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A new way for surgical education — development and evaluation of a computer-based training module

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Abstract

Computer-based training (CBT) programs teach the material of a specific field and at the same time offer various ways of objectively assessing the knowledge gained. The interactive use of multi-media components such as text, graphics, animation, sound, digital slide shows, and videos as well as quizzes can theoretically facilitate the learning process. The aim of this study was the development and evaluation of a CBT-program by surgeons for student training. Using SuperCard, a teaching module for Distal Radius Fracture (DRF) was developed, which contains detailed clinical information. Video clips and vivid animations combine theoretical knowledge with practical experience. Fourth-year medical students (n = 103) were tested after using the module for 90 min. Other students (n = 47) served as the control group. In a 90 min lecture, DRF was discussed. CBT gained in all evaluated criteria (distinctiveness, detailed description, presentation of materials, structure, motivation for learning, time saved learning and memory retention) 15–20% better scores than the lecture. Although 82% of the students stated that their experience with computers was limited or insufficient, 100% found the use of CBT systems useful in student teaching. Most of them suggested the use of such programs as a method of exam preparation/self study (90%) or as a supplement to a lecture (40%). Based on these evaluations, CBT modules are an appropriate future teaching and learning system that is well accepted. In conclusion, the results of this study show that CBT-programs could be a valuable supplement to medical education. In addition, further development of CBT-programs and their use as information systems for

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surgical residency programs at universities can be suggested.

Keywords: Computer-Based Training; Fracture of the distal radius; Surgical education; Medicine; Multimedia

1. Introduction

Surgical education is built upon four pillars. *Surgical theory* imparts necessary factual knowledge and eases the decision-making process during diagnosis and therapy. Aided by etiology, pathology, differential diagnosis, and therapeutic alternatives, *clinical surgery* is capable of inspiring critical thought and leads deductively to algorithms which provide sound solutions to problems. *Operative techniques* learned from frequent assistance during operations mold talented students into skilled surgeons [1]. The results of experimental and *clinical research* inspire the surgical ward and aid in further development of the field.

The rapid acquisition of knowledge in the surgical field creates particular problems not only for instructors who constantly wish to teach up-to-date information, but also for the students wanting to more effectively use this wealth of knowledge. The abundance and complexity of surgical knowledge necessitates a redirected orientation of education through means of innovative informational-transfer methods. The goal of this redirection is not necessarily a change of material, but rather the reorganization of the mode of presentation. The intent should be to convey an optimal amount of important information in the least amount of time.

Today in the field of surgical education, an array of basic demands is being placed on the media used for teaching and learning. These demands include authenticity, user-friendliness, productivity, interactivity, didactic effectiveness of the medium, and a reasonable cost-to-return relationship [2]. Through the realization of these conditions with a computer, it is possible to create a learning environment which may provide, ease, and encourage a self-steered and directed method of learning [3,4]. Anglo-American findings point to the efficiency of computer-based instruction [5]. Because the representation of medical knowledge — especially in the form of pictures and video-sequences — is technically (via computer) and financially possible, it is very important that surgical Computer-Based Training (CBT)-Systems be developed and employed [6]. The goal of this study was to evaluate a CBT-program which was developed at the Surgical Clinic at the University of Heidelberg and used in student instruction.

2. Materials and methods

2.1. Development and implementation

In order to develop a suitable CBT-program, various authoring systems were at first evaluated (Table 1). Based on the assessed criteria, it was determined that SuperCard is most suitable for the compilation of a CBT-program in the surgical field [7]. For this reason SuperCard was used to construct an instructional module for the distally fractured radial bone

[8]. The equipment used for the developers workplace consisted of (in the hardware realm) an Apple Quadra 840AV (Hardware capacity 1000 MB, RAM: 64 MB), a SuperMac DigitalFilm Videocard, a Panasonic VCR, an AGFA Scanner Arcus Plus, and an Apple Color Printer. The tutorial program can be upgraded and updated at any time by using a self-authoring programming system [9]. This self-authoring system permits the compilation of new modules without previous programming knowledge [10].

The developed CBT-program contains extensive clinical information regarding pathogenesis, the diagnostic process, X-ray results as well as surgical techniques, case studies, and questions about DRF. Illustrative animations and video-clips combine theoretical knowledge with practical experience. The user can independently test himself with multiple choice questions previously used in nationwide examinations (original-IMPP questions). Considerable emphasis was placed on a didactic, thought-through production. The consistent basic layout and the uniform construction of the diverse units permits the student to quickly familiarize himself. The user has several navigational possibilities at his command: to flip through the pages, to assess the indices, to perform free and guided searches, and to use a structured overview. The user can thus follow, leave or re-access the intended tutorial path or freely search for relevant information. No previous computer knowledge is necessary in order to work with this module.

Table 1
Comparison of different authoring systems

	Authorware Professional (v.2.2.0)	HyperCard (v.2.2)	SuperCard (v.1.7)	Apple Media Tool (v.1.0)
Authoring/ programming environment	Medium	Good	Good	Medium
Learning difficulty	High	Medium	Medium	Low
Presentation of the teaching content	Good	Medium	Good	Good
Integration of multimedia components	Text, graphics, sound, animation, Quick Time movies, videodisc, video	Text, graphics, sound, animation, Quick Time movies, video	Text, graphics, sound, animation, Quick Time movies, video	Text, graphics, sound, Quick Time movies
Branching	Medium	Good	Good	Medium
Indexing	Difficult	Possible to program	Possible to program	Not possible
Searching	Not possible	Possible to program	Possible to program	Not possible
User control	By functions	Possible to program	Possible to program	Not possible
Answering possibilities	Input of text, button, clickable and movable objects, key press	Check box, button, others can be programmed	Check box, button, others can be programmed	Difficult to realize
Answer evaluation	Good	Medium	Medium	Difficult
Extensibility	Complex	Good	Good	Medium

The computer program has been implemented as a hybrid version and can be run on PCs as well as on Macintosh computers.

2.2. Application and evaluation

This module has been routinely employed during teaching at the Chirurgische Universitätsklinik of Heidelberg in its Mac-version (hybrid version is available) since WS 1994/95. The evaluation of the CBT-program was carried out by comparing surveys of two student groups (n = 150). The first group of students (n = 103) consisted of two subgroups. The first of these was a group (n = 61) of fourth-year students doing practical studies in surgery (CBT-P). The second subgroup (n = 42) was actually taking part in a Medical English class (CBT-ME) and volunteered to test the program. Both subgroups were given a questionnaire after working with the module for 90 min. They were asked to evaluate their experience with the medium concerning the criteria mentioned below. The addition of time needed to introduce this group to the module amounted to between 15 and 20 min. The second student group (n = 47) (at the same educational level) attended a 90-min long lecture on DRF, was given the same questionnaire thereafter, and was asked to assess the quality of the lecture based on these same criteria. The following criteria were assessed: clearness, detailed description, presentation, intelligibility, motivation for learning, time-saved learning, and memory retention. The assessment was rated on an ordinal scale: poor < sufficient < satisfactory < good < excellent.

2.3. Statistical analysis

Horizontal full-range boxplots [11] were used to describe graphically the individual distributions of the evaluated criteria in the two student groups defined by the teaching methods. We also constructed specialized star polygons [11] to get a descriptive comparison of the joint distributions of the answers to the criteria for the different teaching methods. To investigate the effect of the selected teaching method on the answers to the different criteria ordinal logistic regression [12] was used. Besides the selected teaching method we considered also the age and the sex of the participants as covariates in the model. An effect was considered as statistically significant if the corresponding p-value was below 5%. We also used biplots [13] for a graphical representation of a multivariate analysis of the criteria. The biplot is a joint representation of the selected teaching method and the ratings of the participants for the different criteria. Arrows describe the variability of the ratings. Correlations between the results of two criteria can be approximated by the angles between the two axes, where an acute angle shows a positive correlation and an obtuse angle describe a negative correlation. No correlation corresponds to an angle of 90.

2.4. Results

Altogether, 78 men and 72 women between the ages of 21 and 34 took part. No difference in the outcome of the students evaluations was found due to gender, but a significant statistical disparity based on the age-distribution resulted after using the Wilcoxon–Rank/Sum test (p < 0.001). After investigating the results of the self-evaluation portion of the survey regarding PC-

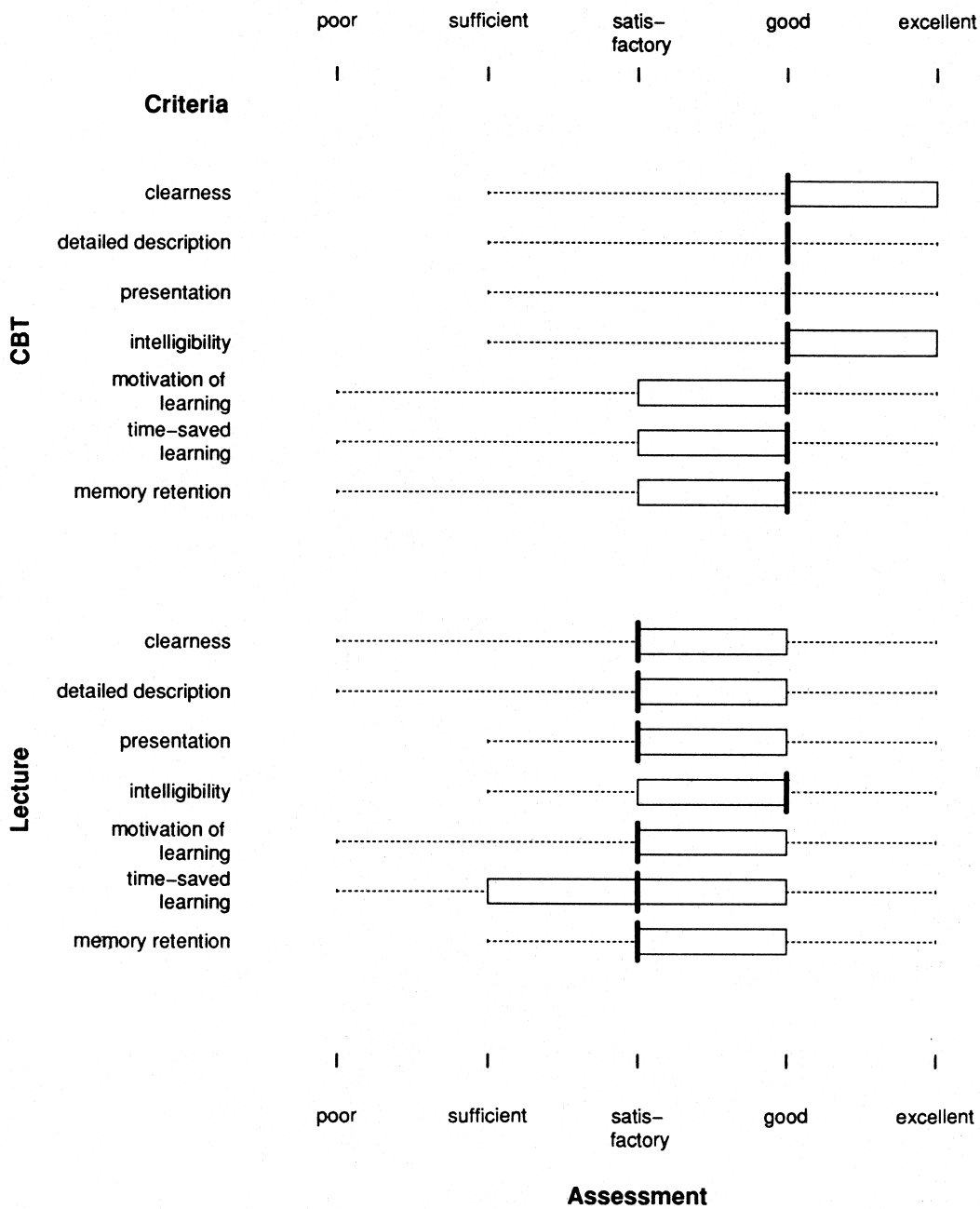

Fig. 1. Horizontal boxplots show the distribution of the evaluations for the seven selected criteria. The boxplots respectively portray the range from the worst to the best (broken lines), whereby the centrally located rectangles depict the range between the lower (25%) and upper (75%) quarter of the evaluation. The median is represented by the bold, vertical line.

Table 2
Self-assessment of the participants on their prior knowledge on computing

	Poor	Sufficient	Satisfactory	Good	Very good
Men	17	12	14	9	1
Women	23	9	9	2	0

knowledge of those operating the CBT-System, a separate distribution according to gender was determined (Table 2). The complete statements of 96 people could be used here. The use of the Cochran–Armitage-Test (a test which reflects a trend in the differences between men and women) reported a p-value of 0.012 [14,15]. The women tended to give themselves lower ratings regarding their knowledge of PCs than did the men.

In Fig. 1 the distribution of the seven chosen criteria has been depicted in the form of horizontal boxplots and separated according to the two teaching methods warranting comparison. It is clear to see that a consistent, more positive evaluation was given to the CBT than to the lecture.

This result is confirmed by the star-polygon graphics as well (Fig. 2). The star-polygons were calculated for three groups: the group of CBT students was accordingly subdivided into two groups — one consisting of students in their third clinical semester (CBT-P) and the second made up of those students who worked with the system during the Medical-English course (CBT-ME). No considerable difference regarding the evaluation of both CBT groups (CBT-P

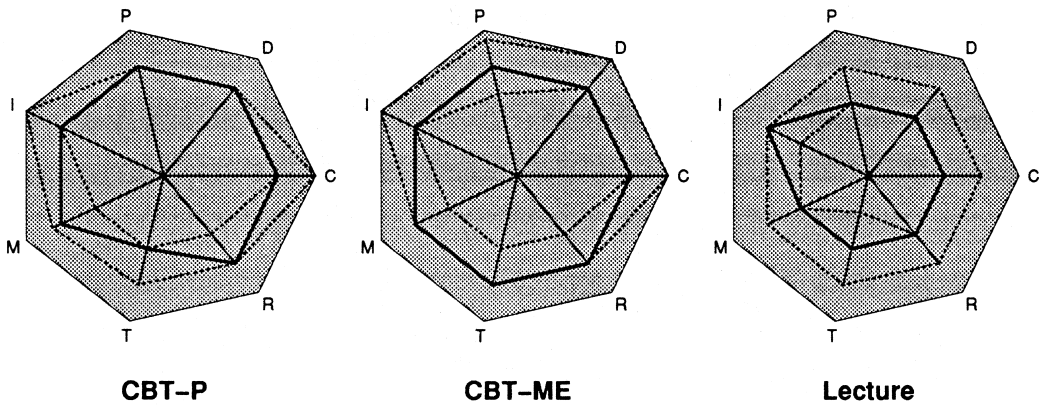

Fig. 2. Star-polygons for the seven selected criteria have been applied to the lecture, CBT-P, and CBT-ME groups. The first letters of the criteria have been printed on the outer edge of the stars. Each star represents the evaluations of a test group. The seven criteria of the evaluation can be interpreted by reading the composite graphics counter-clockwise. At the same time, the corresponding evaluation ratings (poor-excellent) correlate to the distance of the plot from the center of the star according to the following rule: poor = 1, ..., excellent = 5 units. The gray-shaded areas show the altogether best-possible assessment for each star and facilitate a comparison of the three groups. In each diagram a dotted line symbolizes the lower (25%-value) and the upper quarter (75%-value). The median value is represented by a boldly printed line.

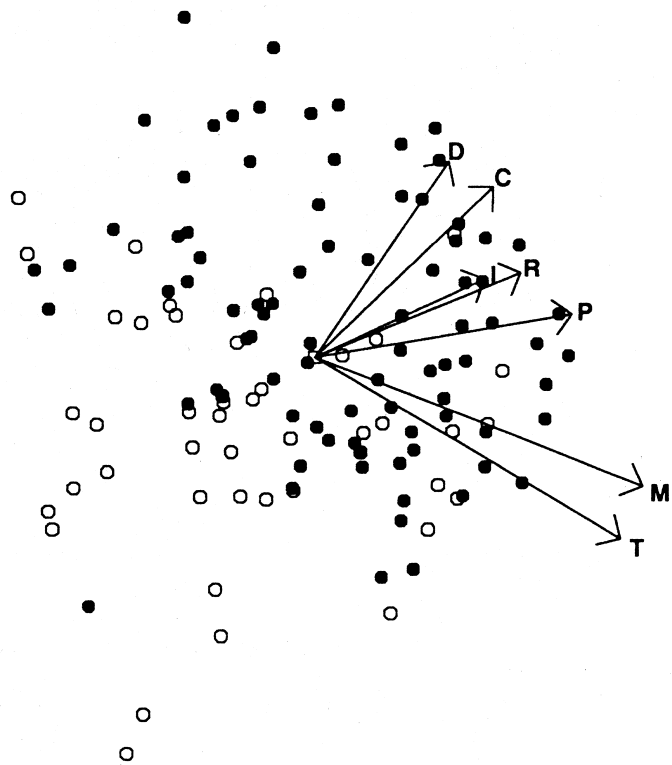

Fig. 3. Biplots for the seven selected criteria applied to the lecture (o) and CBT (•) groups. The individual criteria have been indicated respectively by their first letters. Open circles represent the points for the evaluations of the students attending the lecture, and closed circles correspond to the points for the evaluations of the CBT groups.

versus CBT-ME) was observed. Distinct disparities were found, however, after comparing the CBT group evaluations with those of the group attending the lecture.

An ordinal logistic regression was employed to test the influence of the method of instruction on the evaluation. A significant statistical difference in regards to the form of instruction was observed for the following criteria: intelligibility ($p = 0.027$), time-saved learning ($p = 0.013$), clearness ($p < 0.001$), memory retention ($p < 0.017$) and detailed description (p is less than 0.001). In each case a better evaluation was given to the CBT-System. A p-value of $p = 0.0178$ was calculated for the motivation of learning category. As a matter of fact, the CBT received a better assessment in all seven criteria than the lecture. In general, other factors such as sex and age proved to have little relevant effect. A gender-based disparity was ascertained, however, in which the women tended to better evaluate the presentation criteria. A marginal influence based on age ($p = 0.075$) was determined. A higher rating was given to the category detailed description by older students.

The biplot-graphic in Fig. 3 depicts the data calculated for the seven analyzed criteria. Open circles represent the evaluations given by students taking part in the lecture, and closed circles represent the evaluations of the CBT-students. Here it can be observed that five categories (clarity, detailed description, presentation, intelligibility, and memory retention) make up a

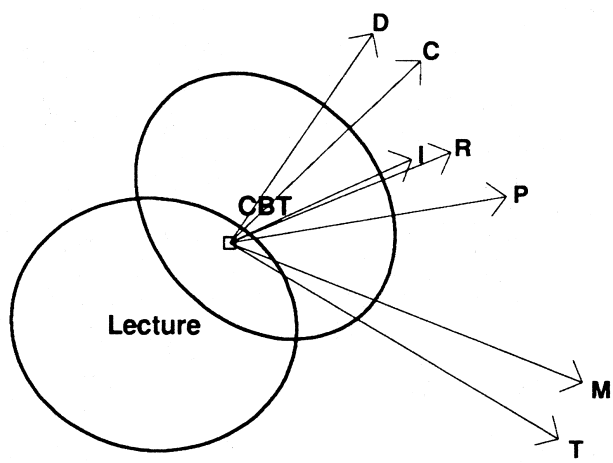

Fig. 4. Biplots for the seven selected criteria, applying to the lecture and CBT groups. The individual criteria have been indicated respectively by their first letters. The ovals make it possible to observe the particular differences between the two groups.

clear grouping (a high positive constellation). These five criteria also appear to have approximately the same variability. The second group is comprised of the criteria learner-motivation and time-saved learning, and both categories show a greater variability in the students evaluations. Fig. 4 made it clear that the group of five criteria separates principally between the lecture and CBT, which again illustrates that the CBT uniformly received the better evaluation. This has been graphically depicted by "group-ellipsoids" which correspond respectively to each group's average value plus or minus a standard deviation. If the CBT-group is split up, an almost complete overlapping of both ellipses for both CBT-groups (surgical practice and Medical-English course) can be observed. This result is reinforced by the star-polygon-analysis.

Although 87.5% of the students indicated that they possessed a poor to satisfactory knowledge of computers, 100% found the employment of CBT-Systems to be advantageous. Most suggested that such programs be offered in the future as supplements to lectures (40%) or as a means of exam preparation/self-study (90%).

3. Discussion

CBT stands for programs which convey the subject matter of a specific field through multimedia and offer various ways to objectively test the knowledge acquired from the use of the instruction-module. Interactivity and the individual-guided feedback of the user set such programs apart from conventional modes of instruction [16–18]. The employment of time-independent multimedia components (MMC) such as texts, graphics, and pictures, coupled with time-dependent elements such as animation, soundbites, and video-sequences, leads to

effective learning [19]. The use of multimedia components is indispensable when one considers that a person usually retains only 10–15% of that which is read, 10–20% of what is heard, and 20–30% of what is seen, but when audio and video materials are presented side-by-side the retention of knowledge increases to 40–50% [20]. These programs are especially advantageous when used in the medical field because they are better able to graphically portray clinical pictures by digitalizing the subject matter and by using simulations.

CBT-Systems have already been used in the past 30 years in the field of medical education [21–23]. Only in the last few years have such programs gained popularity, however. This increasing interest is contingent on a number of factors:

- The widespread availability of multimedia computers.
- Interactivity and individual feedback of the user through instructions.
- The presentation of a large amount of factual knowledge.
- The employment of multimedia components in the form of texts, graphics, and pictures coupled with the use of animation, soundbites, and video-sequences makes the graphic portrayal of the subject matter and the simulation of clinical cases possible.

Up to now only a few programs intended for use in the surgical disciplines have been developed. The high costs of development have hindered attempts to create such programs. This program was solved by making use of a self-authoring system which provides a less experienced author the ability to digitally transcribe the desired subject matter [8–10]. In addition, the uncertainty surrounding the efficiency of this new teaching and learning device has also been a discouraging factor. Our studies show that CBT-instruction was well received by both the students who were forced to participate (CBT-P) and the group of volunteers in the Medical-English course (CBT-ME). Moreover, the CBT-program proved to increase a student's efficiency in learning the material 15–20% when compared to conventional methods of instruction. The integration of visual media is crucial in order to create an interactive environment which leads to effective learning and an increase in the retention of the subject matter [24]. Not to be underestimated is the importance of interactivity, since it keeps students focused on the information presented and actively includes them in the learning process.

It has to be taken into account that students may tend to rate a new educational medium higher than a traditional one (possibility of a false positive result), simply because it is new and thus interesting. Since both subgroups (the students recruited for our study as well as the volunteers) independently judged the new medium to be more effective and since these findings correlate with other studies in this field [25], it can be said that the above-mentioned point may contribute to the positive result but can not be considered its only reason. A possible reason for the positive result could rather be the interactivity of the medium, the possibility to pick an individual learning pace and the incentive of using an innovative and new medium [26].

Up to now there are approximately 40 surgical CD-ROMs of high quality that can be purchased. When surveying the market, a CD-ROM costs between 100 and 50,000 DM. The cost of developing such a CD-ROM at the moment amounts to between 30,000 and 500,000 DM, depending on the level of interactivity and the number of integrated multi-media components. Thus the initial costs for the production of a CBT-module are higher than those of traditional teaching methods. Since no cost-benefit-analysis has been performed for Computer-Based Training [27], an adequate proof of cost efficiency is not possible for medical

education, teaching and learning. Up to a certain degree, a cost effectiveness could be determined for the fields of teleradiology [28] and telemedicine in trauma surgery. But apart from this, the data concerning cost-benefit-analysis is sparse and methodically questionable, so that it can be said that in this regard we are still looking for empirical findings and proper technical evaluation of this new medium [29]. To justify the high initial costs, it can be said that the CD-ROMs become more easily available due to the rapid development of technology and the concurring decrease of costs for production of hard- and software. Modules can be brought up-to-date much easier and cheaper than textbooks and scripts. Additionally, they can serve as a tool to provide knowledge over the intra- or internet. Fischer and Lion [30] have developed a medical problem-based computer system using multimedia components for interactive use via the world wide web. This enables the students to acquire knowledge in a self-organized manner and independent of time and place [31].

Not all of the pillars of surgical education are as equally responsive to computer-based training, however. Surgical theory can be conveyed through these means. Clinical demonstrations can be better illustrated and made easier to comprehend by using a collection of case studies. This form of self-study will not make lectures superfluous. Instead, lectures will become more effective. The basics of the surgical trade can be simulated and trained through computer-based instruction. Surgical research can also be accelerated by the rapid conversion of current information into CBT-programs [32,33].

4. Conclusions

Based on this study, it was determined that CBT-modules employed as teaching and learning devices are superior to conventional methods. In addition, the CBT-system was well accepted by the students taking part. Therefore, it is recommended that CBT-programs be integrated into the learning process as a means of conveying a factual basis of knowledge and as a meaningful supplement to conventional methods of education. These findings also present the opportunity to encourage the continued development of CBT-systems and to strive toward a coordination and cooperation of interdisciplinary fields. It has been planned to develop new modules and to broaden the system so that it can also be used as a hypermedia-based information system. The possibilities, which the use of computers offer in education, should be further explored in the future. The tools are available.

5. Summary

Computer-Based Training (CBT) programs teach the material of a specific field and at the same time offer various ways of objectively assessing the knowledge gained. The interactive use of multi-media components such as text, graphics, animation, sound, digital slide shows, and videos as well as quizzes can theoretically facilitate the learning process. The aim of this study was the development and evaluation of a CBT-program by surgeons for student training. Using SuperCard, a teaching module for Distal Radius Fracture (DRF) was developed, which contains detailed clinical information. Video clips and vivid animations combine theoretical

knowledge with practical experience. Fourth-year medical students (n = 103) were tested after using the module for 90 min. Other students (n = 47) served as the control group. In a 90 min lecture, DRF was discussed. CBT gained in all evaluated criteria (distinctiveness, detailed description, presentation of materials, structure, motivation for learning, time-saved learning and memory retention) 15–20% better scores than the lecture. Although 82% of the students stated that their experience with computers was limited or insufficient, 100% found the use of CBT systems useful in student teaching. Most of them suggested the use of such programs as a method of exam preparation/self study (90%) or as a supplement to a lecture (40%). Based on these evaluations, CBT modules are an appropriate future teaching and learning system that is well accepted. In conclusion, the results of this study show that CBT-programs could be a valuable supplement to medical education. In addition, further development of CBT-programs and their use as information systems for surgical residency programs at universities can be suggested.

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this foundation was the development of a modern multimedia library for surgery and medicine. In the last five years this laboratory, under the leadership of Dr. Kallinowski, has developed a multimedia library, the med.LIVE series. This series contains 45,000 multimedia components with information of a uniform structure that now comprises 53 CD-ROMs. These modules contribute significantly to the training and education of medical students and doctors. Furthermore, this multimedia library is intended to aid in the development of a database-supported online information system. Dr Mehrabi continues to work as vice-project leader of the CBT-laboratory. His current research interests include the pathophysiology of the transplanted liver and new ways for improving the conveyance of surgical knowledge and medical education.

Christine Glückstein studied Medical Informatics at the University of Heidelberg/School of Technology Heilbronn. During the studies and also after the graduation in 1996, she worked for the Surgical Department of the University of Heidelberg, where she was concerned with the development of computer-based training programs and multimedia information systems. Since 1997 she has been occupied with application programs in the field of hospital information systems and works now as a consultant for an international company.

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Christian H. Herfarth, M.D. from the University Clinic of Heidelberg, Germany, got his surgical training at the Surgical Clinic of the University Marburg, Hessia, Germany, where he finished his residency and got his Ph.D. in surgery on liver metabolism in trauma, hypothermia and under the influence of toxins. He was senior lecturer of surgery at the Surgical University Clinic Freiburg (1969-1973). He became Chairman of the Department of General Surgery at the University of Ulm, Germany (1973). In 1981 he went to the Department of Surgery, University of Heidelberg. Since then he has been Chairman of the Department of Surgery. His current research interests are Surgical Oncology, Liver Surgery, Colorectal Surgery and Hereditary GI-Tract Cancer.

Friedrich Kallinowski graduated from the University of Mainz, Germany in 1982. After receiving his Ph.D. in 1986, he worked as instructor and assistant professor in the field of radiation therapy at Harvard Medical School, Cambridge, USA. As a medical specialist for general surgery, he became assistant professor in surgery in 1997. At present he is working as a general and vascular surgeon at the Department of Surgery, University of Heidelberg. In 1994 he founded the Computer-Based Training Laboratory and has been the project director of this laboratory up to today.