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Efficacy of CAI for postoperative nursing based on analysis of learning histories

—Learning achievements for low, moderate and high-performance groups as assessed by analysis of cumulative correct response rates—

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Abstract

Our CAI is a multimedia self-learning material incorporating videos, pictures, X-rays, and audio-based information obtained from patients who underwent gastrectomy under general anesthesia. Because our previous study (Takeuchi et al., 2004) did not analyze the final cumulative correct response rates for the entire courseware, the present study assessed them to clarify the efficacy of multimedia CAI materials. Based on the learning history of each learner, the learning process of low-, moderate- and high-performance groups was ascertained by item analysis of test theories.

The results showed that the average correct-response rate for the final test was 84.6%, and from the viewpoint of goal achievement, the present learning material therefore appears to be effective. Furthermore, when comparing the initial and final cumulative correct response rates, multimedia CAI learning was able to raise the knowledge level of the learners and reduce the differences among the low, moderate and high-performance groups.

Key words

computer assisted instruction(CAI), multimedia, learning history, evaluation, postoperative nursing

Introduction

Although learning is difficult without clinical experience, previous studies have reported numerous advantages in introducing multimedia teaching materials for nursing education, which faces various constraints on training in clinical settings [1)-2)]. However, simulations using a variety of media such as audio, photographs, and video without understanding their significance and essential function may limit their role and not necessarily increase instructional effectiveness [3)].

A survey of previous studies concerning the evaluation of multimedia computer assisted instruction (CAI) conducted in Japan and overseas showed that nearly all involved the evaluation of results of written tests before and after CAI learning or comparisons with lectures or similar types of instruction [4)-12)]. According to a review of 25 studies assessing computer-based learning, the conclusions drawn by these studies are not necessarily valid due to problems such as very low sample size, insufficient control groups and important design defects [13)].

Here, we examined the learning histories of students who took CAI-based learning classes. We then analyzed learning in terms of the number of responses per question, the degree of achievement, the frequency of incorrect responses and total scores in an attempt to determine how the students answered the questions and to clarify the effectiveness of the courseware, as well as its shortcomings. In the first study, we analyzed learning histories using multimedia CAI materials that we developed to clarify the characteristics and efficacy of multimedia CAI learning based on the number of responses per frame and degree of achievement [14)]. Because the previous study did not analyze the final cumulative correct response rates for the entire courseware, the present study assessed them to clarify the efficacy of the multimedia CAI materials. The present study investigated the efficacy of the CAI materials by examining the entire courseware based on learning histories, and it should serve as basic data for the investigation of CAI and the development of CAI materials from different perspectives.

I. Objectives

The objective of the present study is to clarify the effectiveness of multimedia CAI materials via analysis of learning histories. By comparing and analyzing the initial and final cumulative correct response rates using figures, the present study aims to identify the degree of learning achievement for low, moderate and high-performance groups.

II. Methods

1. Scope of the study

1) CAI courseware

Theme: 24-h postoperative nursing care

The courseware examined was multimedia CAI courseware for self-learning that combined a practice-exercise format with a simulation format. The courseware incorporated video, photographs, X-ray images and audio. The investigators began developing the courseware in 1999 with the objective of using CAI to simulate the nursing care of patients in the acute postoperative period, for which on-site training is difficult, and thereby improve the problem-solving abilities of nursing staff [15)].

The present courseware consists of a total of 145 frames: Frame A contains 40 essential frames, and includes the title page, presents learning targets and introduces patients; Frame B contains 34 essential frames and deals

with nursing care immediately after patients return to their wards; Frame C contains 25 essential frames and deals with nursing care within two hours of returning to wards; Frame D contains 26 essential frames and deals with nursing care from 8 to 24 hours after returning to wards; and Frame E contains20 essential frames and deals with assessment. Of the 145 frames, 40 frames ask questions (Figure 1. Course overview).

The material was developed using Study Writer for Windows, version 3.0.

Validity and reliability of teaching material: The 40 questions were prepared in the form of an absolute-criteria test and were based on 40 behavioral objectives corresponding to 8 learning objectives. To improve the suitability of the material, 3 individuals who had been instructors for at least 5 years and who had specialized in acute adult nursing examined whether the objectives reflected the theme, whether the structure of the questions was correct, and whether the questions faithfully reproduced conditions, behavior, and criteria described in the objectives. The concordance rate between the 3 individuals with respect to the structure of questions concerning objective categories was 100%. Trials were performed with 4 students who had previously been asked to use the material, and examination of reliability showed no variability in the grades given by the 3 instructors.

2) Subjects

Subjects were 63 second- and third-year nursing students at a four-year nursing school who had completed lecture instruction on acute adult nursing but had not received training in clinical nursing and who agreed to participate in the study (30 second-year and 33 third-year nursing students).

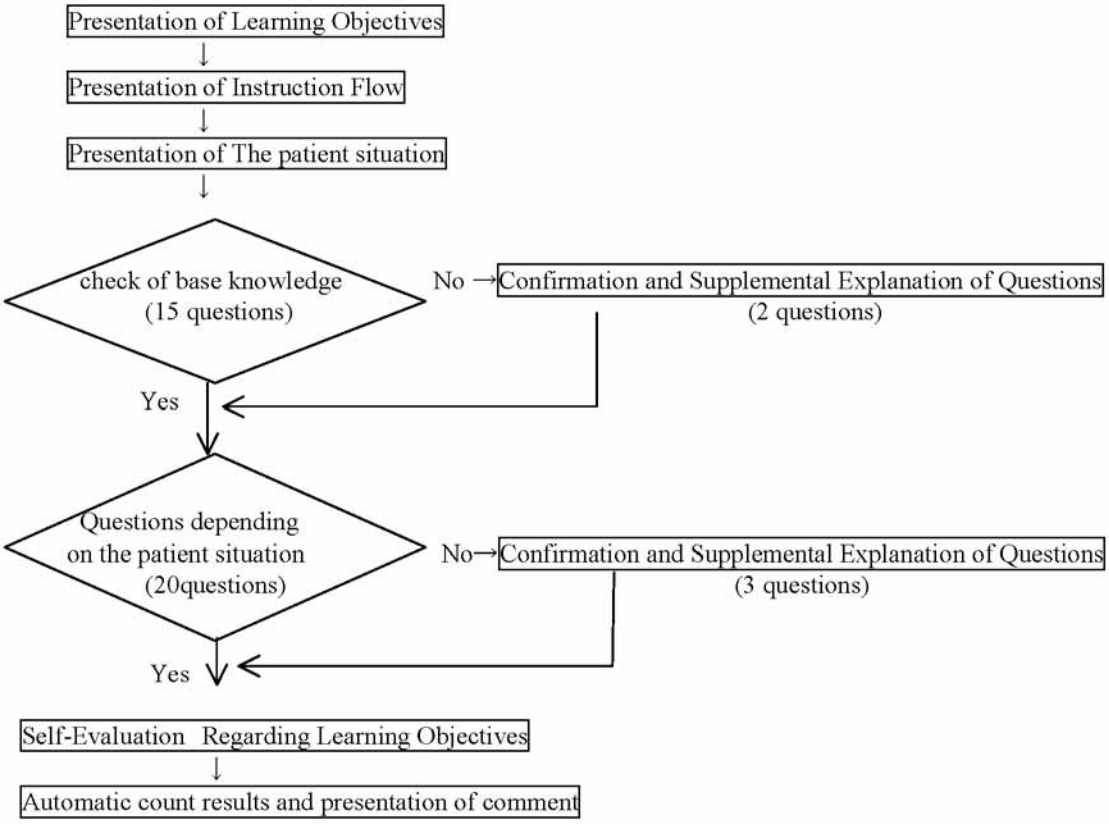

Figure 1. Course Overview

Since this study investigated the effectiveness of multimedia CAI course ware which enabled real-time learning, and did not discuss about relative effectiveness or equity of the instrument compared with other study methods, reference or control groups were not necessary demanded.

2．Study procedures and ethical considerations

1) In September 200x, a written request for research volunteers, which described the main points of the study, was distributed to 158 second- and third-year students.

2) Sixty-three students expressed an interest in participation and visited the investigators. It was again explained to the students orally that participation would be voluntary and would have no effect on their performance evaluations and that their names would be encoded to protect their privacy. Subjects then consented to participate in the study.

3．Study methods and period

CAI courseware was provided over the college's local area network using a PC room equipped with 60 personal computers configured so that the learning records were recorded on the instructor's computer. The tests were conducted on September x and October x, 200x. The use of textbooks and speaking with acquaintances were prohibited, and the investigators observed the circumstances under which the instruction occurred.

4．Measurement instruments

The software used to automatically obtain the CAI learning records over the network was Study Net for Windows (version 3.0). The history of responses and answers was recorded frame-by-frame for each learner.

5．Analysis

As an analysis method based on learning histories, we prepared correct response rate curves based on item-characteristic curves [16-17], and then interpreted the results using these curves [14]. The number of subjects in the study (63) was inadequate to provide a detailed and reliable item characteristic curve. Consequently, the subjects were divided into three ability levels and the characteristics of each item were shown by the correct-response rates of these groups.

Since the correct initial response rate was considered to be a reflection of subject ability, assignment of the subjects to three groups was based on the distribution of the total number of correct answers given as the first response on items that all subjects were required to answer. The low-performance group was composed by who took lower than or equal to the mean－1 SD points, the moderate-performance group was composed by who took between upper than the mean－1 SD and lower than the mean＋1 SD points, and the high performance group was composed who took upper than or equal to the mean＋1 SD points.

For many of the items in the teaching materials developed for this study, if an incorrect answer was given, the subject could obtain assistance and make several attempts to answer the same item. To determine the change in the correct response rate as the number of responses increased, the initial and final cumulative correct response rates for each question were determined and the rates were graphed for analysis. The initial correct response rate for a question was the proportion of subjects who gave correct responses for the question at the first response among the total number of subjects who took the question. The final cumulative correct response rate for a question referred to the proportion of subjects

who gave correct response on the final attempt among the total number of subjects who took the question.

The analysis software used was SPSS version 10.0J for Windows. Significance testing was performed using Fisher's exact test, with a significance level of 0.05. For the tests of the length of learning time and the number of repeat frames, ANOVA and Tukey's multiple comparison test were used.

III Results

1. Mean correct response rate for all questions and learning time

Overall trends were examined before performing analysis based on learning history. The mean correct response rate for the initial responses to the 40 questions included in the teaching material was 66.6%, and the mean final correct response rate was 84.6%. Thus, an increase of 18.0 points from the initial response rate was seen. For the 30-item module (group of questions for which 2 or more responses were permitted), which excluded 10 items for which only 1 response was permitted (mean correct response rate, 61.2%), the mean initial correct response rate for the initial response was 68.4%, and the mean final correct response rate was 92.3%, a 23.9-point increase.

The average length of time to complete the course (learning time) was 40 minutes and 48 seconds (standard deviation: 13 minutes and 3 seconds). The minimum number of frames that each student must view to complete the course is 83, while the other 62 frames provide additional explanations that students may view if they wish or supplementary explanations that students are required to view when incorrectly answering certain questions. Subsequently, the learning time ranged widely from 11 minutes and 0 seconds to 82 minutes and 16 seconds.

2. Subject grouping

All subjects were required to answer 35 of the questions, and the results of the initial responses to these questions were used to group the participants (5 of the 40 questions on the test were omitted). To calculate the total number of correct initial responses to these 35 items, each correct answer was assigned a value of 1 point, each incorrect answer was assigned a value of 0 points, and the total score for each subject was determined (results for initial response). The mean score for the initial response was 24.32 (correct response rate, 69.5%), the standard deviation was 3.14, the minimum was 16, and the maximum was 33. The mean score for the final response was 31.1 (correct response rate, 88.9%), with a standard deviation of 1.56, a minimum of 28, and a maximum of 35.

As mentioned above, subjects are divided into three ability groups. The 16 subjects (11 second-year and 5 third-year nursing students) with a score of ≦ 22 points (mean－1 SD = 21.18) were assigned to the low-performance group, the 33 subjects (17 second-year and 16 third -year nursing students) with a score between 23 and 26 points were assigned to the moderate-performance group, and the 14 subjects (2 second-year and 12 third-year nursing students) with a score of ≧ 27 points (mean + 1 SD = 27.46) were assigned to the high-performance group.

Since these groups were divided with the initial scores of each subjects, elder grade students were tend to be included in higher-performance group. However, this did not mean that the elder, the clever. The initial score reflected the initial ability of the domain studied by this course ware. Hence lower grade students who learn less than upper grade students were tend to get lower initial score,

although they acquired high ability as at the grade.

3. Analysis of correct response rates for low-, moderate- and high-performance groups

Figure 2 shows the initial correct response rates for the three groups, while Figure 3 shows the final cumulative correct response rates. The questions were divided into those allowing multiple responses to be input and those allowing a single response to be input. For each group, frames were aligned in decreasing order of the final cumulative correct response rates from left to right. Here, if final cumulative correct response rates were the same, frames were aligned in the order of presentation.

The left 30 frames from D516 to B101 allowed multiple responses to be input, while the right 10 frames from B221 to D520 allowed single responses to be input. When comparing the upper figure showing the initial response rates and the lower figure indicting the final cumulative correct response rates, the curves

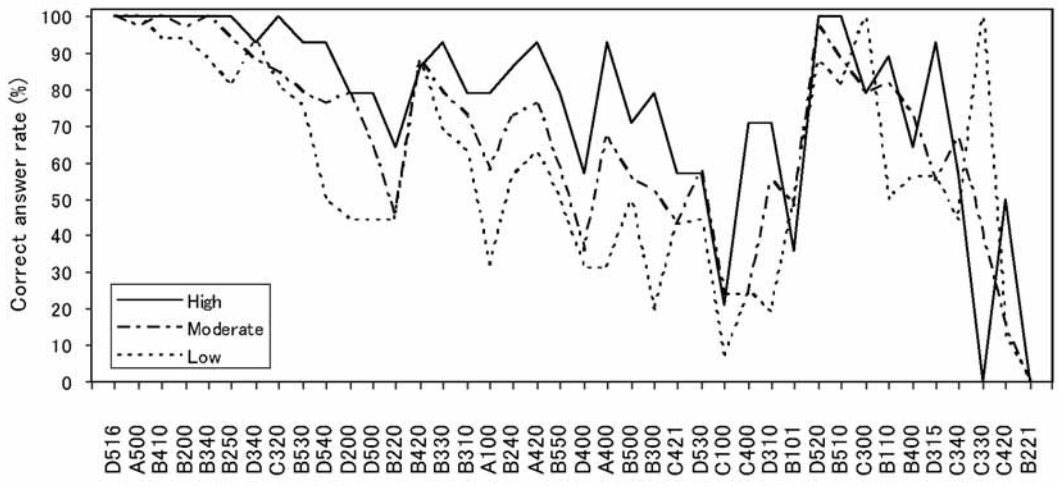

Figure 2. Correct answer rates at the initial response

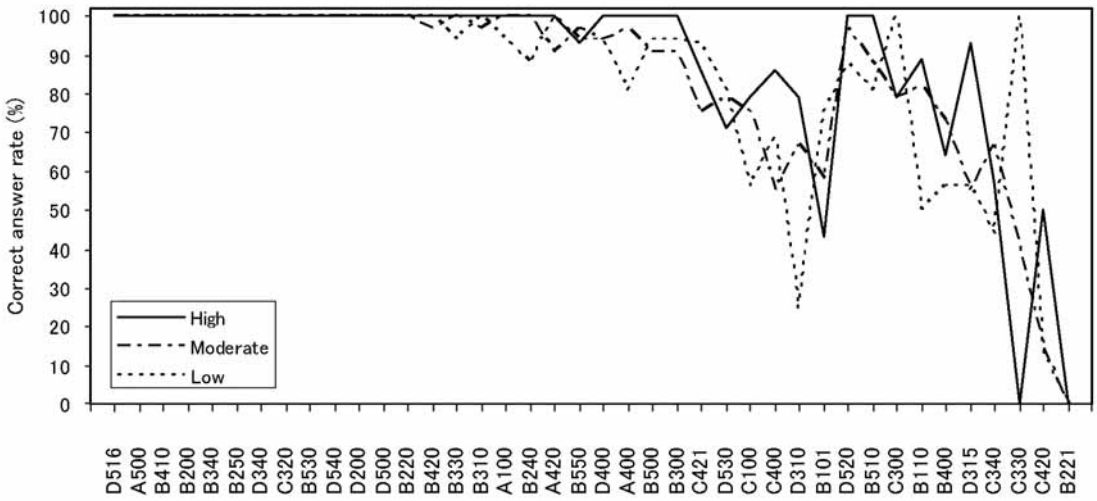

Figure 3. Correct answer rates at the final response

for the right 10 frames were exactly the same because these frames represented questions where only a single response was allowed.

Here, the frames with low final cumulative correct response rates for the low-, moderate- and high-performance groups and the degree of learning improvement for the three groups were analyzed.

(1) Results for the high-performance group

For the high-performance group, the correct response rate for the first six left frames was 100% from the beginning (Figure 2). Next, for the high-performance group, the correct response rate reached 100% for 17 frames and ≥80% for 5 frames, and in the remaining two frames, the final correct response rate for D530 was ≥ 70% but that for B101 was 42.9%. However, B200 was the confirming question for B101, and its correct response rate was 100% (Figure 3).

B101 (Figure 4) dealt with post-anesthesia recovery, and the subjects watched a video clip of a nurse interacting with a patient who had partially recovered from anesthesia. If this question was incorrectly answered, the same video was played again to allow the subjects further consider post-anesthesia recovery. In other words, if B101 was correctly answered, the subjects moved on to B200, which dealt with the definition of partial post-anesthesia recovery. However, if B101 was incorrectly answered, the subjects moved on to B110, which gave additional hints and asked the subjects "How did the patient in the video respond to the nurse's inquiries". If B110 was correctly answered, the subjects then moved on to B200; however, if B110 was incorrectly answered, the subjects again watched the video and moved back to B101. In other words, the subjects could correctly answer neither B101 nor B110 if they did not watch the video from the viewpoint of nursing. B200 was designed to determine whether the subjects understood post-anesthesia recovery, and could only be answered correctly if the subjects viewed the video and understood the definition of anesthesia recovery. The initial correct response rate for the high-performance group was 35.7% (5/14), and many subjects confused partial post-anesthesia recovery with full post-anesthesia recovery. However, the initial correct response rate for B110 (the question

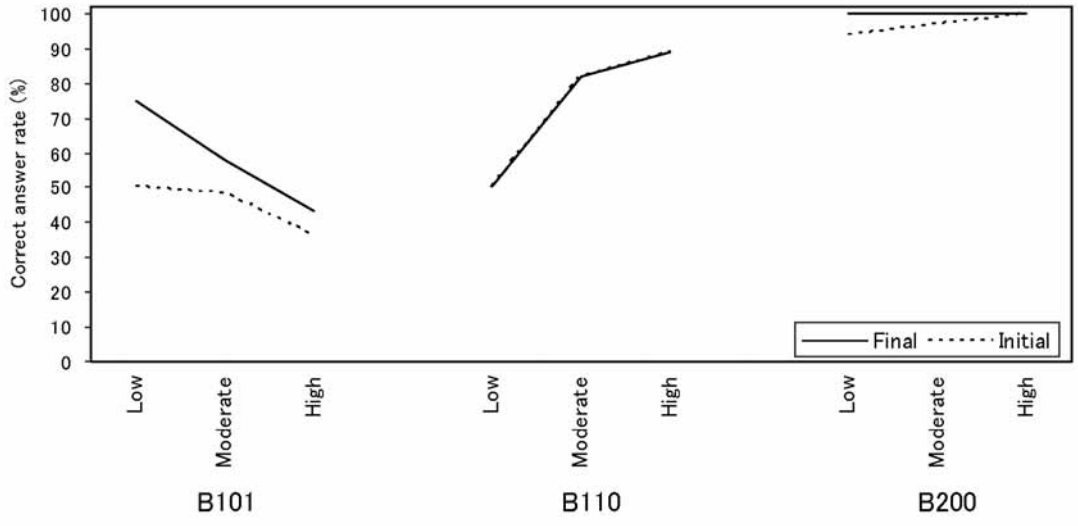

Figure 4. Correct answer rates at the initial and the final response for the learning module —partial post-anesthesia recovery—

posed when incorrectly answering B101) was 88.9% (8/9), thus confirming that the subjects correctly processed the information presented in the video.

(2) Results for the moderate-performance group

For the moderate-performance group, the initial correct response rate for three frames (D516, B410 and B340) was 100% (Figure 2). The final cumulative correct response rate then reached 100% for 13 frames and ≥80% for 8 frames, and in the 6 remaining frames, the final cumulative correct response rate was ≤ 50% for B101 at 48.5%, as was seen in the high-performance group. However, the final cumulative correct response rate for B200 (the confirming question for B101) was 100% (Figure 3).

(3) Results for the low-performance group

For the low-performance group, the initial correct response rate for two frames (D516 and A500) was 100% (Figure 2). Then, for the low-performance group, the final cumulative correct response rate reached 100% for 14 frames and ≥80% for 9 frames, and in the remaining 5 frames, the correct response rate was the lowest for D310 (Figure 3) with initial and cumulative correct response rates of 18.8 and 25.0%, respectively. However, as mentioned below, D340 was the final confirmation question for D310, and its final cumulative correct response rate was 100%.

D310 dealt with the breathing sounds of a patient who had just undergone surgery (presented in D300). D310 was a virtual-reality frame where the subjects could move the stethoscope on the screen using the mouse to listen to lung sounds. In the left lower lung field, discontinuous rales were audible (abnormal sounds associated with atelectasis, a postoperative complication), and normal sounds were audible in the other areas. If D310 was correctly answered, then the subjects moved onto D315, which dealt with the differences between continuous and discontinuous rales. If D310 was incorrectly answered, the subjects moved back to D300 to listen to the breathing sounds again and were instructed to answer D310, without any additional hints. Next, whether answered correctly or incorrectly, the subjects moved onto D320 to learn about the differences between discontinuous and continuous rales and were instructed to answer D340. In other words, D340 was designed to confirm whether the subjects understood the topic covered in D310.For the low-performance group, the initial correct response rate for D340 was 93.8%, and the final cumulative correct response rate was 100%.

(4) Learning improvement for the low-, moderate- and high-performance groups

When examining the initial correct response rates for the low-, moderate- and high-performance groups, the three lines did not cross in any frame, and there were marked differences between the low and high-performance groups (Figure 2). However, in terms of final cumulative correct response rates, the results improved for all three groups, and the differences among the three groups decreased. The final cumulative correct response rates for the left 13 frames (D516-B220) was 100% for all three groups (Figure 3).

The initial correct response rate for B101 was 50.0% (8/16) for the low-performance group, 48.5% (16/33) for the moderate-performance group and 35.7% (5/14) for the high-performance group, but a Fisher's direct probability test did not show any significant intergroup differences (n.s.). In addition, the initial correct response rate for B200, which reviewed partial post-anesthesia recovery, was very high for all three groups (low-

performance group, 93.8%; moderate-performance group, 97.0%; and high-performance group, 100%) (n.s.) (One incorrect answer each for the low- and moderate-performance groups) (Figures 2 and 4).

The initial correct response rate for D310 was 18.8% (3/16) for the low-performance group, 54.6% (18/33) for the moderate-performance group and 71.4% (10/14) for the high-performance group, and a Fisher's direct probability test showed that the correct response rate for the high-performance group was significantly higher ($p<0.01$). In D340, the subjects learned about the differences between discontinuous and continuous rales and again performed chest auscultation. The initial correct response rate for D340 was 93.8% (n=15) for the low-performance group, 87.9% (n=27) for the moderate-performance group and 92.9% (n=13) for the high-performance group (n.s.), thus confirming that high correct response rates were achieved by the subjects in the low- and moderate-performance groups who did not initially have the correct idea about discontinuous rales (Figures 2 and 5).

4. Learning time and repeated learning for the low, moderate and high-performance groups

The average length of time to answer the question frames for the low, moderate and high-performance groups was 13 minutes and 37 seconds, 13 minutes and 9 seconds and 12 minutes and 2 seconds, respectively. The average length of time for the overall course combining the question and explanatory frames for the low, moderate and high-performance groups was 37 minutes and 44 seconds, 41 minutes and 45 seconds and 42 minutes and 6 seconds, respectively. However, these differences were not statistically significant.

The average total number of frames repeated for the low, moderate and high-performance groups was 52.1, 48.6 and 43.1, respectively. Each difference was statistically significant using Tukey's multiple comparison test. This result demonstrated that higher levels of performance were associated with lower numbers of repeated frames.

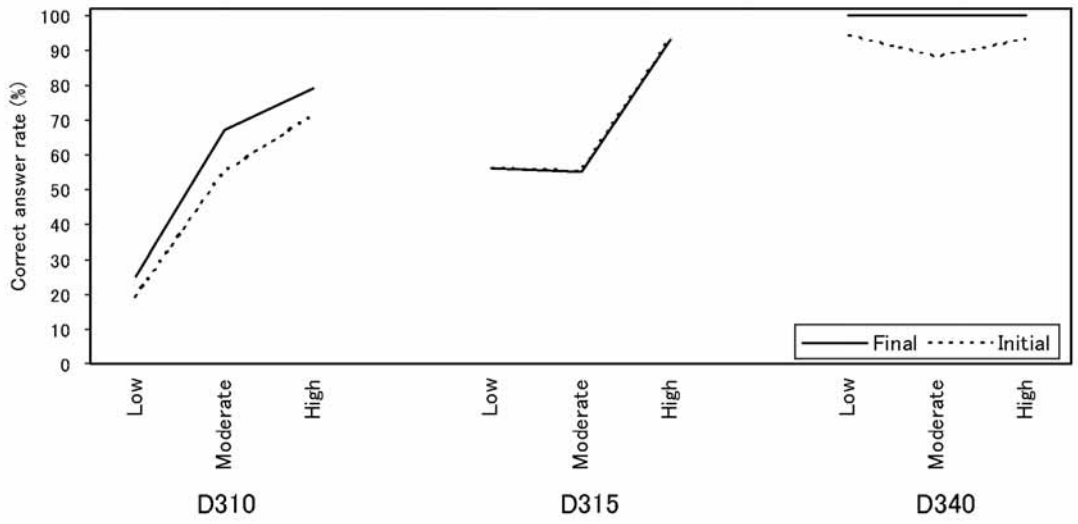

Figure 5. Correct answer rates at the initial and the final response for the learning module —discontinuous rales—

IV. Discussion

1. Mean correct response rate for all questions

For traditional group classes, correct-response rates of 60% to 80% for all learners have been established as indicating target achievement (performance). In contrast, levels of 80% and higher are typically used as the criterion for target achievement with individual instruction by CAI [18]. The recommended criterion for effectiveness in target achievement with the Codebdel training method [19], a standard method used for telecommunications training, is the 80/80 criterion (≥80% of learners achieve a score of ≥ 80 points). From this perspective, the teaching material used in the courseware described here, which had an overall final mean correct response rate of 84.6% and a final mean correct response rate of 92.3% for the module questions, fulfilled the overall criterion for efficacy. However, as discussed below, there were some questions for which a final correct-response rate of 80% was not achieved. These questions will require detailed analysis and improvement.

2. Analysis of correct response rates for the low, moderate- and high-performance groups

For the high-performance group, the final cumulative correct response rate for B101 was the lowest. B101 dealt with partial post-anesthesia recovery. By combining video presentation and the definition of post-anesthesia recovery, the cumulative correct response rate for B200 (designed to confirm that the subjects understood post-anesthesia recovery) was 100% for the low, moderate and high-performance groups. In other words, all subjects understood post-anesthesia recovery. Judging post-anesthesia recovery was the module with the highest improvement rate for the moderate and high-performance groups, and this supports the effectiveness of video as an audiovisual learning material. The presentation enabled subjects to link the individual points comprising the definition of partial post-anesthesia recovery with the generalized response of the patient shown in the video (simultaneous opening of eyes and replying when called to, followed by response to a command but immediate closing of eyes). It was surmised that this approach to learning, by enabling the recognition of information in a form closely related to the information provided in the images, may increase learning effectiveness for settings where information can be expressed as images but is difficult to express in writing, making conceptualization difficult. We hope to examine this point as a topic of future investigation.

For the low-performance group, the lowest final cumulative correct response rate was for D310, which dealt with discontinuous rales. When learning sounds, there are limits to textbook learning. The CAI used in this study allowed the learner to hear sounds while explaining with figures how the abnormal sounds occur. Repetition of this type of instruction results in a stepwise deepening of the learner's understanding. This was evidenced by the fact that instruction using the courseware enabled the subjects in the low-performance group, whose initial (D310) correct response rate was low, to increase to a rate comparable to that of the high-performance group (low-group, 93.8%; moderate-performance group, 87.9%; and high-performance group, 92.9%) on the confirming question (D340) (Figures 2 and 5).

In addition, subjects were asked several times to use the mouse to place a stethoscope on a drawing of the body and listen to breathing sounds. This type of virtual reality simulation

is an advantage of CAI. It has been reported that individuals who received only auditory stimulation remembered 20% of the material presented, those who received both auditory and visual stimulation remembered 40%, and those who acted on the auditory and visual stimulation remembered 75% [2]. The instruction on discontinuous rales in this study required integrated activity, whereby a mouse-operated figure of a stethoscope was placed (action) over a drawing of a body (visual stimulation), and the sites of normal lung sound auscultation and abnormal lung sound auscultation (auditory stimulation) were determined. It also required high-level thinking to determine the abnormality. Although these nursing activities are routinely required in clinical settings for the early detection of abnormalities, such settings are not conducive to on-site training, and thus virtual reality instruction is likely to be effective.

The final cumulative correct response rate for all three groups increased and the rate of improvement was particularly high for the low-performance group. Therefore, it could be deduced that CAI-based learning increased the knowledge level of learners; this was particularly apparent in the low-performance group. However, little increase was seen for the high-performance group. Hence, no conclusive findings were obtained. Nakayama [18] reported that the score distribution for learners was wide for traditional classes and the difference between high and low score-learners was high, but with CAI-based learning, scores for everyone were high, and the distribution of scores was narrow and steep. Moreover, Hayashi [20] compared intervention using pamphlets and that using CAI-based courseware incorporating figures and pictures, and documented that while CAI was effective in increasing the knowledge level of everyone to comparable levels, pamphlets increased the knowledge level of subjects, but were not as effective in improving the knowledge level of low-score learners. Furthermore, Maruyama [21] compared a group with CAI-based self-learning incorporating video and a group with self-learning based on video cassettes; both groups learned the knowledge and skills for intramuscular injection. They reported that recognition was significantly greater for the CAI group when compared to the video group, and that although there was no significant intergroup difference in skill, the degree of fluctuation in skill acquisition among learners was smaller. The finding that the knowledge level of learners could be raised supports previous studies and is one of the characteristics of multimedia CAI learning.

3. Analysis of repeated learning and learning time for the low, moderate and high-performance groups

The results showed that higher levels of performance were associated with lower numbers of repeated frames. As the subjects were divided into three performance groups based on initial scores, it is unsurprising that the subjects with higher scores answered fewer questions and viewed fewer frames.

Conclusions

1. When comparing the initial and final cumulative correct response rates, multimedia CAI learning was able to raise the knowledge level of the learners and reduce the differences among the low, moderate and high-performance groups.
2. The correct response rates were nearly 100% in the high-, moderate- and low-performance groups for such frames that utilized the most prominent features of

multimedia CAI , that is, auditory stimulation provided by sound, visual stimulation provided by drawings and photographs, and actions (using the mouse) in response to these stimuli. This result verified the effectiveness of teaching with multimedia, including virtual reality simulations.

3. However, subjects were less likely to be able to accurately express the relevant concepts if subjects merely watched videos without adequate instructions, although subjects may understand the images. When combining video presentation with definitions and explanations, scores improved in all groups, thus suggesting the effectiveness of this learning strategy.

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テスト理論の項目分析に基づいた術後看護用CAI教材の有効性

－累積正答率の分析による成績低・中・高群の学習達成度－

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要　旨

筆者らが開発したコンピュータ教材（CAI）は，実際に全身麻酔で胃切除術を受けた患者から得た情報を基に，ビデオ映像・写真・音声などを組み込んだ自己学習教材である。本研究は，前回の報告（竹内他，2004）を発展させたものであり，前回分析しなかった最終累積正答率の分析を行うことによって，マルチメディア CAI 教材の有効性を評価するものである。分析に当たっては，各学習者の学習履歴をとり，そのデータをテスト理論における項目分析の手法を利用して，成績低群・中群・高群の学習過程を検討していった。

その結果，全体の最終平均正答率は84.6%であり，学習目標の達成基準を満たす教材であることが確認できた。さらに，初回正答率と最終累積正答率を比較した結果，マルチメディア CAI による学習は，学習者の知識水準を一定以上引き上げることができ，かつ成績低群・中群・高群の差が縮まるということが明らかとなった。

キーワード

コンピュータ支援学習（CAI），マルチメディア，学習履歴，評価，術後看護