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Computer Simulation and Medical Education: Complementary Tools for the Third Millennium

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Abstract

Background: *Educational change has been especially noticeable in medicine since the existence of virtual campuses. Several campuses have been created in the frame of the French Virtual Medical University.* ***Objective:*** *We present different multimedia resources that have been developed to help medical students with an active and easier understanding of complex physiopathological phenomena.* ***Methods:*** *The on-line course materials were created using original IBC-made multiscale simulators and registered trade-mark software tools.* ***Results:*** *Interactive multimedia resources are freely available for the site's users. Two- and three-dimensional simulations born out of mathematical qualitative and quantitative models at the molecular, cellular or organic level keep students active with regards to fundamental mechanisms by interactively manipulating the simulation environment. Authors comment the already available course materials.* ***Conclusion:*** *Providing evaluation tests, teachers anticipate that the increasing content of this virtual campus will allow users to gain a complete understanding and an integrative view of many physiopathological mechanisms.*

Keywords:

computer simulation, medical education, physiology, virtual reality, multimedia

Introduction

Medicine is an art founded on experiential know-how, the basic sciences, and epidemiological data. There is a universal agreement that physicians must have knowledge of these two basic subjects, human physiology and anatomy. The corpus of data and knowledge underlying medicine is growing exponentially and Medical Education faces the great challenge of training students within this expanding data universe spanning from the "nano" to the macroscopic scales. All biological functions and their modulations thereof can be attributed to the interplay between the variable expression of specific genes, the functional variability and diversity of their protein products within multiple biochemical systems, and the interactions between the cells, tissues and organs in which the said genes are expressed.

Modern approaches to teaching and learning basic science include collaborative learning, problem-based learning and the use of computers. Computers and information and communication technologies (ICTs), the Internet and Internet-related resources are of special interest in physiology [1]. Available computer technology allows the use of dynamic models, making learning more efficient. Many difficult concepts in physiology are truly learned only when the student's brain converts heard or read words, static pictures and diagrams into moving models [2]. Computers are now sufficiently powerful and the Internet sufficiently fast to allow fast distribution of multimedia materials which are especially useful for teaching physiology [3]. Furthermore, the interactive capability of computer-based instruction (CBI) keeps the student involved so that learning is more interesting and not purely passive. Future CBI will also have to tackle the challenge of helping students master the wide and deep corpus of knowledge we evoked in the first paragraph.

Our current approach focuses on the scientific foundations of medicine, and combines Computational Integrative Physiology (CIP), Qualitative Modeling (QM), and Reasoning capabilities. The aim of CIP is to provide computer models of the human body's multi-scale biochemical and biophysical dynamics that are occurring in response to its environment [4].

Qualitative Modeling involves natural-language and common-sense representations of the physical world. Qualitative models can model complex physical systems and processes as well as produce natural language descriptions and summaries of simulated system behaviour [5]. This self-descriptive property conveys a central role to these models since reasoning processes such as tutoring can operate at a symbolic level where qualitative models constitute the *object* level..

Finally, a *trully interactive* CBI must exhibit *intelligent behavior* (e.g, reasoning capability). Indeed, for a CBI to "interact" with a user beyond responding to "start", "forward", or "backward" clicks, it must have an *understanding* of the current user-context and carry-out *meaningful actions* accordingly. Such an understanding

could not hold without the proper representations and semantics describing a user-context nor without the specific inference schemes to carry-out meaningful actions.

In this global conceptual context, our objective was to create freely accessible simulation tools and to put them on the web at learners' and teachers' disposal. In what follows we will focus on some of the multimedia resources that host our quantitative and qualitative computational models. System intelligence will be addressed in subsequent papers.

Materials and methods

Pedagogical content media types

Pedagogical multimedia contents include texts, static images (radiographies, magnetic resonance imaging (MRI), etc…), sounds (voice, cardiac and pulmonary sounds), dynamic recordings (echogram, videogram), dynamic two- (2D) or three-dimensional (3D) simulations. Each pedagogical content includes at least two frames: on the left side of the screen, the title and a short explanatory text of the lesson and on the right side, the multimedia material : videogram, 2 or 3D animation. Different buttons allow the learner to display more detailed explanations about the phenomena, to add sound, music, to hear the reading of the text, to navigate along the different pages of the session.

2D and 3D dynamic computer simulations

The 2D and 3D dynamic simulations of multiscale biological functions were generated using original IBC-made computer models coupled to a generic and multi-domain knowledge base [4] [5]. The IBC computer simulators are able to reproduce normal or pathological cases in a virtual reality context and from the cellular to the organic level.

Set-up and functioning of the website

A part of our 2D and 3D dynamic simulations are present on the website that we created in 2005 and that we described in a precedent paper [6]. This website, called the "Campus Numérique de Physiologie" (CNP) is accessible through the French Virtual Medical University (UMVF) site at the following adress: http://www.umvf.org, "virtual campus" heading. There is also a direct Internet access: http://www.campus-physiologie.org

Our first work was to update the Content Management System (CMS) of the platform with the latest version of Joomla, an open source Mambo-derived CMS which uses a MySQL database. The platform has also been more securized at the Apache webserver level.

Results

More than 30 pedagogical items are now available on the CNP, but for the moment we have focused our effort in the sole domain of the cardiovascular physiopathology: in this medical area, the cardiovascular hemodynamics and cardiac electrophysiology sections present several concepts usually considered to be of special difficulty for the student's understanding. This is the reason why we developed simulator-based 2D and 3D animations in those two sections. We present here some examples of the resources available in each section.

Cardiovascular hemodynamics section

This section allowed also us to introduce into the proposed resources a simplified but very useful 3D anatomical model. The learners can use this virtual human body containing important biological systems like the skin, the muscles, the skeleton or the cardiovascular sytem, as an anatomical relative position reference for various organs (see figure 1).

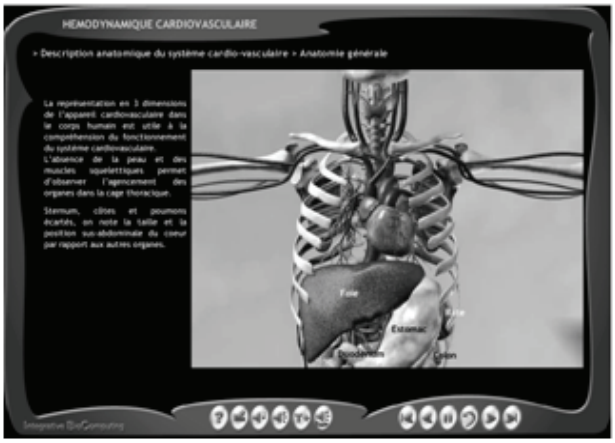

Figure 1 – 3D anatomical relative position reference

.In this section, students can watch in details hard to understand 3D phenomena such as the successive or slightly asynchronous mechanical events of the cardiac cycle and the corresponding cardiac hemodynamic recordings.

Figure 2 gives an example of mechanical and hemodynamic processes viewed in parallel for a better understanding.

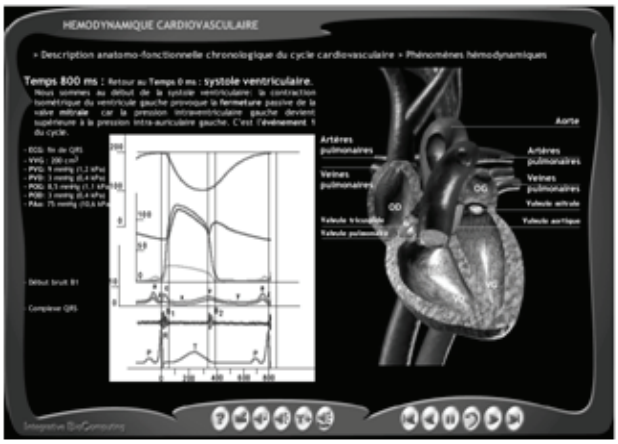

Figure 2 – Hemodynamics

Cardiac electrophysiology section

In this section, learners can watch in two dimensions a myocardic repetitive reentry process associated with the genesis of a ventricular tachycardia (see figure 3).

Figure 3 – A 2D simulated reentry

Students can also start the electric cardiac activation process: using an original IBC-made 3D chromatic simulation program [7], they are able to follow the step by step depolarization and repolarization pathways along the fast conducting system, the endocardium and epicardium. 3D visualization of the cardiac electrical signal moving forward is essential to understand the corresponding genesis of the normal and pathologic human heart EKG, which can be studied in any standard lead (see Figure 4).

Qualitative simulation

New resources are under developpment and we will soon add quantitative simulations to the list of available website resources. Within this new learning context, students will be able to analyse combined impulse formation and impulse conduction disturbances using different means: a crude depolarisation wavefront, a Lewis diagram, and the high level concepts that label (qualify) the simulated

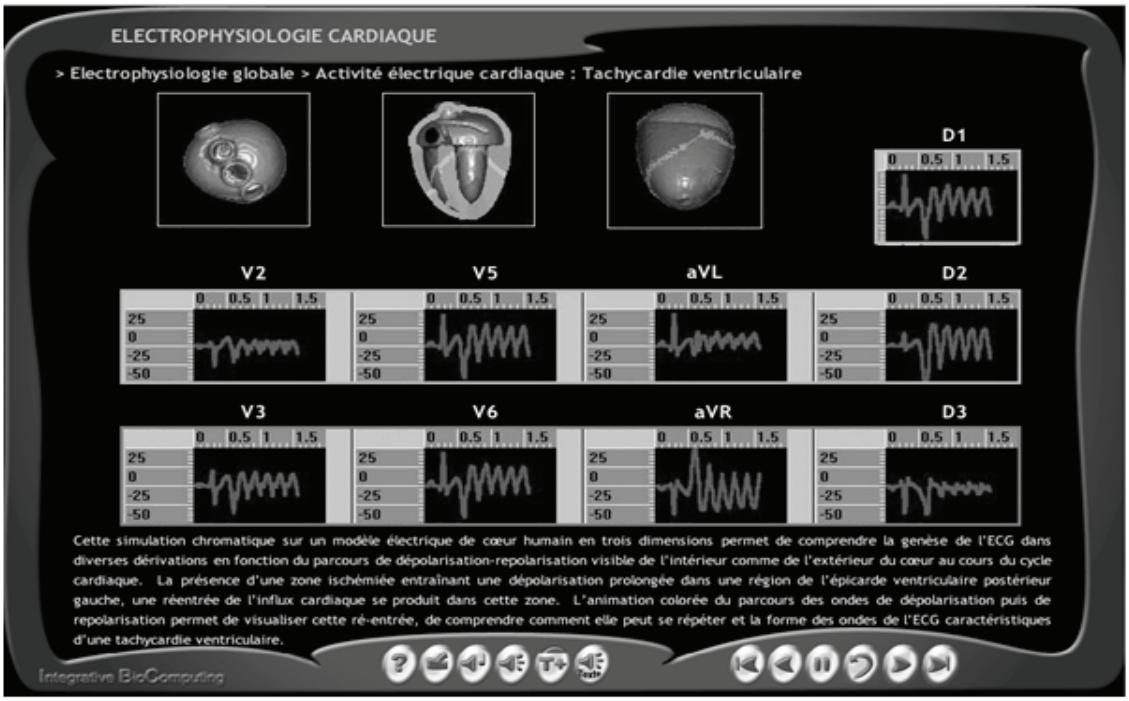

Figure 4 – 3D simulated ventricular tachycardia with a model-generated ECG

arrhythmia (see Figure 5). Given initial conditions, our QM generates these results in an ongoing fashion and in synchrony with the underlying electrical processes [8].

Discussion

Computer-assisted learning is generally assumed to be worth and to have a positive influence on student learning [3], [9-10]. Nevertheless, in agreement with the views of the teachers of the french "Société de Physiologie" and in opposition to classical virtual universities, it was decided before its development that the CNP would not be a web-based course aimed at distance learning. Learning materials of the CNP are not intended to become a surrogate for classical forms of teaching. ICTs and multimedia are uniquely used as tools for learning, providing learners with complementary knowledge in fundamental sciences necessary to scientific and medical education. Choosing to provide learners only with complementary teaching resources, we wanted to keep the possibility of face-to-face Physiology courses for on-campus students and to avoid

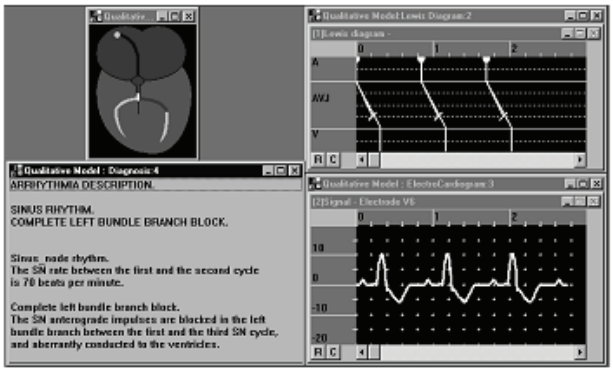

Figure 5 – Qualitative simulation of an arrhythmia

some dangers linked to complete on-line courses and confirmed by different surveys : the will of a physical classroom in preference to a virtual one is expressed by many students whose majority disagree with both synchronous and asynchronous electronic communication tools when a direct interactive aid by dedicated teachers is possible [9] [11].

Though the CNP is for the moment moderately interactive, medical first-cycle students of Rennes and several already graduate practitioners are highly enthusiastic about the complementary use of multimedia resources to improve

the understanding of physiopathological mechanisms and the possibility to re-active their memory before or after clinical reasoning learning or practical workshop sessions. This statement is in agreement with a recent survey [12] showing that medical students mostly use Internet in order to find additional learning information. Nevertheless, the CNP is in permanent evolution in order to improve its technical effectiveness and to come up to the users' expectation [13-14] and thus needs being appraised as precisely as possible: methods of assessing the effectiveness of our e-learning systems will be explored by inquiries about both customer satisfaction and service quality. A general questionary, established from examples of the literature will allow to verify the user's satisfaction level. E-learner satisfaction is linked to learner's performance. Assessment of learners' understanding level will be assessed by specific questionaries written by the authors in each teaching content. To reach this goal, the actual CMS Joomla will be replaced as soon as possible by a learning content management system (LCMS). LCMS are aimed to offer functionalities allowing easy construction of a questionnaire. After a preliminary inquiry in 5 french and 1 canadian universities, unpublished results show that Medical Physiology professors find the simulation tools of the CNP useful as complementary resources for a better understanding of the described biological mechanisms. The loud synthetic reading of the text does not seem to be very useful and more interactivity is required.

A part of the teaching quality of the CNP will be warranted by the teachers validating committee and by the administrator's control of the hardware and software efficiency and updating. Though it has been shown that in basic sciences and Physiology, didactic fashion is more efficacious than too much interactive style [10] and since it was demonstrated that understanding is the most useful in clinical reasoning [15-16], original IBC-made software tools will be used to develop movies from 3D colour images and photographs in the jpeg file format to give the learner the possibility of a real interactive navigation in a three-dimensional cardiovascular environment. Well designed computer-aided learning is useful for conceptually difficult topics [17] [3]. Furthermore, an original IBC-made cardiac simulator is in preparation, soon at teacher's disposal to create different scenarii of pathological affects.

Developing computer assisted learning applications is a lengthy process. Innovators within traditional courses who have often produced creative and high quality material to supplement existing courses are in a minority [14]. We hope that the rising success of the CNP will enhance the creativity of the teachers but the development of teaching scenarii using multimedia and the multiplication of the teaching contents of the CNP for the next years depends on both the vitality of the members of the French “Société de Physiologie” and the acceptation of the different teaching projects to be granted by the UMVF.

Conclusion

We have presented different multimedia resources incorporating quantitative and qualitative models that have been developed to help medical students with an active and easier understanding of complex physiopathological phenomena in the context of the complementary teaching resources of the CNP. It should be noted that the opposing view to classical virtual universities concerns *current* CBI technologies which generally have very little intelligence and therefore limited “real” interactivity with a mitigated acceptance by the students.

Related to this issue, we are currently developing an *interactive* CBI that will exhibit *autonomy* and *intelligent behavior* in a e-learning/e-training context. It will combine CIP and qualitative models with reasoning methods. Such developments are necessary if future CBI technologies have to carry-out the task of performing Problem-Based Learning and Clinical Reasoning Learning sessions in an autonomous fashion. For instance, good medical practice presupposes diagnostic ability that includes a solid grounding in physiopathology. Loosely speaking, in physiopathology-based diagnosis, solutions and explanations are provided by going "backwards" through the causal paths, from the observation to the cause(s) of a mental physiopathological model. This form of hypothesis-formation, called *abduction,* can be mimicked by computers capable of performing model-based diagnosis. Thus CBI technologies that perform abductive inference will be well tooled to tackle PBL sessions in an autonomous fashion.

Although these are long-term goals, we believe that model-based learning resources such as described in this paper and the experiences derived from their use in the classroom will provide valuable inputs to our more advanced developments in CBI technology.

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