, consistency and speed, diagnosis and treatment scenario representation, accuracy of the clinical problem simulation, accuracy and value of the feedback and the effectiveness of the student evaluation models. The main conclusions were that the patient simulator is a useful tool in testing the diagnostic and treatment skills of medical students and that the user interface requires further development to ensure its full acceptance in the field of medical education. (Contains 16 references.) (AEF)

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A Knowledge-based Learning and Testing System for Medical Education

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This study involves research on the development and the testing of a prototype of a patient simulator. Development of the prototype required three main stages: analysis, design and implementation. This paper will focus on the design and implementation stages of the study which were recently completed. The present version of the simulator runs on a Macintosh Quadra 800 and has a window-based interface with a limited use of graphics. The field-testing of the simulator on medical students showed us that the prototype would be useful in testing a student's diagnostic and treatment skills, however it would be advantageous to enhance the interface with audio and visual effects.

I. Introduction

The current medical school curriculum has been questioned in numerous studies, the main areas of concern being course instruction and student evaluation (Barrows, 1983; Anbar, 1987; Barker, 1988; Warner, 1989). New methods of teaching and testing the skills of medical students must be developed to ensure that students have the necessary medical knowledge and clinical skills to meet current societal health needs. The traditional medical curriculum and internships must be supplemented by standardized teaching modalities such as computer-assisted instruction (Carbonell, 1989; Fattu and Patrick, 1990).

This paper focuses on the design and implementation stages in the development and testing of a patient simulation system. This system was designed based on the restructurable modelling method and implemented using Negoplan, a knowledge-based shell (Szpakowicz & Kersten, 1993). The system's reasoning mechanisms are described in Kersten *et al.* (1993). MacDonald (1993) presents the development methodology, the knowledge bases and the results of field testing.

II. Knowledge-based Simulation

Simulation is a method of analyzing a problem situation by creating a model of the situation that can then be manipulated by trial-and-error methods (Fishwick, 1991). Patient simulators can be defined as a representation of a clinical situation in which an individual conducts the diagnosis and management of a patient (Assman, 1979).

Patient simulators possess many advantages: they allow students to have access to conditions which may not be routinely encountered in the clinical setting, they pose no risk to an actual patient, they provide an enhanced sense of reality, they provide immediate feedback, and they are capable of evaluating a student's response.

Current knowledge-based patient simulators possess some but not all of the above-mentioned advantages (Patient Simulator II, 1989; Parker & Miller, 1989; Champetier DeRibes, 1989; Johnson, 1989). The presented patient simulator differs from other approaches in that it possesses all of the advantages mentioned above. The patient simulator is presented through a discussion of the design and implementation stages of the study.

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III. Design

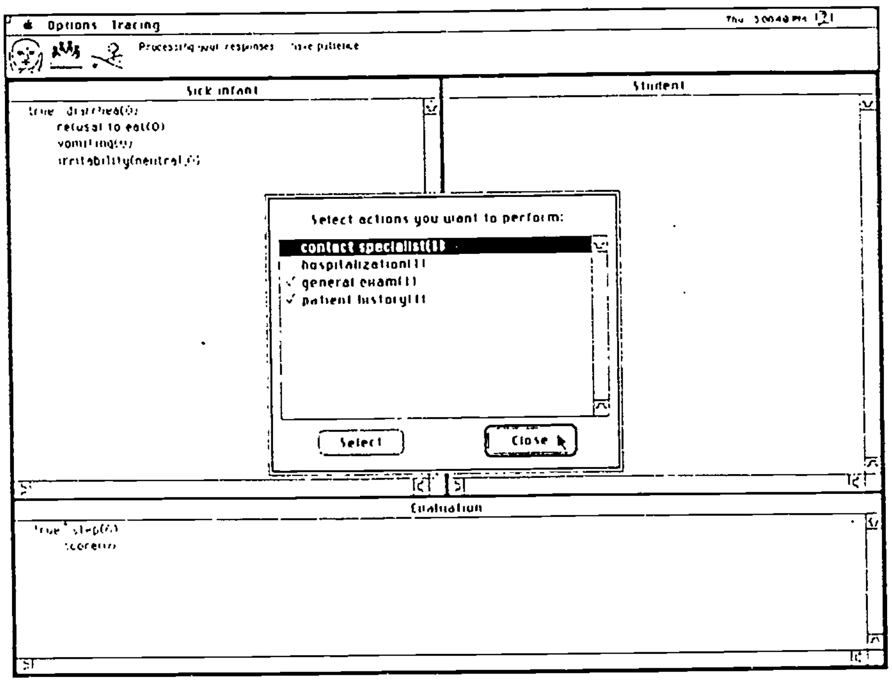
The design stage commences once the analysis stage has been completed. The main purpose of the analysis stage was to determine the user's requirements and to elicit and model knowledge. The cases modelled in preparation for encoding were: a viral intestinal disease, a bacterial intestinal disease and a bacterial neurological disease. These cases were selected because the visible symptoms are similar for each disease, therefore making the diagnostic process more challenging for the students.

The main purpose of the design stage was to encode the models of knowledge. The shell chosen to implement the patient simulator was Negoplan (Szpakowicz and Kersten, 1993). Negoplan is a knowledge-based shell based upon the principles of restructurable modelling, therefore allowing for changes in the case management process by merging these changes with the case management model, resulting in a new representation of the patient. The patient simulator can be run with a scoring system if so desired. The scoring system is designed to allocate points for each step in case management. The student following the shortest route to diagnosis would receive a perfect score.

Figures 1-5 show screen snapshots from the patient simulator running a typical case management scenario. The scenario demonstrates the shortest path to the diagnosis of a bacterial intestinal infection. The first window (Sick Infant) displays the patient's condition and displays the results of the actions selected by the student. The second window (Student) displays the actions that the student selects. The third window (Evaluation) displays the scoring system and the step in the case management process.

In Fig. 1 the student is presented with the initial representation of the patient, and based on the symptoms, makes the first selection to inquire about the patient's history and to perform a general exam as is indicated by the checkmarks.

Figure 1. Initial Representation and Selection 1



The results from the student having selected the patient's history and a general exam are presented in Fig. 2. The student selects general tests to aid in the diagnostic process and selects the provision of an interim treatment to alleviate the patient's symptoms. As is indicated in the evaluation window, the score is currently fifteen.

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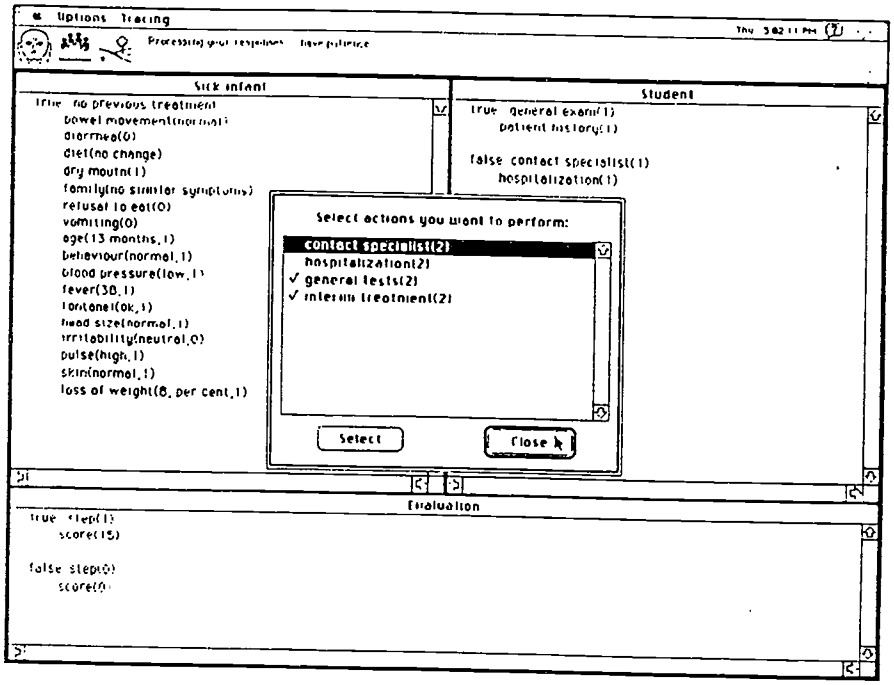
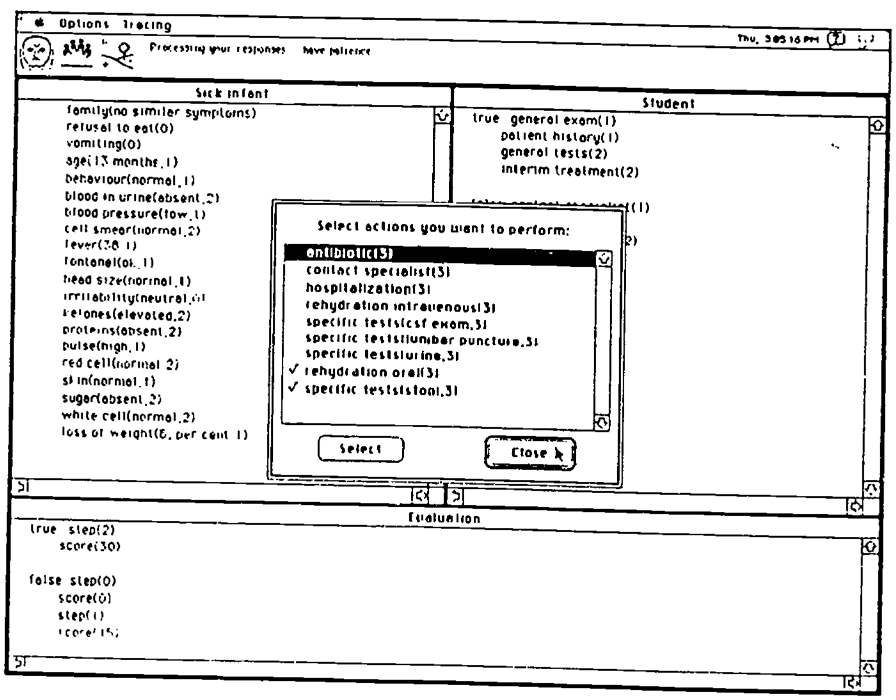
Figure 2. Modification 1 and Selection 2



In Fig. 3 the representation of the patient changes once again and the results of the general tests are displayed. The test results are normal, with the exception of the level of ketones which is elevated, indicating a possible infection of the intestinal tract. The student chooses oral rehydration as the interim treatment and a stool test as the specific test. The score is now thirty.

Figure 3. Modification 2 and Selection 3



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After the third modification, the results of the stool test are displayed as can be observed in Fig. 4. In addition, the interim treatment has alleviated the infant's symptoms. The diarrhea and the vomiting have disappeared. At this point the student has sufficient information to make a diagnosis of a virus of the intestinal tract. The score is forty-five.

Figure 4. Modification 3 and Selection 4

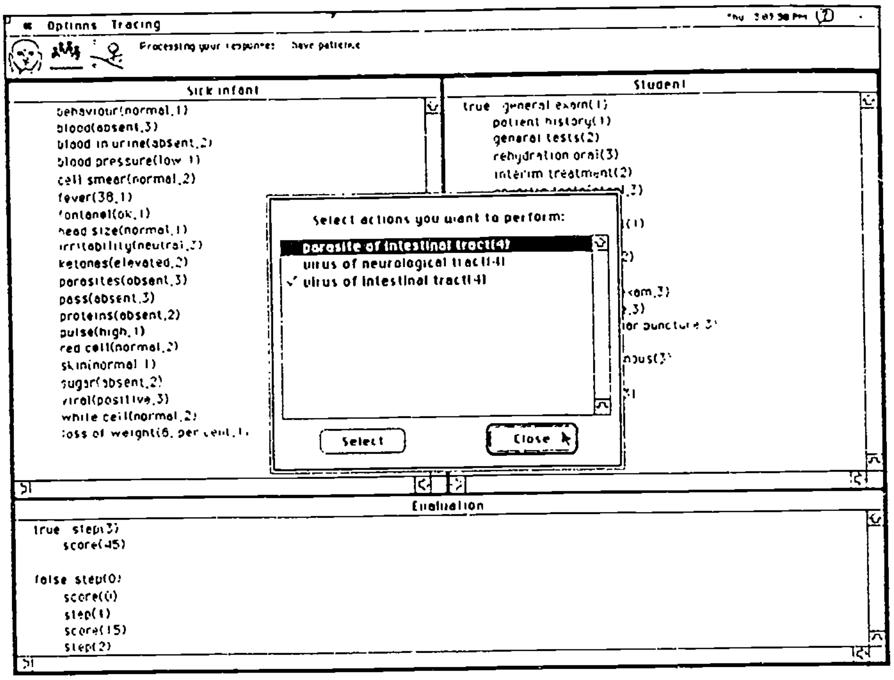
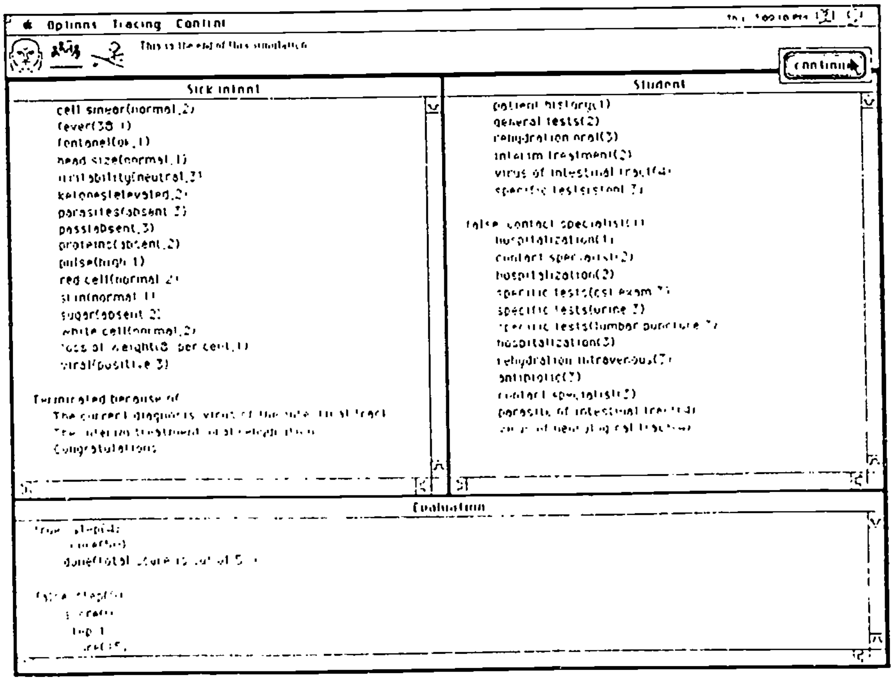


Fig. 5 depicts termination of the simulation in which the student is informed that he/she has made the correct diagnosis and has provided the correct interim treatment therefore receiving a perfect score of fifty.

Figure 5. Modification 4 and Termination



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IV. Implementation

The field evaluation of the patient simulator was performed on an ongoing basis. Twelve students from varying academic fields evaluated the patient simulator based on the following factors: system ease of use, system consistency and speed, diagnosis and treatment scenario representation, accuracy of the clinical problem simulation, accuracy and value of the feedback and the effectiveness of the student evaluation modules.

The main conclusion drawn from the testing sessions was that the patient simulator is a useful tool in testing the diagnostic and treatment skills of medical students. However the majority of students commented that the patient simulator could be improved by enhancing the user interface. The user interface, although functional, requires further development to ensure its full acceptance in the field of medical education.

V. Conclusions and Future Work

The knowledge bases are still being expanded in order to provide as diverse a testing environment for medical students as possible. The knowledge base is being further developed to include additional infantile infections, specifically, endocrine and metabolic diseases, neurological and psychiatric diseases, and cardiovascular diseases. Current infections in the knowledge base are being expanded to include more detail on the patient's symptoms, the patient's history, the general exam and tests, and the specific tests.

The current user interface will be further enhanced through the following forms of multimedia. First, graphical images will be added to the patient simulator through the use of a scanner that will provide the student with a visual display of specific components of the case management process. Second, actions will be selected through icons which will provide the student with less structured responses than does a predetermined list as exists now. This scenario more closely resembles the case management process. Third, results of the exams and tests will be provided in a sorted order and in a form similar to how a physician receives results in a realistic medical setting, for example, receiving lab results in numerical format thereby allowing the student to make his or her own deductions. Last, sound output will be used to illustrate the behaviour of certain organs such as the infant's heartbeat.

The rationale behind expanding the current user interface design is twofold. Most importantly, the testing scenario with which the student is presented should mirror a realistic medical scenario to provide the student with as rigorous a testing process as possible. In addition, in order to maintain the student's interest in the patient simulator, it is important to make the user interface both useful and competent to ensure the student's confidence in the system.

As the patient simulator is further developed through the enhancement of the user interface and the expansion of the knowledge base, testing will continue and will grow more extensive as the system nears completion. Although much research has been conducted in the area of computer-aided learning programs, there remains a gap in the study of knowledge-based simulation in medical education. With the further development and testing of knowledge-based patient simulators, these tools could provide solutions to many of the current problems facing medical educators today.

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Acknowledgments

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