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Original Article

Effects of an interactive simulation material for clinical dentistry on knowledge acquisition and memory retention in dental residents

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With the development of technology, the knowledge and skills needed to become a dentist are increasing. Computer-assisted simulation learning materials have been utilized for dental education because of their high efficiency and efficacy. However, it is not well understood which material design is strongly associated with an education effect. We therefore investigated the effects of interactivity with learning materials on learners' knowledge acquisition, memory retention, and anxiety reduction. Learning effects and degree of anxiety were compared between dental residents who learned using an interactive-type material, which required decision making and provided feedback (Group I, n=26), and those who learned using a display-type material, which merely displayed the appropriate action on a computer screen (Group D, n=23).
Quiz scores immediately after learning and 3 weeks later were significantly higher in Group I than those in Group D (*p*<0.001 and 0.016, respectively). Regarding anxiety, state anxiety after learning with interactive material was significantly decreased in Group I (*p*<0.05), whereas no significant change was observed in Group D.
Our results suggest that interactivity with computer-assisted simulation materials is more effective for knowledge acquisition, memory retention, and anxiety reduction.

Key Words: Simulation Training, Memory Retention, Teaching Methods, Computer-assisted Instruction, Dental Education.

Introduction

With the development of technology, the knowledge and skills needed to become a dentist are increasing annually. As a result, dental schools and hospitals are currently facing a paradigm shift in their teaching methods. The amount of time available to teach students has remained constant over time, however, the content that needs to be taught is increasing[1, 2]. To acquire clinical knowledge in dentistry, treating patients in clinical practice is considered most effective. However, the number of

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cases that can be experienced by dental students during dental school training is limited[3]. Factors such as geographical location and school and hospital features may also affect the number of suitable cases for clinical education of dental students or residents[4, 5]. Computer-assisted simulation learning materials can help to reduce the burden on educational institutions and equalize the educational opportunities in each organization because of their high efficiency, high efficacy, and standardization of experiences. Therefore, computer-assisted simulation materials have been utilized as a relatively novel method for teaching in dentistry[6, 7]. Tokyo Medical and Dental University (TMDU) has also used computer-assisted simulation materials for teaching dental students, which are held in good repute and educational effect[8–11] .

There are various kinds of computer-assisted simulation materials with several instructional designs, such as interactivity, effectiveness of audio/visual aids, or virtual realism. The learning effects of these materials have been reported in numerous studies[12–16]. However, the particular design of computer-assisted simulation materials that is strongly associated with an education effect is unclear. Some studies have focused on the effect of the materials' interactivity. Maggio et al. reported that interactive computer-assisted learning materials on tooth morphology with quizzes resulted in higher quiz scores, aggressiveness, and student satisfaction than traditional lecture video materials created with Microsoft PowerPoint[17]. Additionally, video learning materials that can be freely selected, played, and replayed by students led to better learning results and student satisfaction compared to video materials that cannot be freely selected, played, and replayed or paper-based lectures[18]. Although the learning materials used in these studies were designed as interactive materials, they did not assess decision-making processes such as solving problems. Therefore, the learning effect of interactive learning materials with learners' decision-making is still unknown.

In medical education, some studies have focused on the effects of computer materials using moving images on memory retention. For example, in medical students, materials with moving images about learning rare, but critical cases were superior for memory retention than similar materials using traditional Microsoft PowerPoint presentations[19]. Yang et al. also reported that computer materials about medical cases that emphasized important points by using images and moving images were more effective for memory retention than conventional text-books[20]. However, it remains unclear which design of computer-simulated materials, such as interactivity, the effect of images and moving images, or both, results in these learning effects.

Few studies have focused on the effect of interactive learning materials with learners' decision-making. Our previous study reported that interactive materials that incorporate clinical decision-making could be effective in knowledge acquisition compared to non-interactive materials[11]. However, it is unclear whether interactive materials would be effective for memory retention.

Another important factor that can affect learning is stress. Sugiura et al. and Polychronopoulou et al. reported that dental students experience considerable stress[21, 22]. Moreover, anxiety may influence the learner's performance and practice outcomes[23]. Thus, reducing students' anxiety is an important issue in dental education.

We hypothesized that interactive computer-assisted simulation materials with decision-making and feedback are not only effective for knowledge acquisition, but also for memory retention. We also hypothesized that the use of such materials can effectively reduce anxiety.

Therefore, the purpose of this study was to evaluate the effect of decision-making with provided feedback during learning with interactive computer-assisted simulation materials on knowledge acquisition, memory retention, and reduced anxiety compared to learning with non-interactive materials.

Materials and Methods

The Ethics Committee of TMDU School of Dentistry approved this study (No. 1146). We enrolled 64 dental residents in year 2015 at TMDU Dental Hospital. We created learning materials to teach "rapid response to an acute change in an inpatient's condition" with SIMTOOL, an authoring tool for clinical simulation material development that was developed by TMDU staff in 2003. Faculty members, including those who are not computer experts, can use SIMTOOL to create simulation-learning materials easily with images, audio, and videos[9, 10].

We created two types of learning materials, interactive-type and display-type (Figure 1). In the interactive-type learning material, the learners were prompted to decide what to do next by selecting an appropriate answer among several presented alternatives when facing the situation, "an acute change in an inpatient's condition." On the next page, the learners were told whether their choice was correct and received feedback and explanations of their choices. Before advancing to the next page, they were also given commentary for the

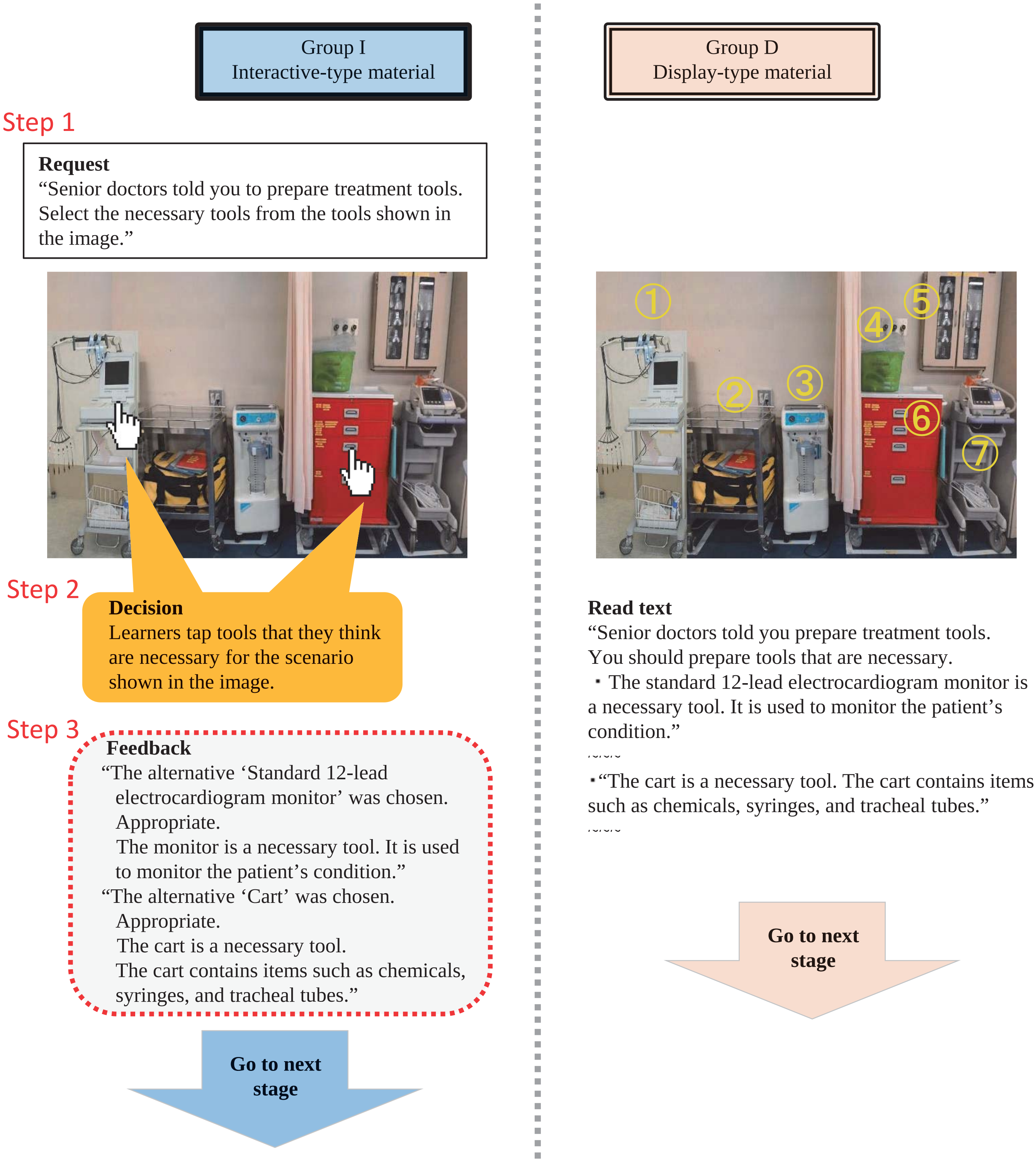

Figure 1. Examples of both learning materials.

Participants in Group I had to make decisions that seemed appropriate in the presented scenario. Participants in Group D read the correct response and explanations for the same scenario shown in Group I. Both learning materials used the same description and images.

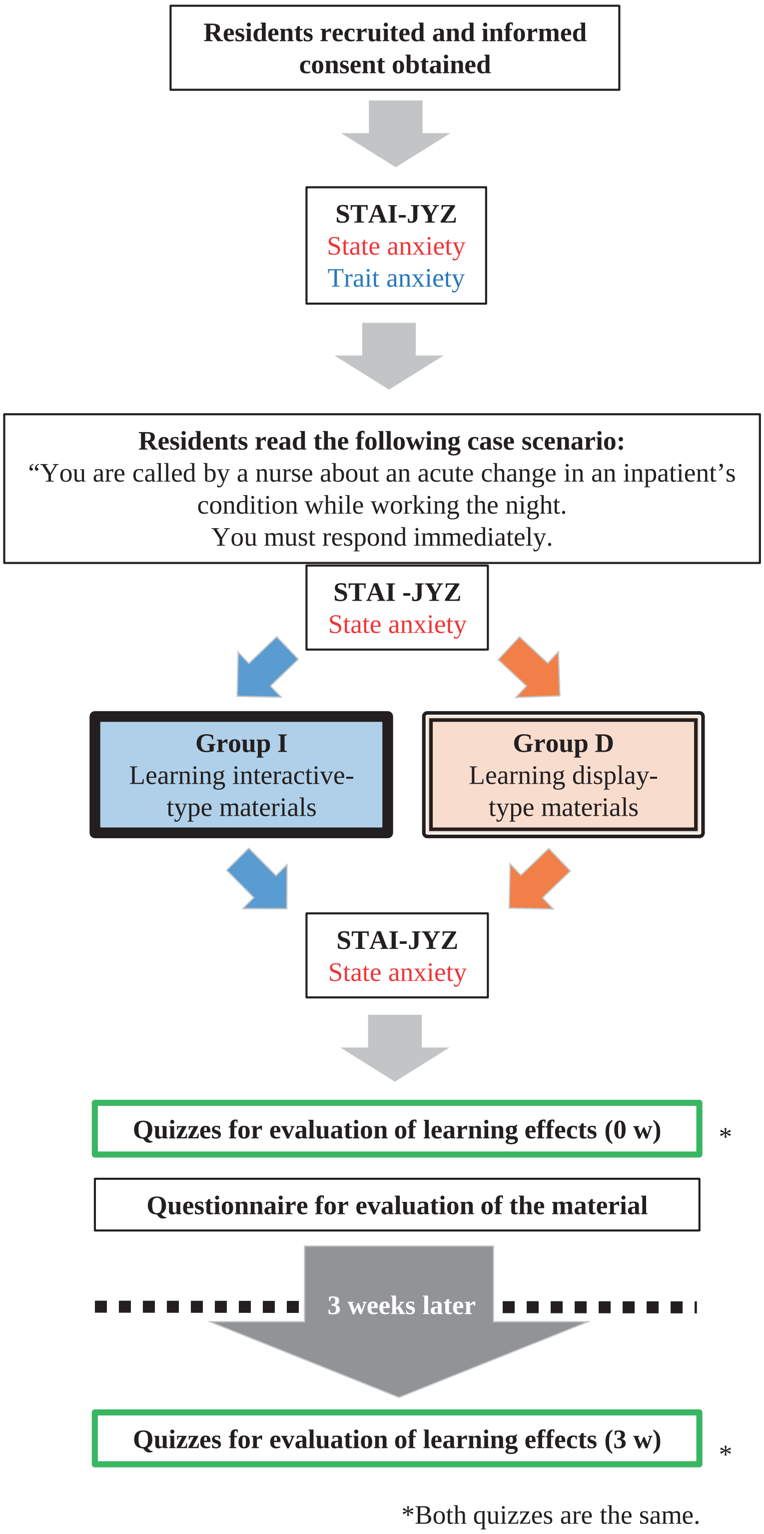

Figure 2. Flowchart of experimental procedure for Groups I and D.

alternatives that they did not choose. In the display-type learning material, the learners read the appropriate action and explanations. Thus, the display-type learning material did not request the learners to make decisions. Except for the factor of the decision-making process in the interactive-type learning material, all other contents, sentences, and images used in learning materials were the same. Thus, learners in both groups obtained the same information at the end of learning with both materials.

The State-Trait Anxiety Inventory-JYZ (STAI-JYZ) was utilized to measure learners' anxiety. The STAI-JYZ was originally developed by Spielberger et al. and revised for Japanese individuals by Hidano et al. in 2000; it measures two types of anxiety: state and trait anxiety [24, 25]. State anxiety refers to the current state of anxiety, nervousness, and stress. Trait anxiety refers to the tendency for a stable personality to become anxious when subjected to stress.

We randomly divided the 64 participants into two groups, Groups I and D. As 38 of 64 participants were TMDU graduates, randomization was stratified according to dental school where the participant had received dental education (e.g., TMDU graduate or other dental school graduate) and sex. All participants were blinded to group assignments during learning. Figure 2 shows the experimental procedure in both groups. Informed consent was obtained from all residents prior to starting the first STAI-JYZ test. First, learners took the STAI-JYZ to measure their trait and state anxiety, and then they read a scenario that required a rapid response to an acute change in a patient's condition. Immediately after reading the scenario, they took the STAI-JYZ test to measure their state anxiety only. Then, participants in Group I learned with interactive-type material, while participants in Group D learned with display-type material. After learning with the respective materials, all learners took the STAI-JYZ test to measure their state anxiety, took quizzes to evaluate the learning effect of the materials, and completed a questionnaire to evaluate the material usability and effectiveness of reducing anxiety and improving self-confidence. Learners completed all tasks at their own pace. In addition, before starting the simulation, learners in both groups were informed that they could not return to previous pages after moving on to the next page. After 3 weeks, learners re-took the same quizzes to measure memory retention of the materials[19].

Learning materials, quizzes, and the questionnaire were accessed and completed on the WebClass™ (Data Pacific (Tokyo, Japan) Ltd., Japan) e-learning system. The learning effect was then evaluated as follows. Personal information, such as the learner's name, time taken to complete tasks, and group assignment was anonymized. Scores point values assigned to each question and scoring criteria were established, and scores were graded by three blinded evaluators. Comparisons of quiz scores of the two groups were analyzed by the Mann-Whitney *U* test. Changes in the quiz scores of each group from immediately after learning (0 w) to 3 weeks later (3 w) were analyzed by the Wilcoxon signed-rank test. Comparisons of trait and state anxiety of the two groups were analyzed by the Mann-Whitney *U* test. Changes in state anxiety scores between examination points were analyzed in both groups by the Wilcoxon signed-rank test with Bonferroni correction. Regarding the questionnaire, we categorized results according to learning group (Group I or D) and responses (positive or negative) and conducted a 2×2 Chi-square test for each question. All statistical analyses were conducted using IBM SPSS (version 24) (IBM, Armonk, NY, U.S.A.), and p values <0.05 were considered statistically significant.

Results

We posted a request for 64 residents to take part in the study on a notice board, and a total of 49 residents signed-up for the study. Informed consent was obtained from all participants before administering the first STAI-JYZ test. Forty-nine residents (Group I: n=26, 13 males and 13 females, 15 TMDU graduates and 11 other dental school graduates; Group D: n=23, 10 males and 13 females, 13 TMDU graduates and 10 other dental school graduates) participated at 0 w. Three weeks later, 32 residents (Group I: n=18, Group D: n=14) participated in this study. There were no significant differences in sex and dental school between Groups I and D. One participant in Group I did not complete the STAI-JYZ for trait anxiety, STAI-JYZ for state anxiety after reading the scenario, or quizzes for evaluation of the materials. This individual was absent on the second experimental day. The 32 residents who participated on the second experimental day completed all tasks.

Table 1 shows a comparison of the quiz scores between the two groups. Quiz scores immediately after learning the materials were significantly higher in Group I than in Group D; the same finding was observed 3 weeks later (0 w: $p<0.001$, 3 w: $p=0.016$). Figure 3 shows quiz scores of 32 residents who participated in both 0 w and 3 w tasks. Quiz scores from 0 w to 3 w decreased significantly in both groups (Group I: $p=0.002$, Group D: $p=0.003$).

Table 1. Comparison of quiz scores of the two groups.

Both quiz scores (0 w, 3 w) were significantly higher in Group I than those in Group D. **: $p<0.01$, ***: $p<0.001$ (Mann-Whitney *U* test).

Quiz scores

	Group I	Group D	*P*
0 w	76 (70–88) (n=25)	46 (34–59) (n=23)	***
3 w	58 (46–70) (n=18)	35 (22-46) (n=14)	**

Median (1st quartile - 3rd quartile)

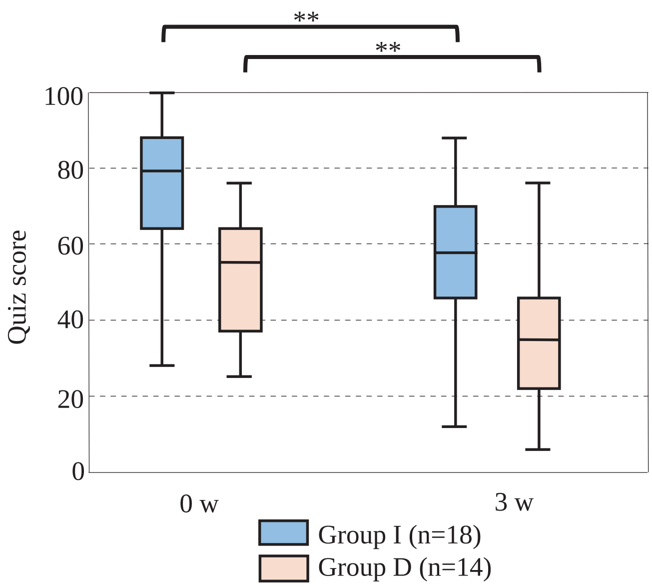

Figure 3. Quiz scores of 32 residents who participated in both 0 w and 3 w tasks.

Boxplots of quiz scores at 0 w and 3 w are shown for both groups. Quiz scores in both groups decreased significantly from immediately after learning (0 w) to 3 weeks later (3 w). **: $p<0.01$ (Wilcoxon signed-rank test).

Table 2. Comparison of trait and state anxiety between the two groups.

The STAI-JYZ indicates the degree of anxiety using a numerical value (score) ranging from 20 to 80. A higher score (55–80) suggests stronger anxiety, nervousness, and stress, whereas a lower score (20–35) suggests a relaxed state. No significant difference was observed in the degree of trait anxiety and state anxiety at each examination between the two groups. n.s.: not significant (Mann-Whitney *U* test).

Trait anxiety

Group I	Group D	*P*
50 (46–56) (n=25)	50 (44–58) (n=23)	n.s.

Median (1st quartile - 3rd quartile)

State anxiety

	Group I	Group D	*P*
Before reading scenario	46.5 (38–51) (n=26)	44 (40–49) (n=23)	n.s.
Before learning material	54 (48–61) (n=25)	51 (44–60) (n=23)	n.s.
After learning material	50 (39–53) (n=26)	46 (39–51.5) (n=23)	n.s.

Median (1st quartile - 3rd quartile)

We also compared trait and state anxiety at each time point between Groups I and D (Table 2). There were no significant differences in trait or state anxiety at each time point between the groups (state anxiety: $p=0.920$, $p=0.549$, $p=0.616$; trait anxiety: $p=0.861$). Figure 4 shows the change in the state anxiety score. In Group I, state anxiety scores increased significantly after reading the scenario ($p<0.05$) and decreased significantly after learning the material ($p<0.05$). In Group D, state anxiety scores also increased significantly after reading the scenario ($p<0.05$), but they did not decrease significantly after learning the material. There was no significant change in state anxiety score before reading the scenario and after implementing the learning materials in both groups.

The results of the questionnaire for evaluating the learning material are shown in Figure 5. In both groups, most responses were positive. After dividing the responses into positive and negative responses, we performed a comparison between the two learning material groups. There was no significant difference in responses (positive or negative) to all questions between the two groups. The participants generally answered that they were interested in the contents and motivated to learn, although they regarded the material as difficult.

Learners positively responded also at free comments to this materials as follows. In Group I, learners wrote, “I feel that it is good to be able to obtain knowledge on

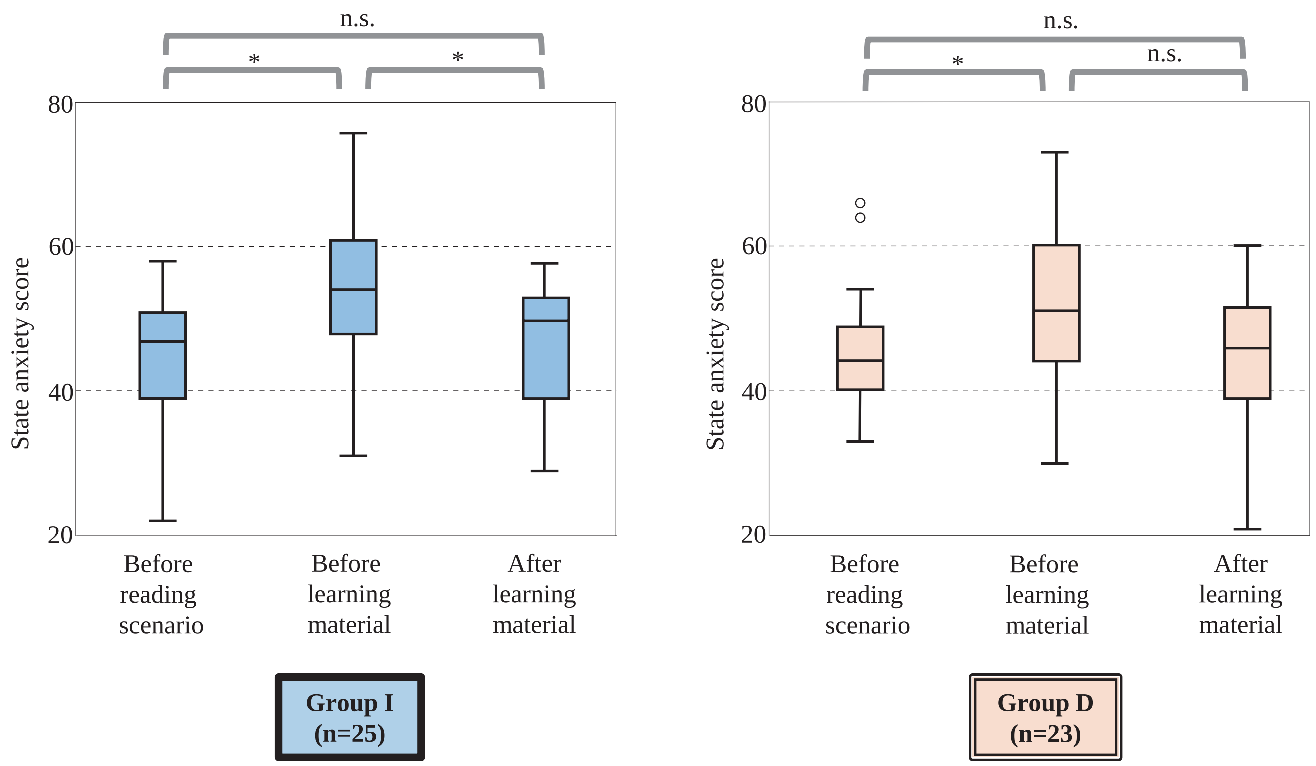

Figure 4. Change in state anxiety scores.

Boxplots of the state anxiety score for each examination point in both groups. In Group I, state anxiety scores increased significantly after reading the scenario and decreased significantly after using the learning material. In Group D, state anxiety scores increased significantly after reading the scenario and decreased after using the learning material, although the decrease was not significant. *: $p<0.05$, n.s.: not significant, o: mild outlier (Wilcoxon signed-rank test with Bonferroni correction).

situations that we do not typically encounter." and "It is difficult to learn through textbooks, but I think that this material is similar to learning from actual patients." In Group D, learners wrote, "I think that the learning materials are easy to understand and the operability is good, especially because it is a situation that does not often appear in normal clinical practice, so I think that it will be useful for emergency situations such as ward work", and "I think it will be helpful to remind us of a situation that is rarely experienced in normal general practice."

Discussion

As we hypothesized, the results suggested that interactive computer-assisted simulation materials with decision-making and feedback were effective not only for knowledge acquisition, but also memory retention and anxiety reduction.

At two time points (i.e. 0 w and 3 w), the quiz scores of learners who studied using the interactive-type simulation material with decision-making steps and feedback were higher than those who studied using the display-type materials without the decision-making process. Therefore, we believe that an interactive design, such as learners' decision-making and feedback, is effective for knowledge acquisition and memory retention. This is because all of the explanation contents, images, and documents used in the two types of learning materials were the same, except the need for decision-making and providing feedback to learners in the interactive-type group. In addition, instead of using multiple-choice questions to assess the learning effect, we adopted a descriptive format for all quizzes because learners may accidentally select correct answers without gaining knowledge. Furthermore, a descriptive format can clearly indicate the learner's degree of understanding because a correct answer cannot be given without sufficient knowledge or memory. Therefore, we considered that the degree of knowledge acquisition and long-term memory retention was properly measured in this study.

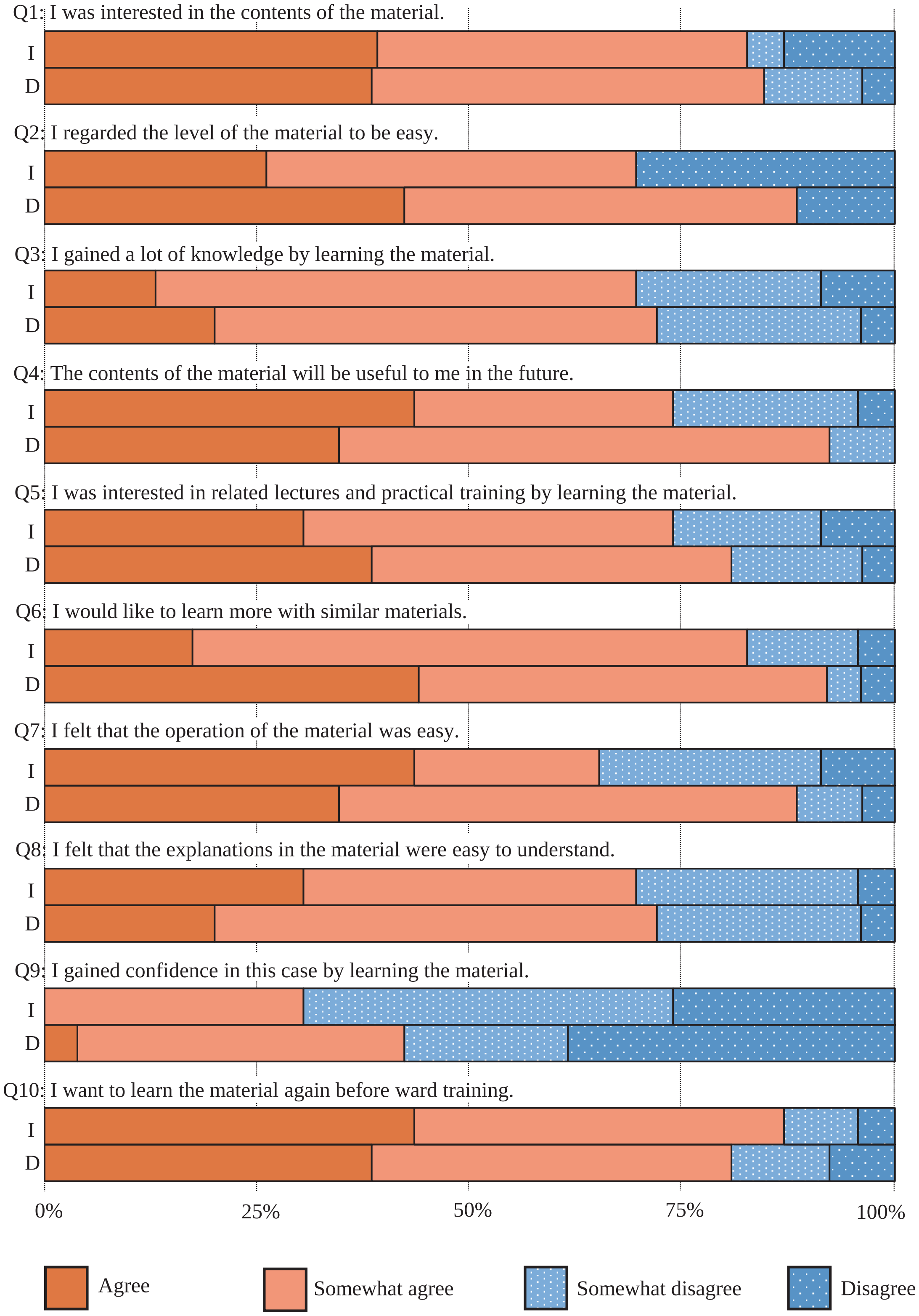

Figure 5. Results of questionnaires for evaluation of the learning materials.

There was no significant difference in the responses (positive or negative) to all questions between the two groups (Chi-square test).
I: Group I (n=26), D: Group D, (n=23).

This study demonstrated that interactivity factors, such as learners' decision-making in solving a clinical problem by themselves, are also effective in knowledge acquisition and memory retention. Since previous studies revealed that moving images and sounds are effective for knowledge acquisition and memory retention[19, 20], moving images and sound were not included in the materials used in this study.

In this study, we recruited dental residents as participants because they have relatively little clinical experience but are more involved in clinical cases than dental students, and they could easily imagine the presented situation. Participants could easily imagine that the situation in the presented scenario was very difficult to handle alone and that the patient's condition could be life threatening if they made poor choices.

State anxiety increased significantly in both groups after presenting the case scenario. Moreover, state anxiety decreased significantly only in Group I after learning with the material. Therefore, both the difference in material type and anxiety reduction might have affected quiz scores. The STAI-JYZ indicates the degree of anxiety as a numerical value ranging from 20 to 80. A higher score (55–80) indicates intense anxiety, nervousness, and stress, whereas a lower score (20–35) indicates a relaxed state[24]. In this study, although state anxiety scores changed throughout the tasks, most were considered to be "moderate" (45–55). Therefore, the psychological burden induced by our materials is considered to be appropriate.

State anxiety immediately after learning was significantly reduced in the interactive-type group, indicating that an interactive design incorporating learners' decision-making and providing feedback may reduce anxiety. Students and young dentists who have relatively little clinical experience frequently experience anxiety in clinical cases. As we hypothesized, our findings suggested that interactive computer-assisted simulation materials might reduce clinical anxiety. In the future, we plan to evaluate how interactive simulation materials affect operator skill and which factors result in clinical anxiety reduction and optimal performance.

Conclusion

The interactive simulation learning material that included decision-making steps and provided feedback was more effective than display-type material for knowledge acquisition, memory retention, and anxiety reduction. Interactivity with computer-assisted simulation materials could increase learning effects.

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