MEDICAL APPLICATIONS OF COMPUTER-BASED LEARNING

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ABSTRACT
Interactive access to instructional materials and educational information is now possible by means of a wide range of relatively low-cost technologies. This means that many new and exciting educational applications of computer-based learning are starting to become available. This paper therefore discusses some new applications of computer-based learning within the domain of medicine. In particular, we consider its role as an agent for '*patient education*'. Our approach to the creation of '*patient education systems*' is discussed and then illustrated by means of a case study approach involving a recent study that we have made in relation to female urinary incontinence.

KEYWORDS
multimedia, human-computer interaction, computer-based learning, medicine, health-care, patient education, patient-education system

INTRODUCTION

Nowadays, '*the computer*' and '*the Internet*' are quite commonplace phenomena. Indeed, they are becoming increasingly available in homes, schools, public libraries, hospitals, shopping malls and workplace environments. Most people therefore have access to and/or use a computer of some sort during the execution of their daily routines. This is particularly true in the case of professional people whose job entails handling some form of online information. Access to such information can be achieved in a variety of ways. Some of the most common of these include: using an office desktop computer that is attached to the Internet; the use of interactive TV, use of a laptop computer with a built-in modem; and use of a PDA (Personal Digital Assistant) or WAP phone.

Bearing in mind what has been said above, it is clear that computer technology is now playing an invaluable role within our societies. This is particularly true in the context of medicine and health-care applications. Within these domains there are six broad areas where computer technology is now making significant contributions:

- record keeping activities (administration)
- patient monitoring (data collection)
- research and development
- information dissemination
- diagnostic and therapeutic applications
- education and training

Administrative applications of computing within medicine are probably one of the most well-known. Virtually all hospitals and clinics now keep 'patient records' and increasingly, general practitioners are incorporating computer-based patient-record systems into their surgeries. *Patient monitoring* through real-time data collection is, of course, another well-known and widely used application of computers within medicine; this is particularly so within the context of intensive care units and the control of sophisticated online equipment such as ECG, ultra-sound and CAT scanners. Naturally, many of these developments arise as a result of the use of computers to support *research and development* activity within medical science and health-care applications. For example, the development of new drugs and the assessment of the effects that they have on patients are critically dependent on the use of computer technology.

Because progress in medical science takes place at such a fast pace, it is imperative that the details of new drugs and treatments are made available (both to experts and to the general public) as quickly as possible. The *dissemination of medical information* by electronic means (such as the Internet and various private networks) has therefore become of major importance in health-care applications. Another important development within the context of medical computing has been the availability of 'interactive computer systems' in which a patient can have a one-to-one dialogue with an online computer program. Such facilities are increasingly being used for *diagnostic purposes* (as we discuss later in this paper) and for *therapeutic applications*. The origins of this type of development are rooted in the early work that was conducted by Weizenbaum in 1966 using his ELIZA program [42] and the medical interviewing tools described by Bevan et al [7].

From our own perspective as academics involved in computer-based learning (CBL) research, one of the most interesting areas of computer application within medicine is that which we have called '*education and training*'. It is this area that we are primarily concerned with in this paper. Within this context there are four broad areas where computers are now increasingly being used:

- educating and training medical students
- continuing professional development for medical staff
- general awareness applications
- patient education

Conventional applications of computer-based learning for medical staff are well-documented in the literature - see, for example, Stillman et al [32], Lowdermilk and Fischel [25], Tomaiuolo [34] and Neild [27]. Because of the rapid changes that are taking place in medical knowledge, and as a result of government legislation, many consultants, doctors and medical staff now have to continually update their skills and, in so doing, 'prove their competence'. Increasingly, CBL techniques are being used as a mechanism for the realisation of lifelong learning and continuing professional development for medical staff.

As was mentioned earlier in this paper, the Internet and various other types of interactive learning product (often published on and distributed using compact-disk technology) are now becoming increasingly available to the general public in order to educate people with respect to medical issues and the avoidance of healthcare problems. In addition, many hospitals, clinics, surgeries and medical staff are now becoming interested in the use of interactive computing facilities for use in patient education. It is this specific issue which we address in the remainder of this paper.

As far as this paper is concerned, we will define '*patient education*' as a process by which patients acquire *knowledge* about medical conditions which relate specifically to them - of course, they may also subsequently develop special *skills* which will allow them to cope with those conditions. There are three main reasons underlying our motivation for providing this type of educational facility. First, to provide patients with a greater understanding of the implications of their medical problems. Second to make them aware of the available treatment options. Third, to allow them to become sufficiently informed so that they can participate in joint decision-making (along with clinicians) regarding the available treatments.

In order to realise the above objectives we propose that appropriately designed computer-based '*patient education systems*' should be used. Such systems employ CBL techniques in order to fulfil the educational requirements that are needed to become an '*informed patient*'. As we shall discuss later in the paper, these systems are usually built using multimedia computer technology. In principle, they can be used in the home, at a clinic or in a hospital environment under the supervision of clinicians.

Bearing in mind what has been said above, in the remainder of this paper we outline our approach to the design and development of patient education systems using interactive multimedia technology. The following section therefore provides a rationale for and expands upon the use of CBL techniques for patient education. Subsequent sections then discuss the role of multimedia CBL resources and provide an outline of our approach by means of a short case study. In the final part of the paper we draw some conclusions and generalisations from the work that has been undertaken.

CBL FOR PATIENT EDUCATION

There is a growing amount of evidence to support the belief that providing patients with information about their illness or medical problem has an important role to play in the process of shared decision-making between a patient and his/her doctor [15, 16]. The important role that patient education can play is implicit in the model of patient decision-making that is depicted in Figure 1 [37].

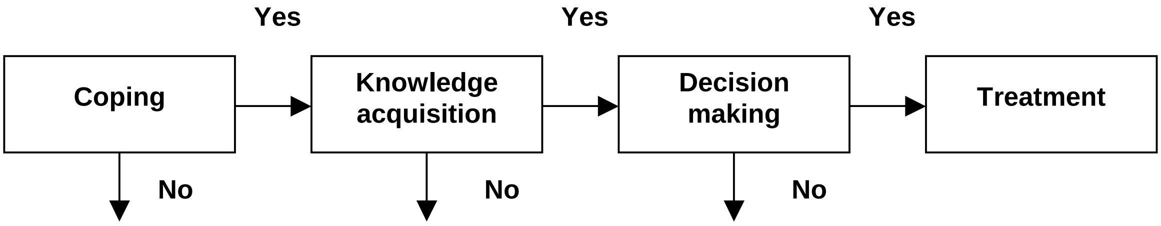

Fig. 1 Model of Patient Decision-Making

Patients need to be 'coping' with their disease before they can acquire knowledge related to that disease, through a *process* of *patient education*. Patients require knowledge in order to make decisions regarding their treatment. In practice, however, medical practitioners (but usually not patients) have the knowledge that is required to make decisions about treatment. The need for patient education and *patient education systems* to support this process is reflected in developments in health care. According to Weed [41] patients should no longer be seen as passive recipients of health care, but as active participants who must be able to manage their own health and illness, in the same way that they can manage their own transport. Weed believes that patients, rather than doctors, should become the primary decision makers in medicine, but this requires up-to-date, clear, unambiguous, understandable, and easily accessible information:

‘*In a demystified health care system modern information tools should be used routinely by all patients, in conjunction with providers who are trained to help at various steps in the system where patients cannot function on their own (such as feeling their own spleen or replacing a hip)*’ (Weed, 1997, p. 233).

Positive effects of providing patients with clear information (in addition to doctors’ explanation) at the time of diagnosis have been reported for more than a decade. This is particularly true for those suffering from a life-threatening disease. The important findings are as follows. First, research has shown that patients are less anxious, uncertain and have a better quality of life [1, 20]. Second, doctors are less burdened by ignorant questioning behaviour and are able to share the decision-making process with the patient [4, 10, 41]. Third, health care, at large, can benefit because patients are more satisfied, are more willing to comply, need fewer visits to doctors and therefore health-care costs can be reduced. Our model of patient education using patient education systems is depicted schematically in Figure 2.

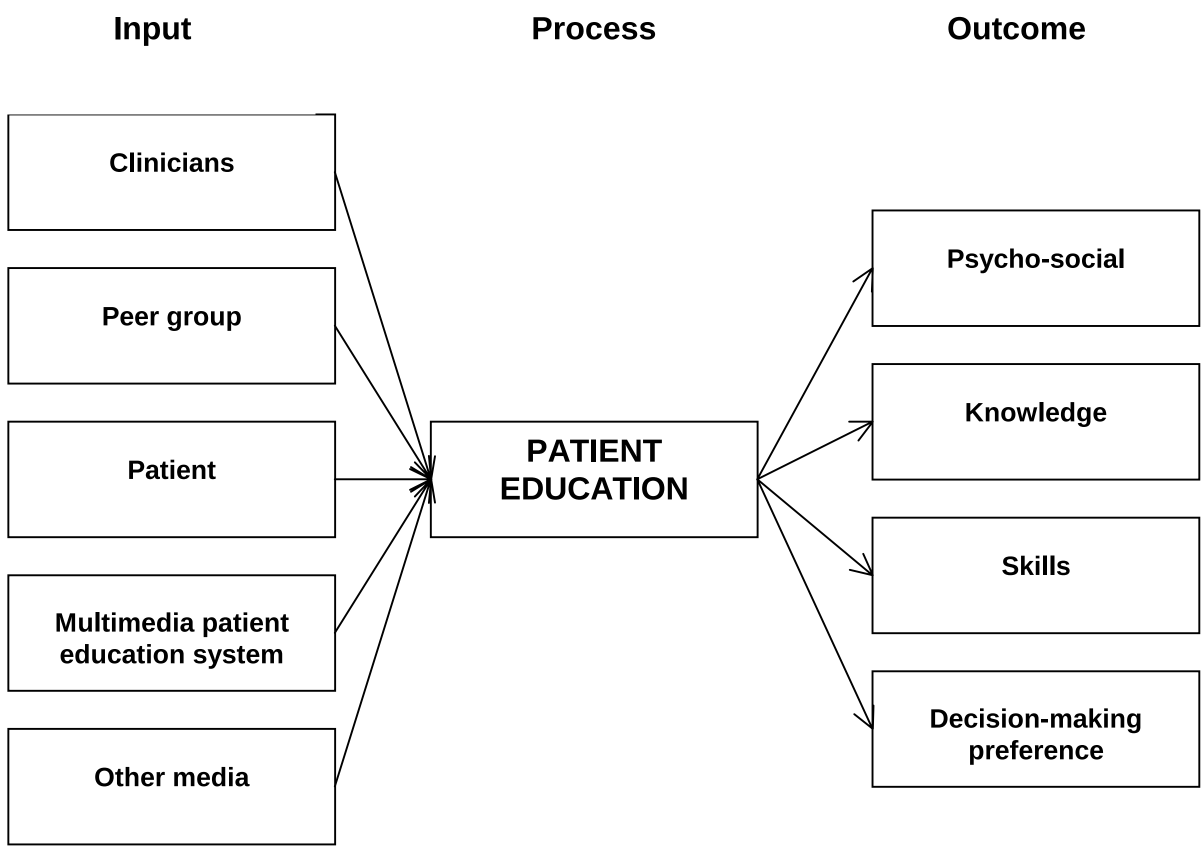

Fig. 2 Schematic Model of Patient Education

The model shows that both the patient characteristics and the designed characteristics of the patient education system influence the process of patient education. This process could involve reading text, watching videotape, listening to an audiotape, contact with peers or clinicians or interacting with a multimedia patient education system. The model highlights several types of outcome for patients: psycho-social (less anxious patients), cognitive (more knowledgeable and skilled patients) and joint decision-making (patients more able to participate). Although agents other than the patient are included in the model we will focus on the effects of multimedia patient information systems on patient outcomes. The model shown in figure 2 forms the basis for our on-going research programme into the evaluation of educational multimedia programs for patients with prostate cancer [39, 40] and other diseases as reported in this paper.

MULTIMEDIA PATIENT EDUCATION SYSTEMS

Conventional delivery mechanisms of patient education include printed materials, audio tapes and videotapes. A main disadvantage of these systems is that the information is presented at a particular level that can be too complex for many patients while at the same time being insufficient for those patients who desire extra or more detailed information than is provided [31]. In addition, when using these systems for patient education, updating of relevant information can be a slow process. According to Smith and Timoney [31]: '*It is impossible to predict how much outdated information is given to patients*' (p. 27).

More recently, multimedia programs have been developed and used for patient education systems [11, 14, 30]. According to Barker and Giller [3], a multimedia program is one that combines text, sound, graphics, video and interactivity in order to achieve a particular outcome. Evaluations of multimedia programs have produced positive results. For example, Dupuis et al. [12] found that patients who underwent brain surgery after using an educational multimedia program experienced less anxiety and developed a more positive perception of their health care experience. In benign prostate hyperplasia, van Schaik et al [38] found that the provision of multimedia patient information was found to reduce self-assessed prostate symptoms.

The following potential advantages of using multimedia computer programs in patient education have been identified [11, 31, 41]. First, multimedia information can be the most comprehensive form of information because it combines various media that can complement and reinforce each other to aid patient learning. Second, multimedia materials can be used in a flexible way so that patients do not have to 'work through' the whole of a program - patients can interactively select information at different levels appropriate to them and then go straight to particular areas of interest, skipping over any other information. Third, whenever there are new developments in procedures for diagnosis, treatment or other aspects of care, programs can easily be updated. Fourth, multimedia can be cheaper to develop and distribute than conventional video productions. Fifth, when proven to be accurate and effective in a local setting, a multimedia system can be widely distributed and then used by other patients and clinicians - for example, by making it available through the World Wide Web. Sixth, easy access to multimedia programs could enhance national and international consistency in treatment protocols and so might be used in guidelines development [13].

Easy access to medical information can now be gained through the Internet and the World Wide Web. However, Impiccatore et al [17] found that most of the medical information relating to fever in children was unreliable when compared to recommendations made within guidelines. Furthermore, Widman and Tong [43] urged physicians to develop guidelines for providing medical advice over the Web.

Bearing in mind what has been said above, relating to the success and possible advantages of using multimedia programs for patient education, it is important to consider how various multimedia resources can best be combined in order to achieve this goal in the most effective way. Van Schaik et al. [37] have discussed how multimedia can be used for this purpose. Their findings are summarised below.

Use of Text. Text on the screen can be used to convey conceptual and other information that cannot adequately be expressed graphically. Text should be concise, easy to read and should blend in well with the user interface. This can be achieved by using appropriate colours (for example yellow or white on a dark background) and suitable font styles (for example, Comic Sans MS). Text fonts should be sufficiently large (for example, a point size of 16-20) to accommodate the target audience. This can motivate users to read the displayed text and avoid eye strain so that they will not just ignore the text and move on to the next screen.

Use of sound. Sound now plays a major part in most multimedia presentations because people have become accustomed to it as a result of its use in TV and radio. The use of sound is attractive because it is usually much easier to listen to a message than it is to read it from a screen. Sound can be employed in two main ways. First, background music can be used to soothe and calm thereby helping a user to relax and become engaged. Second, voice-over can be used to simultaneously echo descriptive text messages that are presented on a screen. Voice-over can help patients to relax thereby eliminating any apprehension they might have. An important advantage of voice-over is that it can cater for patients who might have forgotten their reading glasses. Another advantage is that patients can repeat a voice-over as many times as they need until they feel that they understand the content that is being presented. Alternatively they can simply move on to the next screen before the voice-over has been completed.

Using Graphics. According to Sechrest and Henry [30], images should be kept as simple as possible and should focus only on points that are relevant for patients' knowledge acquisition and self-assessment. In this way, consistency and uniformity of graphical illustration can be achieved and patients' understanding thereby promoted. Illustrations can show anatomical structures at various angles, their location and different stages of a disease. Simplified two-dimensional cartoon style characters can be used for easy identification by patients. A hospital metaphor could be provided by using a consistent background throughout the application; this could take the form of a picture of a hospital main entrance - thereby providing a familiar setting for its patients.

Using Animation. Animation should be kept simple and impressive; it is important to avoid the use of complicated animation sequences - which may overload patients with information they do not need or want. Animation techniques can be used in a number of ways, for example:

- *changing elements* - this is simple animation generated by rapidly displaying a sequence of images to show how a medical condition changes (such as the various stages of prostate enlargement);
- *moving elements* - this involves moving words or images around the screen in order to keep users interested and involved;
- *appearing and disappearing elements* - these are used to focus a patient's attention to individual elements in a presentation - this effect is usually achieved by introducing different elements over time (for example, when explaining control buttons and their various functions);
- *screen transitions* - these are commonly used to display different screens and shots with various transition effects - again to keep users stimulated and attracted to the screen.

Using Interaction. Patient interaction with a system is used for the purposes of navigation, question answering and selecting options (such as replaying a voice-over). Interaction is achieved using various types of control (such as 'buttons') which are visible objects that patients can 'touch'. Controls need to be clear and unambiguous, but not necessarily predictable or 'dull' - as they can provide an opportunity to involve users in the content (they can also be employed to intrigue, amuse and entertain them). The controls that are embedded in a patient education system can be located in any part of the screen - but it is important to keep frequently used controls in the same screen location. The size of a control can be made proportional to its importance of its function, for example the '*next*' arrow-control can be made larger than the other controls as it is usually the one which is most frequently used.

For simplicity of operation, an application should use a small number of controls, for example a '*move to next screen*' control (for example an arrow pointing to the right), an '*exit*' control (for example, a door icon) and a '*play sound*' control (represented by a loud-speaker icon). These controls should be positioned on the screen in a consistent location - thereby making it easy to remember their purpose. Navigation from one screen to another within the program should be simple - by selecting the '*move to next screen*' control. As an aide memoir the program could provide a 'bookmark' facility for each page that a patient has previously visited. This could help patients keep track of their progress through the program.

CASE STUDY - FEMALE URINARY INCONTINENCE

In order to illustrate out approach to the development of interactive multimedia patient education systems, the case study that is presented in this section outlines some work which we undertook in conjunction with South Cleveland Hospital in Middlesbrough, UK [21].

Rationale

Urinary incontinence is affecting many women both in the UK and elsewhere in the world. However, most women seem to 'suffer in silence'. Most research reports a prevalence of 10-25% with women between the ages 21-60 and of 5% of men within this age group. For people older than 60 the prevalence is even higher. These results are similar in different countries: the UK [8, 19]; the Netherlands [22, 23]; Minnesota, USA [28]; Sweden [29]; and Turkey [35]. Haugen and Moore [16] predict that urinary incontinence affects approximately 10 million Americans and that the estimated annual total cost is about 10 billion dollars in the United States alone.

The most coherent categorisation of urinary incontinence is the differentiation between *stress* and *urge* incontinence [2, 5, 6, 23].

Stress incontinence is generally seen as the involuntary loss of a small amount of urine during physical activities, or activities such as coughing and sneezing, that increases intra-abdominal pressure, and during which there is no feeling of urgency to void. The assumption is that these people have a 'dropped' bladder or 'cystocele'. For the majority of women the most common cause is thought to be a damage to the pelvic floor support due to childbirth, however, there are women who show the symptoms of stress incontinence without having had children.

The main symptom of *urge incontinence*, on the other hand, is the urgency of voiding which is felt almost at the same time that the leaking starts. These people will leak a larger volume of urine. The assumption is that this is caused by abnormal contractions of the bladder. It might go together with nocturnia (night-time voiding) and a history of late bed wetting as a child is assumed.

Other types of urinary incontinence [2, 6, 33, 43, 45] which are found less frequently are: *mixed* (Stress and Urge) incontinence, *overflow* incontinence, *transient* incontinence, *sensory urge* incontinence, *functional* incontinence and other sorts, such as caused by fistulas.

In order to enhance the knowledge that patients with urinary incontinence have of their condition and thereby improve their capability of making decisions about potential treatment a multimedia patient education system was developed.

Design and implementation

The basic patient education system for the female urinary incontinence study was produced as part of a graduate MSc project [21]. It was designed in conjunction with hospital consultants who specialised in this particular area of medicine. The overall structure of the system is illustrated schematically in Figure 3.

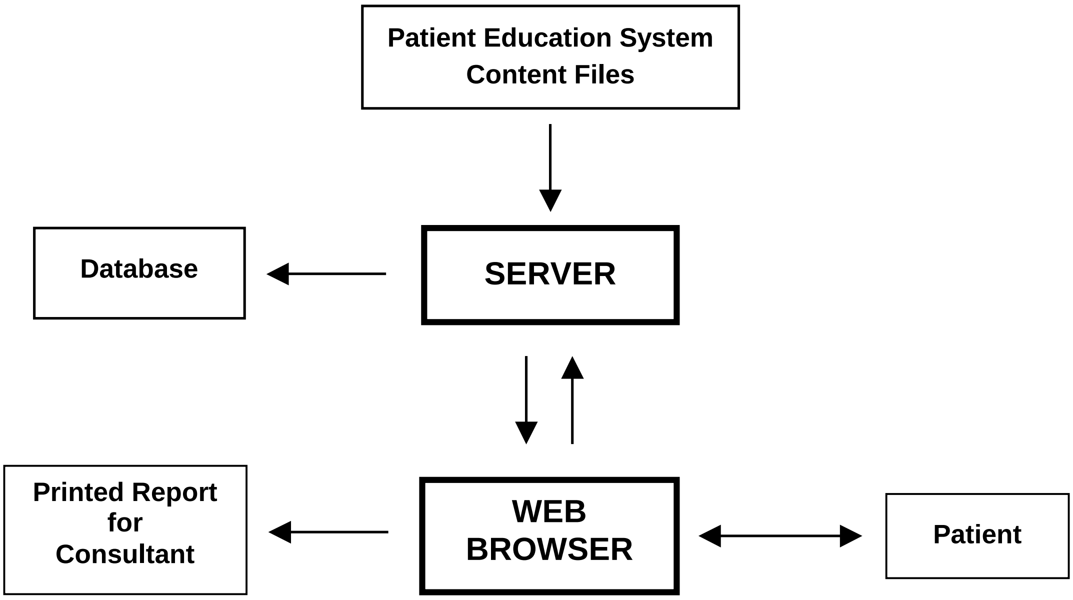

Fig. 3 Basic Patient Education System for Female Urinary Incontinence

The original intention of the project was that the software that made up the patient education system (PES) should be mounted on a suitable server that could be attached to a hospital-based intranet facility. The PES could thereby be made easily accessible at any location within the hospital that had intranet/Internet connectivity. Bearing this in mind, the system was constructed as an integrated suite of HTML files that could be read by a patient using a web browser. These files were all created using Microsoft's FrontPage 98 authoring environment. As well as providing educational information to patients (see below), the system was designed to perform two other important functions. First, it provided patients with a 'quiz' so that they could self-evaluate how much they knew about their condition and/or had learned as a result of using the system. Second, it administered a 'diagnostic' test; the results of this test included an incontinence score similar to the IPSS [38]. These results are stored in a computer database and printed out as a report for the consultant to look at prior to actually seeing a patient in a face-to-face interview.

Naturally, the patients for whom the PES was designed would probably not have any understanding or experience of using interactive computer systems. Therefore, before using the PES program, patients are allowed to practice using the mouse and keyboard. The end-user interfaces associated with the PES were also designed for use by inexperienced, novice users. Many of the multimedia techniques described in the previous section of the paper were employed in order to produce interfaces that were user-friendly, understandable and easy to use. The end-user interface sub-system that was designed for the PES provided patients with access to sections of the program that dealt with: *anatomy* (the brain, the kidneys and the bladder); *types of incontinence* (stress, urge and mixed); *tests and investigations*; *treatment* (kegal exercises, drug therapy, surgery and so on); the *quiz*; and the *diagnostic questionnaire*.

Before filling in this questionnaire, patients are allowed to practice using the mouse and keyboard prior to entering data (answers to questions) into the patient education system. Apart from the entry of the patient's name (which requires the use of a keyboard), questions are answered simply by selecting an option (using the mouse) from a fixed list of choices. Before any data is sent from the browser to the server (and then entered into the database), the browser checks that the name field is complete and that all the questions have been answered.

Evaluation

During the development process, various ongoing formative evaluations were conducted. First, the technical correctness of the information was checked by an incontinence nurse and corrections were made accordingly. Second, the level of English was checked by the research team to ensure that it would be suitable for patients rather than for clinicians. Third, the user interface was evaluated by two user-interface experts and improvements were made based on their recommendations. Fourth, technical tests were conducted in order to check the correctness of: the operation of hyperlinks; spelling and grammar; and the processing of the quiz and the questionnaire. Fifth, an initial evaluation with patients was conducted. Sixth, feedback was obtained from three consultant urologists.

Six patients used the program. The main findings were as follows. Relating to the information provided by the program, the patients liked the use of 'white space' and the consistency of the user interface. Inexperienced computer users asked for help, even when they knew what to do themselves. Some users experienced an initial problem in using the mouse. Patients liked the option that allowed them to go back to previous questions in the incontinence questionnaire. They also liked its self-paced nature. Overall, patients found the program helpful and fun too. They felt the information offered was relevant and easy to understand. The user-interface was appealing to them and they found the program easy to use.

The main results from the consultants' feedback were as follows. Regarding the information offered by the program, they found the content overall sufficient and appropriate. They felt that better pictures were required. They commented that some technical terms were no longer commonly used and that some tests were not necessary. Furthermore, they felt that more information on urodynamics was required. The consultants believed that the incontinence score provided a good indication of urinary incontinence trouble as a basis for detailed medical assessment and suggested more research to assess the usefulness of the score. Overall, the consultants believed that the program would benefit patients - who would be better informed and whose fear would be reduced.

Conclusions

The case study confirmed the need for a multimedia educational system for female urinary incontinence for patient use within the hospital. Both educational material and diagnosis need to be included in a multimedia system for patients. The following 'generic' instructional categories need to be included in any patient education system: *anatomy*, *disease*, *tests and investigations*, and *treatment*. Patients found the program easy to use, appealing and useful. Consultants expected patients who would use the program to be better informed. They also expected that the incontinence score would be useful as a diagnostic aid. A summative evaluation of the system (involving patients) is currently underway.

DISCUSSION AND FUTURE WORK

Arising from the work that we have undertaken over the last few years, we believe that there is now a growing demand and urgent need for patient education systems of the type we have described in this paper. Indeed, this view is supported by the findings of Tweddle at al [36]:

> *'Patients learn about {a disease} using a variety of media, through both formal and informal methods. … Friends and relatives assiduously pursue information as part of the process of caring for and supporting patients. … As learners, people living with {a disease} are often very anxious yet committed to maximising their knowledge. … However, teaching and learning about {a disease} is problematic given the complex subject matter and associated psychological distress and this is exacerbated by limitations in the quality and availability of complementary written information.'*

Although specifically formulated for the context of {cancer} education, the comments written above could apply equally well to any critically serious illness or disease. As well as reinforcing our own views relating to the potential utility of patient education systems, Tweddle et al also emphasise another important point relating to the *limitations in the quality and availability* of the information that is available for patient use - particularly in relation to what is available via the World Wide Web. This is a finding that has also become apparent to us in some of the other studies that we have recently been making in relation to patient education. For example, a recent feasibility study that we conducted in relation to scoliosis indicated that there was very little reliable (authenticated) information available for patients' use [26]. Despite these findings we are optimistic that the situation will improve as patient education systems become more widely available for different medical conditions.

CONCLUSIONS

In the past, computer-based learning has primarily been used for conventional teaching and learning applications within school, college and university settings. In addition, it has also been widely used in a large number of non-academic organisations for staff training purposes. Now that computers are becoming more widespread, many new and novel applications of CBL are emerging. In this paper we have described the utility of computer-based learning within the context of creating patient education systems for use in a number of different settings. We have illustrated the principles that are involved by means of a particular case study in which we have recently participated. We believe that further development of the techniques that have been described in this paper will lead to significant improvements in health-care facilities.

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