Integrating synapse, muscle contraction, and autonomic nervous system game: effect on learning and evaluation of students' opinions

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INTRODUCTION

Physiology is a basic discipline in all courses of the health area and is considered difficult by students, since it requires them to understand different concepts and integrate them with knowledge acquired in other disciplines, to relate the morphological characteristics and functions of different organs and systems of the human body (18). In most institutions, physiology classes still involve a large number of lectures, which can include videos and animations as complementary resources, together with a test after delivery of all of the content (16).

At Brazilian universities, physiology courses are offered in the first and second semesters of dentistry undergraduate courses, or in the second, third, and fourth semesters of other undergraduate health career courses. The physiology of synapses, muscle contraction, and the autonomic nervous system (ANS) are contents delivered in these courses, frequently taught in separate classes. It is necessary to help the students to assimilate this knowledge, so that they are able to understand the normal bodily functions and can apply this knowledge in clinical situations in the future (18).

Students have difficulty in understanding the different effects of neurotransmitters in muscle tissue, the roles of receptor subtypes in physiological responses in the different tissues, the contrary and complementary actions of the sympathetic and parasympathetic nervous systems, factors that alter the physiology of synapses, diseases (such as depression and myasthenia gravis) related to these changes, and the mechanisms of action of medications used to treat these diseases. To improve students’ understanding, traditional lectures can be combined with or replaced by active teaching strategies that increase the interest and participation of the students in classes and enables them to assimilate basic and clinical concepts at increasing levels of complexity, thus promoting meaningful learning (3, 14, 20).

Among active teaching strategies, educational games can assist learning by increasing the students’ interest and knowledge retention, stimulating problem-solving and decision-making abilities, and promoting greater interaction among the students (2, 15, 22, 24, 26). In previous studies, our research group observed that educational games could increase student learning about heart physiology (6, 15) and action potential (12).

To assist students in understanding, assimilating, and integrating concepts related to the physiology of synapses, muscle contraction, and the ANS, the educational game “Integrating Synapse, Muscle Contraction, and Autonomic Nervous System” was developed at the Piracicaba Dental School of the University of Campinas (Piracicaba, São Paulo State, Brazil) and was used in the dentistry course. The present work describes this educational game, evaluates its effect on learning,
and assesses the students’ opinions of its usefulness in undergraduate courses.

Learning assessment can be performed by comparing groups submitted to lectures and activities with educational games (6, 12). However, this approach may not always be possible, considering the limitations of classroom research, such as the course schedule, physical space, number of students per class, number of teachers, and curriculum characteristics. Therefore, in the present study, the assessment of learning was also performed using an approach employing pre- and posttests.

MATERIAL AND METHODS

This study was approved by the Ethics Committees of the Piracicaba Dental School of the University of Campinas (FOP-UNICAMP) (CAAE 42980515.0.0000.5418) and the Federal University of Health Sciences of Porto Alegre (UFSCSPA) (CAAE 42980515.0.3002.5345) and was authorized by the Teaching Committee of the University of Araraquara (UNIARA).

The participants in the study were 121 students enrolled in the Biosciences I discipline of the dentistry course at FOP-UNICAMP, together with 15 students from the pharmacy course at UFSCSPA, who were enrolled in the Physiology I discipline, and 42 students from the medicine course at UNIARA, enrolled in the Physiology and Biophysics III discipline.

The educational game and the tests were constituent parts of the disciplines, so all of the students participated in these activities. In the dentistry course, to ensure autonomy and reduce the vulnerability of students in the decision to participate in the study (25), the request to use the data for the research was made to the students at the beginning of the following semester, after disclosure of the final grades of the Biosciences I discipline. The invitation to participate in the research was made outside of class hours, at a specific scheduled time. The students of the pharmacy course were invited to participate at the beginning of the Physiology I discipline. In the medicine course, the invitation was made in the middle of the third semester, after the lectures on synapses, muscle contraction, and the ANS.

Description of the Educational Game

The game was based on a puzzle that required the organization, in a table, of tokens indicating neurons, receptors, neurotransmitters, and effects on target organs (Fig. 1). This was followed by group discussion of questions on the topics studied. The A3 (29.7 cm × 42 cm) size table contained the names of the nervous system divisions (the somatic nervous system and the sympathetic and parasympathetic divisions of the ANS). It was divided into four columns, indicating synapses, neurotransmitters, receptors, effector organ, and effect (Fig. 1A).

The tokens (Fig. 1B) used to complete the table represented neurons, neurotransmitters (noradrenaline and acetylcholine), adrenergic receptors (α and β), cholinergic receptors (nicotinic and muscarinic), tissues (vascular smooth muscle, smooth muscle of the gastrointestinal system, and skeletal muscle), and effects (contraction and relaxation).

Figure 2 presents the assembled puzzle. The table and tokens were printed in color on 120 g/m² white paper and were laminated.

Description of the Activity

During the Biosciences I (at FOP), and Physiology I (at UFSCSPA) disciplines, the students attended one lecture about synapses, two classes about muscle contraction, and one class about the ANS. During the Physiology and Biophysics III (at UNIARA) discipline, the students attended four lectures about synapses, two lectures about muscle contraction, and four lectures about the ANS. During all of these classes, the lecturer asked questions, so that the students could reflect on the theme being discussed.

In the next class of the three courses, the activity with the educational game was performed. At the beginning of the activity, the students were divided into groups with five to six members. Each group was given a game and was instructed to fill in the table with the tokens in the correct way. When the group finished filling the table, they called a monitor or the lecturer to assess whether the placement of the tokens was correct. If there was any mistake, the students were told that they should review the placement of the pieces, but did not receive any indication of what the mistakes were. The aim was to stimulate discussion among the students, so that they could identify the errors themselves.

During filling of the table, the students should be able to remember and apply their knowledge about the different receptors for neurotransmitters in the body, the different effects of the neurotransmitters, depending on the receptor subtype activated, and the different types of synapses in the somatic and ANS divisions.

After the table had been filled correctly, the students were given questions to answer in groups, about the topics addressed in the activity (Table 1). These questions were elaborated by the coordinator of this study, except for question 6, which is from the book Human Physiology: An Integrated Approach, by Dee Silverthorn (22a). The group members discussed the questions and, as soon as they had finished elaborating on the answers, called the lecturer or a monitor, to whom they orally explained their answer. To ensure that all the students actually participated in the discussion and in elaboration of the correct answers to the questions, each group was given one question at a time. The next question was only delivered after a satisfactory answer had been provided to the previous one. In this way, discussion was stimulated among the students, who were focused on the same question.

Evaluation of the Effect of the Educational Game on Student Learning

The effect of the educational game on the students’ learning was evaluated using two experiments (Fig. 3). In the first experiment, learning assessment was performed by comparing the test scores obtained by the control group (students who only attended traditional lectures) and the game group (students who attended traditional lectures and performed the activity with the educational game). In the second experiment, learning assessment was performed by comparing the pre- and posttest scores (Fig. 3). The aim of these two experiments was not to compare the grades of the students between the participating courses. The objective was to use two different approaches to evaluate the effect of the educational game on students’ learning.

Experiment 1. The students who participated in this experiment were enrolled in the Biosciences I discipline of the dentistry course of FOP-UNICAMP, in the first semesters of 2017 (control group, n = 58) and 2019 (game group, n = 63). To evaluate if there was any difference between the 2017 and 2019 classes that was not related to the use of the educational game, the means of the final grades obtained in the discipline were compared with the scores in the tests. It was assumed that in the absence of any difference between the groups, in terms of their academic abilities, there would be a significant difference between the groups for the scores obtained in the tests, compared with the difference between the groups for the final grades in the discipline. A significant difference between the groups for the scores obtained in the tests could then be attributed to the effect of the educational game.

Students from both groups attended the same number of lectures about synapses (one), muscle contraction (two), and the ANS (one), taught by the same lecturer. In each class, just after the oral explanation of the teacher, the students of both control and game groups were requested to answer, in groups of three or four, questions involving the application of concepts explained in the lecture. These questions
Fig. 1. Table (A) and tokens (B) of the educational game, “Integrating Synapse, Muscle Contraction, and Autonomic Nervous System.”
were similar to those used in the test that would be applied for learning assessment and academic exams. For example, in the class on synapse, the following question was proposed, “Considering the physiology of synapses, explain the mechanism of action of medicines used in the treatment of myasthenia gravis (inhibitors of acetylcholinesterase) and depression (inhibitors of neuronal reuptake of serotonin).”

At the end of the last of these four lectures (ANS class), all of the students were instructed to study, using a textbook, for a test that would be performed in the next class (Table 2). Ten days after the ANS class, the game group performed the activity with the educational game. Twelve days after the ANS class, both control and game groups performed the test (Fig. 3).

The control and game groups answered the same test, which was composed of multiple-choice and open-ended questions, with a total score of 10. The questions that were used in the test are presented in Table 2, with the correct answers italicized/underlined and the value of each question shown within parentheses. The level of difficulty of

Table 1. Questions used in the activity with the educational game

| Question                                                                                                                                                                                                 |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. In the assembled puzzle, it can be seen that the same neurotransmitter triggers opposing actions in muscle tissue. Describe this situation in the puzzle and explain why it occurs. |
| 2. In the assembled puzzle, compare the morphologies of the synapses of a neuron with skeletal muscle, and of a neuron with smooth muscle. Describe the observed morphological differences and discuss how these morphological characteristics are related to differences in synaptic transmission. |
| 3. Relate the organization of the contractile proteins in the skeletal and smooth muscles to the direction of contraction and the function of these muscle types in the organs in which they are found. |
| 4. To hunt animals, indigenous people can use a blowpipe to shoot darts poisoned with curare, a substance obtained from plants, which binds to nicotinic acetylcholine (ACh) receptors, preventing ACh binding and resulting in no response in the cell. It is, therefore, an antagonist of these receptors. Animals affected in this way are immobilized and easily captured. Considering what you have learned about the physiology of skeletal muscle contraction, explain how curare produces this effect. |
| 5. Nicotine is a nicotinic receptor agonist, because it activates this receptor, mimicking the action of ACh. A nonsmoker who chews a nicotine gum can present an increase in heart rate, which is a function controlled by sympathetic neurons. If the postganglionic sympathetic neurons secrete noradrenaline, explain how nicotine, in low concentration, can increase the frequency of heartbeats. |
| 6. In an experiment about synaptic transmission, a synapse was maintained in a medium equivalent to the extracellular fluid, but without calcium ions. An action potential was triggered in the presynaptic neuron and reached the axon terminal. However, the usual postsynaptic cell response did not occur. To what conclusion could the researchers arrive, based on these results? Discuss. |
| 7. In another experiment, muscle cells were maintained in plates with nutrient medium without calcium, at 37°C, with oxygenation. Norepinephrine was added, the effects were evaluated, and the tissues were then washed. Afterwards, acetylcholine was added and the effects were evaluated. In the plates with smooth muscle cells, there was no muscle contraction in either situation. Explain this result. |
| 8. In skeletal muscle cell plates, muscle contraction was only observed in response to the addition of acetylcholine. Explain this result. |
these questions was similar to those applied at the end of each lecture, for both control and game groups.

Experiment 2. The students who participated in the second experiment were enrolled in the Physiology I discipline of the pharmacy course (n = 15) of the UFCSPA.

After the lectures about synapses, muscle contraction, and the ANS, the students were instructed to study for a test. In the next class, a pretest was applied, composed of multiple-choice and open-ended questions (Table 3). Immediately after the pretest, the students performed the activity with the game.

In the next class, the students answered a posttest, which was also composed of multiple-choice and open-ended questions, although the questions were different from those used in the pretest, but covered the same contents (Table 3). The pre- and posttest answers and evaluation criteria are presented below each question in Table 3.

Questions for the Pre- and Posttests

All the pre- and posttest questions had the same value of 2.0 points. The purpose of these tests was to assess whether the student had understood the process of synaptic transmission and muscle contraction. The questions had a similar level of difficulty in the two tests and were on the subjects covered in the classroom and individual study, as well as in the posttest the application of concepts discussed during the activity with the educational game.

The answer to pretest question 1 was only considered correct if the student identified the complete sequence, with no score for each individual correct item. Question 2 of the pretest concerned basic information related to synaptic transmission and muscle contraction, which required the student to present concepts that had already been learned in the lectures and individual study. For question 2 of the posttest, the degree of difficulty was greater, and it was necessary to apply the concepts discussed during the activity with the educational game. In both tests, question 3 required the student to understand synaptic transmission and applications in pharmacology, an essential subject in health courses (Table 3).

The book suggested for study was Human Physiology: An Integrated Approach (5th edition), by Dee Silverthorn (22a). On page 275 of chapter 8, there is a question similar to question 4 of the pre- and posttests. The students were instructed to study these pages of the book, with solving this question acting to reinforce learning. Question 5 of both tests required knowledge of synaptic transmission and muscle contraction.

Learning was not evaluated in the medicine course, because there was not sufficient time for application of the pre- and posttests.

Evaluation of the Students’ Opinions

The game group students of the dentistry course, as well as the students of the pharmacy and medicine courses, were invited to answer a question about their opinion regarding the use of the educational game. Using a Likert-type scale, the students indicated if they thought the activity with the game was useful for learning (1 = not useful for learning; 5 = necessary for learning), with justification of their answers.

The dentistry course students answered this question at the end of the physiology discipline, after the final grades had been disclosed. The students of the pharmacy and medicine courses answered this question immediately after the activity with the educational game.

Statistical Analysis

In experiment 1, the scores of the control and game groups were compared using Student’s t test for unpaired samples, with a significance level of $P < 0.05$.

In experiment 2, the scores from the pre- and posttests were compared using Student’s t test for paired samples, with a significance level of $P < 0.05$.

These scores and the analysis of the opinions provided using the Likert-type scale are presented as means ± standard deviation (SD).

RESULTS

Experiment 1

For the control group, 61 out of the 88 students enrolled in the Bioscience I discipline of the dentistry course in 2017 agreed to participate in the study. Three of these students were excluded because they missed the class in which the test was applied. In the game group, 63 out of the 82 students enrolled in the Bioscience I discipline in 2019 agreed to participate in the study. The total number of participants was 121 students.

In the tests applied in the classes after the lecture (for the control group) and after the activity with the educational game (for the game group), the game group presented a higher score than the control group ($P < 0.05$) (Table 4). There was no significant difference between the control and game groups ($P = 0.135$) for the final grade in the Biosciences I discipline.

Experiment 2

All 15 of the pharmacy students enrolled in the Physiology I discipline agreed to participate. The students completed the pre- and posttests, with significantly higher mean scores obtained in the posttest, compared with the pretest ($P < 0.05$) (Table 4).

In evaluation of the students’ perception about the educational game, concerning whether the activity was useful for...
1. Choose the alternative that represents the correct sequence of events of a chemical synapse, from the activation of the presynaptic neuron to the completion of the neurotransmitter effect. (2.0)
   a) Opening of voltage-dependent calcium channels; (0.1)
   b) Calcium influx; (0.1)
   c) Approach and anchoring of vesicles from the synaptic terminal; (0.1)
   d) Presynaptic cells depolarization; (0.1)
   e) Activation of the SNARE complex by calcium; (0.1)
   f) End of the neurotransmitter effect; (0.1)
   g) Fusion of the vesicles with the plasma membrane; (0.1)
   h) Release of the neurotransmitter in the synaptic cleft (exocytosis); (0.1)
   i) Interaction with the receptor in the postsynaptic cell. (0.1)
   j) End of the neurotransmitter effect; (0.1)

2. Depression is related to a reduction of serotonin synthesis. Pargyline belongs to the class of MAO (monoamine oxidase) inhibitor medications. It is used to treat depression, as it inhibits the enzyme that metabolizes amines, after its re-uptake by neurons in the central nervous system. Based on the physiology of synapses, pargyline can reduce the symptoms of depression because it: (2.0)
   a) Reduces the availability of serotonin in the synaptic cleft; (0.1)
   b) Reduces the amount of serotonin receptors in the postsynaptic neuron; (0.1)
   c) Increases the amount of serotonin receptors in the postsynaptic neuron; (0.1)
   d) Increases the chance of serotonin binding to its receptors in the postsynaptic neuron, since its action increases the time that serotonin is present in the synaptic cleft; (0.1)
   e) Prevents the action of the SNARE complex for serotonin release by the presynaptic neuron. (0.1)

3. In an experiment on synaptic transmission, a synapse between a neuron and a skeletal muscle cell was kept in a medium equivalent to the extracellular fluid, but without calcium ions. An electrical stimulation was applied to one presynaptic neuron, but the usual response of the postsynaptic cell did not occur. (2.0)
   a) What would be this usual response? (1.0)
   b) Considering the physiology of chemical synapses, discuss what conclusion the researchers reached, based on the result obtained. Without calcium in the extracellular liquid, there would not be calcium influx into the presynaptic neuron, so the SNARE complex would not be activated. The neurotransmitter vesicles would not approach and anchor at the presynaptic terminal, avoiding the release of neurotransmitter/ acetylcholine into the synaptic cleft, so that there would be interaction with postsynaptic neuron receptors. (1.0)

4. Explain briefly how the botulinum toxin interferes in synaptic transmission. Based on this mechanism of action, explain how it acts in aesthetic treatments to reduce expression lines (wrinkles). (2.0)
   a) Nicotine activates acetylcholine receptors in the parasympathetic postganglionic neuron, which releases acetylcholine in the heart; (1.0)
   b) Nicotine activates norepinephrine receptors in cardiac cells; (1.0)
   c) Nicotine activates noradrenaline receptors in sympathetic postganglionic neuron, which releases noradrenaline in the heart; (1.0)
   d) Nicotine activates acetylcholine receptors in the sympathetic postganglionic neuron, which releases noradrenaline in the heart; (1.0)
   e) Nicotine activates noradrenaline receptors in the sympathetic postganglionic neuron, which releases acetylcholine in the heart. (1.0)

Correct answers are italicized and/or underlined. The value of each question is shown in parentheses.
contents easier”; and “The game was useful for my learning, because its systematic structure enabled visualization of how the process occurs, which was essential for my understanding.”

**DISCUSSION**

The results obtained in this study indicated that the use of the educational game “Integrating Synapse, Muscle Contraction, and Autonomic Nervous System” increased the dentistry and pharmacy students’ learning about these topics. These students, as well as the medicine students, reported that the educational game was useful for learning. These results were in agreement with the findings of other studies concerning the effects of educational games (5–7, 12, 13, 15, 17, 26) and other active methods, such as attempting to discover the hidden key

**Table 3. Questions used in the pre- and posttests**

| Pretest | Posttest |
|---------|----------|
| 1. Number, in correct order, the sequence of events of a chemical synapse, from activation of the presynaptic neuron to completion of the neurotransmitter effect. (2.0) | 1. Choose the alternative that represents the correct sequence of events of a chemical synapse, from activation of the presynaptic neuron to completion of the neurotransmitter effect. (2.0) |
| (2) Opening of voltage-dependent calcium channels; (3) Calcium influx; (5) Approach and anchoring of vesicles from the synaptic terminal; (1) Presynaptic cells depolarization; (4) Activation of the SNARE complex by calcium; (9) End of the neurotransmitter effect; (6) Fusion of the vesicles with the plasma membrane; (7) Release of the neurotransmitter in the synaptic cleft (exocytosis); (8) Interaction with the receptor in the postsynaptic cell. | 1. Opening of voltage-dependent calcium channels; 2. Calcium influx; 3. Approach and anchoring of vesicles from the synaptic terminal; 4. Presynaptic cells depolarization; 5. Activation of the SNARE complex by calcium; 6. End of the neurotransmitter effect; 7. Fusion of the vesicles with the plasma membrane; 8. Release of the neurotransmitter in the synaptic cleft (exocytosis); 9. Interaction with the receptor in the postsynaptic cell. |
| 2. The autonomic nervous system (ANS) controls the functions of our organs, by means of its sympathetic and parasympathetic divisions. Mark true (T) or false (F) for the statements below: (2.0) (T) Preganglionic fibers of the sympathetic and parasympathetic nervous systems release acetylcholine (ACh), which binds to nicotinic cholinergic receptors in the autonomic ganglia. (F) Preganglionic fibers of the sympathetic and parasympathetic nervous systems release noradrenaline, which binds to nicotinic cholinergic receptors in the sympathetic postganglionic neuron. (F) Most postganglionic sympathetic fibers release noradrenaline, which binds to muscarinic cholinergic receptors in target organs. (F) The postganglionic sympathetic fibers release acetylcholine, which binds to muscarinic cholinergic receptors in the synapse with the target organ. (T) Since the ANS presents basal release of its chemical mediators, the fact that most of our organs receive dual innervation (sympathetic and parasympathetic) is important for the effective control of functions. For example, after a scare, to return the heart rate to baseline levels, the inhibition of the sympathetic system, simultaneously with activation of the parasympathetic system, results in a greater and faster effect than if only the parasympathetic system was activated to reduce the activity of the heart’s pacemaker cells. | 2. Nicotine is an agonist of nicotinic receptors, i.e., it activates these receptors, mimicking the action of acetylcholine (ACh). One of the side effects of the use of nicotine gum, in treatments to quit smoking, is increase of the heart rate. This side effect occurs because: (2.0) a) Nicotine activates acetylcholine receptors in the parasympathetic postganglionic neuron, which releases ACh in the heart; b) Nicotine activates noradrenaline receptors in the sympathetic postganglionic neuron, which releases noradrenaline in the heart; c) Nicotine activates noradrenaline receptors in cardiac cells; d) Nicotine activates acetylcholine receptors in the sympathetic postganglionic neuron, which releases ACh in the heart; e) Nicotine activates noradrenaline receptors in the parasympathetic postganglionic neuron, which releases ACh in the heart. |
| 3. Sertraline hydrochloride is a medication used in the treatment of depression and its mechanism of action is by inhibition of serotonin reuptake. This inhibition causes: (2.0) a) Reduction of the availability of the neurotransmitter serotonin in the synaptic cleft; b) Reduction of the amount of serotonin receptors in the postganglionic neuron; c) Increase of the availability of the neurotransmitter serotonin in the synaptic cleft; d) Difficulty of the presynaptic vesicles to move toward the membrane in the preganglionic neuron. | 3. Pargyline belongs to the class of MAO (monoamine oxidase) inhibitor medications. It is used to treat depression, as it inhibits the enzyme that metabolizes amines, after its re-uptake by neurons in the central nervous system. Depression is related to the reduction of serotonin synthesis. Based on the physiology of synapses, pargyline can reduce the symptoms of depression because it: (2.0) a) Reduces the availability of serotonin in the synaptic cleft; b) Reduces the amount of serotonin receptors in the postsynaptic neuron; c) Increases the amount of serotonin receptors in the postsynaptic neuron; d) Increases the chance of serotonin binding to its receptors in the postsynaptic neuron, since its action increases the time that serotonin is present in the synaptic cleft; e) Hinders or prevents the action of the SNARE complex for serotonin release by the presynaptic neuron. |
words of a scientific paper (8), performing an online game (4), and using a jigsaw technique to elucidate clinical problems (19).

In addition to enabling students to participate actively in the teaching-learning process, educational games also increase interaction among the students and their engagement with the teaching-learning process, educational games also increase critical and reflective thinking (2, 13, 15). Another advantage of using educational games is that, during the activity, there is immediate feedback for the student and the lecturer. The student can perceive where his/her difficulties and doubts lie and resolve them. For the lecturer, this feedback provides information about the students’ understanding of the content, so that he/she can decide how to continue the classes (1).

Assessing students’ perceptions and opinions is important, because it provides evidence that the teaching tool actually helps in learning, enabling further improvement of the strategy used. However, it is essential to evaluate learning to know whether the method being used is actually effective (10). Research performed in the classroom can suffer from certain restrictions that often cannot be controlled by the teacher, such as the scheduling of the course, the physical space, and the presence of monitors together with the teacher during classes. However, it is possible to develop methods to evaluate the effectiveness of an educational strategy, taking into consideration the actual conditions of the classroom.

There are different ways to assess learning, such as evaluation of the performance of control and experimental groups (6, 11, 12, 21), use of pre- and posttests (2, 8, 9), and analysis of poor grades or drop-out rates (27). In this study, control and experimental groups were used together with pre- and posttests as methods of assessment.
When filling in the table for this game, the students should be the students’ previous knowledge acquired during lectures. This meant that it was not possible to divide the students into groups in the same class, since this would have resulted in different treatments for the same class. A way around this problem was to provide only traditional lectures for one class, while the educational game was used with another class, in a different year.

In this approach, it was necessary to evaluate the possible existence of differences between the classes in the disciplines, to know whether different performance in a test used to evaluate the effect of an educational strategy was due to this strategy, rather than to class differences (11). In the present study, this evaluation was performed by comparing the final grades achieved in the discipline by the students of the different classes. Since these grades showed no significant difference between the groups, it could be concluded that the better test performance of the students who had the activity with the educational game (game group), compared with the students who only had lectures, was due to the activity with the educational game.

The assessment of learning by applying pre- and posttests can be used in classes to provide information about a student’s performance before and after application of any particular strategy (8, 9). However, care must be taken when preparing questions for the two tests, since, if they were exactly the same, the students could answer correctly, due to remembering the answer already provided in the pretest (8). In the present study, we cannot exclude some influence of pretest in the performance of students. However, the effect of this limitation was reduced because the questions used for the posttest addressed the same contents as the pretest questions, but were not exactly the same, hence decreasing the memory effect. This pre- and posttest approach evidenced the additional learning effect of the educational game used, compared with the learning achieved only with lectures and studying at home.

In previous studies concerning evaluation of the learning effect of educational games, the students were also divided into control and game groups (6, 12). The control groups attended traditional theoretical lectures, while the game groups participated in the activity with the educational game. Afterwards, comparison was made of the scores achieved by the two groups in a test. In both studies, improved performance in the tests on the topics discussed was observed for the students of the game group, compared with the control group, while positive assessments were made by the students concerning the use of these games (6, 12). The results of the present study corroborated the beneficial effects on learning and the positive assessments of the students observed in the earlier studies. The educational games “Cardiac Cycle Puzzle” and “Understanding the Action Potential” are used as teaching tools in classes on these subjects, with the students learning the contents during the activities with the games (6, 12).

Differently, in this study, the purpose of the game “Integrating Synapse, Muscle Contraction, and Autonomic Nervous System” was to promote active participation and integration of the students’ previous knowledge acquired during lectures. When filling in the table for this game, the students should be able to remember and apply contents learned in previous lessons, such as the various neurotransmitter receptors in the body, the different effects of the neurotransmitters, depending on the subtype of receptor activated, and the different types of synapses of the somatic system and ANS. When discussing the questions provided after filling in the table, they should integrate this knowledge, reflecting on and applying what they had learned.

The game activity promoted interaction and collaboration among the group students, improving academic performance. During the activity with the educational game and discussion of the questions, the students were focused on the activity and the discussion, with no cell phone use or other distracting factors. The use of printed educational games offers the advantages of the material being low cost, highly durable (depending on the matrix used for printing), easy to carry, and replicable anywhere in the world, regardless of the use of digital devices (11).

This educational game could be adapted and used in other classes, gradually increasing its complexity, to integrate the contents related to cardiovascular and endocrine physiology. In the undergraduate dentistry course of FOP-UNICAMP, in the first semester, the students take the Bioscience I discipline, which addresses the topics of muscle contraction, synapses, and the ANS. In the Bioscience II discipline, the physiology of the cardiac muscle is studied within the cardiovascular physiology unit, in the second semester of the course, together with study of the endocrine system.

The use of the game at other times of the course enables students to remember concepts that were learned previously, as well as to add new information. This process is important for learning, since new memories become stabilized, after an initial significant learning, in a process called memory reconsolidation (23). In everyday life, a crucial process in the learning experience is the reactivation of memory, which occurs because individuals constantly experience situations related to previous learning. In physiology classes, for example, the students need to remember the anatomical or histological structures of an organ, to properly understand its function. At this point, the students need to retrieve previous knowledge of anatomy and histology, adding new information about the function of specific organs to an existing memory (23). Therefore, the students learn the contents and remember these contents at future times, integrating them with new knowledge, hence being able to solve problem situations that have increasing degrees of complexity.

In conclusion, the results of this study indicated that the use of the educational game “Integrating Synapse, Muscle Contraction, and Autonomic Nervous System” helped in learning about the topics and integrating the contents, while stimulating interaction among the students. The game received a positive evaluation from the students and could be adapted for use with other topics. The results showed that it was possible to develop a low-cost material that could be applied to a range of subjects and at different times during physiology disciplines.

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