ILLUMINATIONS

Synaptic board: an educational game to help the synaptic physiology teaching-learning process

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INTRODUCTION

The formation of qualified health professionals begins with a qualified health curriculum (12, 22). One of the first challenges that health sciences’ students will face during their undergraduate education is the physiology course. Physiology studies how the body works, and, because of that, it is the basis for the construction of knowledge in other courses, like pathology and clinical approaches (19). In this sense, it is important that physiology contents be well understood, so the students will be able to integrate information (32).

The choice of teaching-learning methods is as important as the content to be taught (39). Research for innovative strategies and teaching methods have shown that active methods can be an alternative or a complementary approach to the traditional lecture (39). This method places the student at the center of their learning process, making them able to relate the contents to others courses, to exercise critical judgment, and, as a consequence, to apply those skills in their future work (8, 30).

The work developed by Anderson et al. (1) showed that the use of active learning methods to teach physiology enabled students to present complicated concepts, evaluate themselves and their colleagues, and contribute effectively in small-group settings. The authors divided the class into groups and assigned questions or topics about different subjects, which should be explained later in the class.

It is known that the motivational factor is determinant in learning. The judgments, opinions, and values that the students have about objects, events, and learning processes impact their motivation (7, 16, 34). To promote long-term learning, it is essential to keep students motivated, and it involves promoting strategies to increase students’ motivation (17). Linked to the concept of motivation is also the definition of flow theory. The state of immersion flow is observed in cases of extreme concentration, combined with a distortion of the perception of time and loss of self-consciousness related to the practice of pleasurable activities (6). In a classroom, the experience of flow occurs when the teaching strategy keeps students focused, intrigued, and feeling pleasurable in the learning process (37).

The educational games (EGs) are used between the active strategies studied in the last years (2, 5, 15, 20, 21, 23, 24, 27). It has been demonstrated that the use of EGs for teaching can motivate the students to learn and, in addition, promote effective learning (11, 18). One kind of game that can be used in education are board games (BGs); this type of game is played by moving pieces on a board, using strategies to continue progressing and look for the victory (11). Additionally, the group interactions during the BG can provide better social contact and provide learning opportunities. It has been suggested that BGs can facilitate learning through an immersion flow and individual need learning necessities (3, 11).

Despite the advantages, there are limited options to use EGs and BGs in physiology teaching. In this sense, we developed a BG to complement the teaching of an important and complex physiology content: the synaptic transmission (ST). Learning ST involves the comprehension of complex mechanisms describing how neurons pass information to each other (31). For Montrezor et al. (25), the essential topics to be learned in ST content are the characterization of synapses, the identification of main functional differences between chemical and electrical synapses, and the functional effects involving these concepts (neural and neuromuscular events). Additionally, to make a correlation to the ST knowledge with clinical and pharmacological applications is important (25). The fact that this content involves complex causal mechanisms explains why it is difficult to understand; therefore, it is important to seek innovative teaching strategies to promote effective learning (13).

The synaptic board game (SBG) was designed and applied in class. The aim of this study is the development of the SBG and the evaluation of students’ perception about its contribution to physiology learning.

MATERIALS AND METHODS

Game design. The whole construction of the game was based on the Design Science Research methodology (29, 36). The first step was to identify which topics in human physiology the students had more difficulty in learning, from the experience of teachers and tutors. ST was chosen. The game development team was composed of a Physiology Master student, two Biomedical Sciences Bachelors, and three undergraduate students from different careers (Biomedical Sciences, Graphic Design, and Production Management). The team met weekly, holding meetings in the brainstorming mold.

We chose a BG aiming to make the topic learning fun and dynamic, promoting a team-based learning moment. The BG involved gradually increases the difficulty levels, to motivate the students to want to reach the end. In addition, we developed simple rules for the game, so that it was intuitive to the players. The game was developed in Brazilian Portuguese, since the goal was to engage local students. The version
presented in this paper was translated, since one of our goals is to share it with the physiology educators’ community.

The essential instruments to play the game are a board, game rules, an Android phone for questions, and pawns. The game’s board has 50 spaces (plus the starting space, action potential, and 3 different destinations) (Fig. 1). It should be played by at least two students, with a maximum of three. The board spaces have been divided into different colors that represent the three levels of question difficulty; the questions must be answered when the player throws one die and lands on a space. To initiate the game, players must choose a pawn to represent them during the game (acetylcholine, green pawn; noradrenaline, yellow pawn; or ion, blue pawn) and, knowing their identity, must keep in mind their correct destination (cholinergic receptor, adrenergic receptor, or communicating junction). To move in the spaces, the players must play the die and answer a question according to the color (difficulty level) of the space in which they land. The physical structure of the board can be seen in Fig. 1, and the rules of the game can be found in Table 1.

Questions about ST (Table 2) were proposed and revised by the authors, which include two physiology professors with experience in the field, from two different universities (one public and one private). The questions were divided into three levels of difficulty (easy, medium, and hard). At the end, 71 questions were written, with 28 being at the easy, 25 at the medium, and 19 at the hard level.

For the questions, we decided to use an android mobile application (app), which was developed by us (Fig. 2). The app was created using the Massachusetts Institute of Technology App Inventor tool, and the students should download it to their own phone. Screen 1 shows the “Let’s Play!” button (Fig. 2A). On screen 2, the students find an access code screen to guarantee their access to the questions only on the day of the intervention; the access code is quizzlfb. (Fig. 2B). On screen 3, the students find three buttons that indicate the three levels of the questions’ difficulty (Fig. 2C). According to the space on the board, the player should choose the corresponding level, and the app shows a random question and indicates if the answer is correct or not (Fig. 2D). For a wrong answer, the correct one is show on the screen. The app questions can also be played as a quiz mode for students to use for later studies, in that the same questions were included. As the app was independently developed by the authors, it is not in the Play Store for download. Thus, to download it, it is necessary to check if the security settings of the phone allow it. The app was developed in Portuguese and English, and both versions can be downloaded by the link: https://drive.google.com/drive/folders/1h8UK-wlpD0mDqCLQXElqGqXx3J-ibdr.

The questions used in the game can vary according to the course and the professor’s planning. In addition, the use of an app is optional. Alternative ways to play the game without the app include the use of cards with different questions levels, the use of a list of questions, the formulation of questions by the students during the game, and others. The pawns for the game can be bought or created. In our case, we designed the pawns on our own, using Fusion 360 software and a 3D printer. We used three pawns for each board, one green, one yellow and one blue, according to the meanings previously described.

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**Fig. 1.** Synaptic board game structure. The board design, spaces structure, pawn colors, and game rules are shown.
Table 1. Synaptic board game rules

1. Choose a character (acetylcholine, noradrenaline, or ion) to represent you during the game. Throughout the game, think about your specific pathway destination (gap junction, adrenergic receptor, or cholinergic receptor).

2. All players must play the die once. The order of the game is highest to lowest number taken.

3. In each space, a question should be answered, which are 3 difficulty levels, distributed as follows:
   - Light pink space: level 1 (easy). If you answer the question right, then you move forward 1 space. In the opposite, if you answer the question wrong, then you move backward 1 space.
   - Dark pink space: level 2 (medium). If you answer the question right, then you move forward 2 spaces. In the opposite, if you answer the question wrong, then you move backward 2 spaces.
   - Purple space: level 3 (difficult). If you answer the question right, then you move forward 3 spaces. In the opposite, if you answer the question wrong, then you move backward 3 spaces.
   - Light pink/dark pink bicolor space. The player can choose to answer a level 1 or level 2 question. Then the character moves forward or backward according to the chosen level.
   - Pink/purple two-color space. The player can choose to answer a level 2 or level 3 question. Then the character moves forward or backward according to the chosen level.

4. When one of the players reaches the end of the board and chooses one of the destinations (according to item 1), it must be reported to the tutor/professor who is responsible for indicating whether it is correct or not. If it is correct, the player will be the winner. In case of error, he/she should go back to space 35, choose a level 2 or 3 question, and continue to play.

Before the class application, the SBG was tested in three pilot studies with students who had already finished the physiology course, and professors. In the pilots, the number of spaces, the difficulty of the questions, and the game time were the main aspects verified. In addition, the participants of this stage were asked to opin about the game and give suggestions for changes, which were evaluated by the authors.

Game application on physiology class. We used the game as an educational tool to reinforce the learning of a subject already taught in a lecture classroom. Forty students from Physiotherapy (54%) and Nursing (46%) careers from a public Brazilian university participated. The mean age of participants was 19 ± 1.60 yr; the participants were 89% female and 11% male. Most of the students (93%) were in the first year, and a minority was in the second year (7%) of the undergraduate program.

The SBG was applied in practical classes 3 days after the lecture class about the ST. Previously, the students were invited to participate in the research, and those who accepted signed a consent form. This study was approved by the Institutional Ethics Committee (Institutional Review Board no. 2.496.166).

The traditional lecture class lasted ~2.5 h. It aimed to address the main concepts of ST, the differences between chemical and electrical synapses, and to exemplify these concepts with brief applied examples, such as pharmacological ones. In the end of the class, the students were instructed to download an app that would be used for the game in the following class and also received a list of questions to study (not the same as for the SBG).

For the application of SBG, the class was divided into three smaller classes. Each class/group has 1 h to play the game. In each class, the students were divided into groups of two or three individuals to play the game. Then the students were instructed about the game rules before it started. After the game was finished, the students answered an opinion questionnaire about the SBG.

Evaluation method. A questionnaire (Table 3) composed of six closed questions was used to address the students’ opinions about the SBG, including a self-assessment of the students about their performance in the course, their opinion about their learning with the use of the game, and about the game’s use in other courses. Besides that, the students were asked to attribute a grade to the activity, considering a scale from 0 to 10. For the closed questions, the absolute frequency was obtained from the data, and the relative frequency was calculated.

RESULTS AND DISCUSSION

Our results show that the students consider that the SBG contributes to ST physiology understanding and learning. Considering their self-rated performance in the physiology course, 68% believe that it was good or great and 33% that it was regular (Table 3, question 1), so most of the students were confident about their performance. This is important because, according to the literature, perceived self-confidence leads to motivated performance (9). Sturges and colleagues (38) analyzed the relation of the motivation of 1,210 academics and their final grades in human anatomy and physiology; the authors found a significant relationship between students’ expected grade and their final grade in class. Motivation is considered an essential factor for learning (14), and EG is an interesting educational tool because it keeps players motivated (4). The game has the ability to engage the player in a captivating and focused way; in the educational context, it increases students’ interest in the content and, consequently, facilitates effective learning (10).

All of the students agreed that SBG contributed to ST understanding and that it is an interesting tool to use in physiology teaching (Table 3, questions 2 and 3). In addition, all of them considered SBG to be an interesting tool, and 93% considered it important to understand ST concepts, complementing the lecture classes (Table 3, questions 4 and 5). Marcondes et al. (21) used a puzzle to teach cardiac cycle for health students and found that, for most students, the use of the game helped to fix the content (64.5%), and for many of them the game was considered essential to understanding the content (30.9%). Machado et al. (20) showed that “the membrane potential puzzle” contributed to students’ understanding of the action potential content, and that it was an interesting tool to use in physiology teaching. The game, “Who Wants To Be A Physician?”, based on the television game show, “Who Wants To Be A Millionaire,” was created by Moy et al. (26), with the purpose of explaining physiology of the lungs for first-year medical students; the authors verified that the students responded positively to the game. So we believe that SBG may be an important tool to help in ST physiology teaching.

In the end, students were asked to attribute a grade to the SBG, considering a scale from 0 to 10 (Table 3, question 7). The average grade attributed was 9.39 ± 0.86. Additionally, 95% of the students affirmed that they would recommend to other teachers the use of EGs in their classes (Table 3, question 6). These results confirm that the game was well accepted and agree with previous studies that investigated students’ opinions.
### Table 2. Questions included in the synaptic board game

| Question No. | Level  | Easy | Question | Correct Answer | Incorrect Answer | Incorrect Answer 1 | Incorrect Answer 2 |
|--------------|-------|------|----------|----------------|------------------|---------------------|-------------------|
| 1            | Level 1: Easy | What is a gap junction? | A membrane channel that allows the connection between two cells in an electrical synapse | A type of postsynaptic receptor present in chemical synapses | A channel that allows the connection between two cells in a chemical synapse |
| 2            | Level 1: Easy | Which is the type of synapse that has a bidirectional response? | Electrical synapse | Chemical synapse | Both |
| 3            | Level 1: Easy | Which is the type of synapse that usually has a unidirectional response? | Chemical synapse | Electrical synapse | Both |
| 4            | Level 1: Easy | Comparing chemical and electrical synapses, which one has the fastest response? | Electrical synapse | Chemical synapse | Both have the same speed of response |
| 5            | Level 1: Easy | Which is the type of synapse that is most easily modulated? | Chemical synapse | Electrical synapse | Both can be modulated equally |
| 6            | Level 1: Easy | Which is the type of synapse that involves the neurotransmitter’s release? | Chemical synapse | Electrical synapse | Both |
| 7            | Level 1: Easy | Which is the type of synapse that involves the propagation of information between two excitable cells? | Both | Chemical synapse | Electrical synapse |
| 8            | Level 1: Easy | An advantage of this type of synapse is the synchrony in the activity of a group of cells. Which is this type of synapses? | Electrical synapse | Chemical synapse | Both |
| 9            | Level 1: Easy | Which is the type of synapse that presents gap junctions? | Electrical synapse | Chemical synapse | Both |
| 10           | Level 1: Easy | Which is the type of synapse that presents a synaptic cleft? | Chemical synapse | Electrical synapse | Both |
| 11           | Level 1: Easy | Which is the type of synapse that has pre- and postsynaptic neuron/excitable cell? | Both | Chemical synapse | Electrical synapse |
| 12           | Level 1: Easy | Which alternative presents organelles that can be find in the presynaptic neuron of a chemical synapse? | Mitochondria and synaptic vesicles | Vesicles with neurotransmitters and gap junctions | Gap junctions and mitochondria |
| 13           | Level 1: Easy | We can find in the postsynaptic neuron of a chemical synapse: | Chemical receptors | Gap junctions | Gap junctions and receptors |
| 14           | Level 1: Easy | Which is the type of synapse that can have ionotropic receptors? | Chemical synapse | Electrical synapse | Both |
| 15           | Level 1: Easy | Which is the type of synapse that can have metabotropic receptors? | Chemical synapse | Electrical synapse | Both |
| 16           | Level 1: Easy | Which type of synapse depends on the arrival of an action potential to initiate communication? | Both | Chemical synapse | Electrical synapse |
| 17           | Level 1: Easy | Which type of synapse has almost zero synaptic delay in the information passage between cells? | Electrical synapse | Chemical synapse | Both |
| 18           | Level 1: Easy | In chemical synapses, the electrical signal is transformed in a chemical signal. This chemical signal is sent in the form of a: | Neurotransmitter | Receptor | Ca²⁺ channel |

Continued
| Question No. | Category | Question                                                                 | Correct Answer | Incorrect Answer 1 | Incorrect Answer 2 |
|-------------|----------|--------------------------------------------------------------------------|----------------|-------------------|--------------------|
| 19          | Level 1: Easy | In chemical synapses, who responds to chemical signal in the postsynaptic neuron? | Receptor       | Neurotransmitter   | Ca²⁺ channel       |
| 20          | Level 1: Easy | Which type of synapse involves a larger number of mitochondria?           | Chemical synapse | Electrical synapse | Both involve an equivalent number of mitochondria |
| 21          | Level 1: Easy | Which cell type cannot be part of a synapse?                             | Hepatocyte     | Neuron             | Muscle cell        |
| 22          | Level 1: Easy | Considering three types of cells cited, which one can be part of a synapse? | Smooth muscle cell | Red blood cells    | Dermis’ cells      |
| 23          | Level 1: Easy | Considering the cells/structures cited below, which one cannot be part of an electrical synapse? | Neur muscular junction | Heart             | Smooth muscle     |
| 24          | Level 1: Easy | During chemical synapse activation, the arrival of an action potential in the synaptic terminal stimulates the opening of: | Ca²⁺ voltage-dependent channels | Vesicles         | Na⁺ voltage-dependent channels |
| 25          | Level 1: Easy | During chemical synapse activation, the opening of Ca²⁺ voltage-dependent channels stimulates: | The fusion of vesicles containing neurotransmitters with presynaptic neuron membrane | The transport of vesicles from pre- to postsynaptic neuron | The receptors opening in the postsynaptic neuron |
| 26          | Level 1: Easy | In a chemical synapse, in addition to the calcium, the neurotransmitter exocytosis in the synaptic cleft requires: | ATP            | Sodium            | Acetylcholine      |
| 27          | Level 1: Easy | In a chemical synapse, where are the neurotransmitters released?          | In the synaptic cleft | Directly in the postsynaptic neuron | Into the gap junction |
| 28          | Level 1: Easy | What is the structure that guarantees the connection between two cells in an electrical synapse? | Gap junctions  | Synaptic cleft    | Ionotropic receptor |
| 29          | Level 2: Medium | The neurotransmitters presented in a chemical synapse are:               | Excitatory or inhibitory | Always excitatory | Always inhibitory |
| 30          | Level 2: Medium | Which type of receptor can be present in a chemical synapse?            | Both           | Ionotropic         | Metabotropic       |
| 31          | Level 2: Medium | The stimulation of an ionotropic receptor always promotes:              | The opening of an ion channel | The opening of a Ca²⁺ channel | The influxes of Na⁺ ions |
| 32          | Level 2: Medium | What is the effect of a metabotropic receptor stimulation?              | The activation of second messengers | The activation of first messengers (neurotransmitters) | The transport of vesicles |
| 33          | Level 2: Medium | What type of receptor is coupled to a G protein?                        | Metabotropic   | Ionotropic         | Both               |
| 34          | Level 2: Medium | How are the neurotransmitters stored in the presynaptic neuron?          | Inside vesicles | Free in the cytoplasm | Inside the endoplasmic reticulum |
| 35          | Level 2: Medium | The postsynaptic receptor of a chemical synapse must be                 | Specific for a neurotransmitter | Always coupled with a G protein | Always an ion channel |
| 36          | Level 2: Medium | What is the fundamental role of Ca²⁺ in the chemical synaptic transmission? | To promote the neurotransmitter exocytosis | To stimulate the generation of an action potential | To help the cell restore its resting potential |
| 37          | Level 2: Medium | The Ca²⁺ channels present in presynaptic neuron are activated by:       | Voltage        | Mechanical stimulus | Ligand             |
| 38          | Level 2: Medium | In the chemical synapse, the neurotransmitters are released by:         | Exocytosis     | Endocytosis        | Pinocytosis        |

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Table 2.—Continued

| Question No. | Category | Question                                                                 | Correct Answer | Incorrect Answer 1 | Incorrect Answer 2 |
|-------------|----------|--------------------------------------------------------------------------|----------------|-------------------|-------------------|
| 39          | Level 2: | In a chemical synapse, the postsynaptic receptors are NOT activated by:  | Ions           | Ligands           | Chemical messengers |
| 40          | Level 2: | Considering a chemical synapse, it is correct to affirm that the neurotransmitters are release from the _______ of the presynaptic neuron. | Axon terminal  | Neuron body       | Dendrites         |
| 41          | Level 2: | An advantage of a chemical synapse is:                                    | The larger possibility of modulation of the final response | The faster response | The propagation of the signal in two directions |
| 42          | Level 2: | A neuron can:                                                             | Make multiple synaptic connections | Make just one synaptic connection with another neuron | Make synapses with nonexcitable cells |
| 43          | Level 2: | A synapse may NOT occur on:                                               | Nonexcitable cells | Smooth muscle cells | Heart cells       |
| 44          | Level 2: | The heart cells need synchronous activation to guarantee the effectiveness of the heart contraction. Knowing this, what kind of synapse is better to fulfill this function? | Electrical synapse, because this type of synapse promotes quick signal propagation | Chemical synapse, because this type of response promotes great modulation | Electrical synapse, because this type of response promotes unidirectional propagation |
| 45          | Level 2: | What is most prevalent type of synapse in the central nervous system?    | Chemical synapse | Electrical synapse | Both are present in the same frequency |
| 46          | Level 2: | The electrical synapse, in comparison to chemical synapse, has:           | Higher signal propagation speed | Greater possibility of modulation of the final response | Signal propagation in only one direction |
| 47          | Level 2: | A step of the chemical synaptic transmission is NOT:                      | The binding of neurotransmitters to receptors in postsynaptic neuron | The binding of neurotransmitters to receptors in postsynaptic neuron | The arrival of the action potential in axon terminal of the presynaptic neuron |
| 48          | Level 2: | The fusion of vesicles containing neurotransmitters with the postsynaptic neuronal membrane is NOT: | The opening of voltage-dependent Ca\textsuperscript{2+} channels in the terminal of the presynaptic neuron | The fusion of vesicles containing vesicles with the presynaptic membrane | The fusion of neurotransmitter-containing vesicles with the presynaptic membrane |
| 49          | Level 2: | A step of the electrical synaptic transmission is NOT:                   | The fusion of the vesicles containing neurotransmitters with the postsynaptic neuronal membrane | The electrical stimulus passage through the gap junctions | The ion passage through the gap junctions |
| 50          | Level 2: | The electrical synapse favors bidirectional movement of:                 | Ions           | Neurotransmitters  | Vesicles          |
| 51          | Level 2: | In a chemical synapse, after the arriving of action potential in the axon terminal, what is the next step? | The opening of Ca\textsuperscript{2+} voltage-dependent channels in the axon terminal | The release of neurotransmitters in the synaptic cleft | The fusion of vesicles with the presynaptic membrane |
| 52          | Level 2: | In a chemical synapse, after opening of Ca\textsuperscript{2+} channels, what is the next step? | The fusion of vesicles containing the neurotransmitters with the postsynaptic neuronal membrane | The release of neurotransmitters in synaptic cleft | The neurotransmitter binding to postsynaptic neuron receptor |
| 53          | Level 2: | In a chemical synapse, after releasing the neurotransmitters, what is the next step? | The binding of neurotransmitters to postsynaptic neuron receptor | The voltage-dependent Ca\textsuperscript{2+} channels opening | The vesicles containing the neurotransmitters fusion with the postsynaptic membrane |
| 54          | Level 3: | A neurotransmitter may NOT bind to:                                       | A gap junction  | A channel protein  | A transmembrane protein |
| 55          | Level 3: | Electric synapses are present in the unitary smooth muscle and in the cardiac muscle. The properties of this type of synapse are important for: | The rapid propagation and synchronous activation of these muscle fibers | The great modulation and fast response | The unidirectional propagation and synchronous activation of these muscle fibers |
| Question No. | Category | Question | Correct Answer | Incorrect Answer 1 | Incorrect Answer 2 |
|-------------|----------|----------|----------------|-------------------|-------------------|
| 56          | Level 3: Hard | Fast electric synaptic transmission favors: In which part of the neuron are the main chemical neurotransmitters synthesized? | A synchronous response of a group of cells | A greater signal modulation | Both |
| 57          | Level 3: Hard | In which part of the neuron are the main chemical neurotransmitters synthesized? | In the neuronal body | In the dendrites | In the axon terminal |
| 58          | Level 3: Hard | Considering chemical synapses, we know that ionotropic receptors generate effects on the postsynaptic membrane faster than metabotropic ones. So, what is the advantage of metabotropic receptors? | The amplification of the final response | The excitement of a larger number of cells | The mobilization of a great number of neurotransmitters |
| 59          | Level 3: Hard | After a chemical synapse, what is a possible destination for the neurotransmitter? | The diffusion out of the synaptic cleft | Evaporation | Internalization by postsynaptic neurons |
| 60          | Level 3: Hard | After a chemical synapse, what is a possible destination for the neurotransmitter? | The inactivation by enzymes present in the synaptic cleft | Evaporation | Internalization by postsynaptic neuron |
| 61          | Level 3: Hard | After a chemical synapse, is it correct to say that an action potential will be generated in the postsynaptic neuron? | Only if the sum of stimulus received by the postsynaptic membrane reach the threshold | Yes, always | No, never |
| 62          | Level 3: Hard | A postsynaptic potential is: | A graduated electrical potential that can occur in response to a chemical synapse | A subtype of action potential | An electrical potential that can also occur in nonexcitable cells |
| 63          | Level 3: Hard | Postsynaptic potentials can be summed. This summation can be: | Temporal and/or spatial | Atemporal and/or special | Localized and/or specific |
| 64          | Level 3: Hard | Acetylcholine produces motor plate depolarization and heart hyperpolarization. Norepinephrine produces a stimulatory response in heart and inhibitory response in vascular smooth muscle. What is the main factor that determines these different effects of the same neurotransmitter? | The different receptors found in the target cells | The amount of neurotransmitter released | The type of synapse |
| 65          | Level 3: Hard | An agonist of a neurotransmitter corresponds to a substance that: | Binds to postsynaptic receptor, mimicking the effect of the neurotransmitter | Binds to the postsynaptic receptor, nullifying the effect of the neurotransmitter | Avoid the neurotransmitter release by presynaptic neuron |
| 66          | Level 3: Hard | An antagonist of a neurotransmitter corresponds to a substance that: | Binds to the postsynaptic receptor, blocking the effect of the neurotransmitter | Binds to the postsynaptic receptor, mimicking the effect of the neurotransmitter | Avoid the neurotransmitter release by presynaptic neuron |
| 67          | Level 3: Hard | The synapse between a neuron and the skeletal muscle, called neuromuscular junction, is considered infallible. One reason is that: | It always uses the same neurotransmitter, acetylcholine, which is released in a large amount | It is a very fast electrical synapse | It always uses the same neurotransmitter, sodium, which is released in sufficient quantities to ensure muscle contraction |
| 68          | Level 3: Hard | Generating or not an action potential in the postsynaptic neuron after a chemical synapse depends on: | The summation of the postsynaptic potentials generated in the neuron membrane, which can or cannot lead the membrane potential to the threshold. | The summation of the action potentials generated on the neuron membrane | After a chemical synapse, the action potential always occurs in the postsynaptic neuron |
about EGs. In a study realized by Rose (33), most of the students reported that a BG developed by the authors that helped them to understand and learn the metabolic pathways was helpful to their learning. Another example is the biofilm building, a BG created to teach students about bacterial biofilms (24). Shiroma and colleagues (35) developed a game about psychopharmacology to teach medical students; the students reported that they enjoyed the game and affirmed that it was effective in increasing their knowledge about the subject. Finally, in a study developed by Odenweller and col-

**Table 2.—Continued**

| Question No. | Category | Question | Correct Answer | Incorrect Answer 1 | Incorrect Answer 2 |
|--------------|----------|----------|----------------|--------------------|--------------------|
| 69 | Level 3: Hard | In an experiment about synaptic transmission, a chemical synapse was placed in a fluid equivalent to extracellular fluid, but without calcium. An action potential was initiated in the presynaptic neuron. Although the action potential reached the axon terminal, the response in the postsynaptic cell did not occur. What conclusion did researchers reach based on this result? | That the event between the arrival of the action potential at the presynaptic terminal and the response generation in the postsynaptic neuron is calcium dependent | That all action potentials are calcium dependent | That all liquid fluid must have calcium |
| 70 | Level 3: Hard | One of the classes of antidepressants is the selective serotonin receptor inhibitors. What do these drugs do with serotonin activity in synapse? | They increase the time that serotonin is available in synaptic cleft | They decrease the time that serotonin is active in synaptic cleft | Anything |
| 71 | Level 3: Hard | Why are axon terminals sometimes called biological transducers? | Because they convert an electrical signal (action potential) to a chemical signal (neurotransmitter) | Because they convert a chemical signal (neurotransmitter) into an electrical signal (action potential) | Because they generate energy |

**Fig. 2.** Synaptic board game app. A: Screen 1 shows the “Let’s Play!” button. B: on screen 2 the students find an access code screen to guarantee their access to the questions only on the day of the intervention; the access code is quizzlfb. C: on screen 3, the students find three buttons that indicate the three levels of questions’ difficulty. D: according to the space on the board, the player should choose the corresponding level, and the app shows a random question and indicates if the answer is correct or not.
In question 7 of this study, a BG for ST content for physiology classes was used to provoke student interaction, which can produce team learning (33). In order to get a better performance (33). They also enable student-to-student interaction; which are powerful tools to use in the classroom, instigating the students to understand more about physiology content, without necessity of a game moment of collective discussion of the content in working groups. The undergraduate students affirmed that the EG is important to complement the theory taught by the professor in a lecture class, and they also consider it as an important tool to provide a funny and sociable moment. In fact, EGs have been shown to be a way to make synaptic physiology learning easier and more fun.

Table 3. Students opinion about the synaptic board game

| Question                                                                 | Objective                                                                 | Answers                  | Summary of Responses, n (%) |
|-------------------------------------------------------------------------|---------------------------------------------------------------------------|--------------------------|------------------------------|
| 1. How do you rate your performance in this course?                     | To verify students’ self-criticism regarding their performance in physiology | Great: 2 (5); Good: 25 (63); Regular: 13 (33); Bad: 0 (0) | 37 (93)                     |
| 2. Do you think using the SBG contributed to your understanding of the content? | To verify students’ opinion about game contribution in ST learning | Yes: 40 (100); No: 0 (0); | 33 (8%)                     |
| 3. Do you think that the SBG is an interesting tool to use in physiology teaching? | To verify students’ opinion about SBG effectiveness as a tool to use in physiology teaching | Yes: 40 (100); No: 0 (0); | 33 (8%)                     |
| 4. In your opinion using the SBG in the classroom was ... (Check as many options as you like.) | To verify students’ general opinion about SBG | Important for your understanding of the ST concepts, complementing the lecture classes: 37 (93); Essential for your understanding of the ST concepts, because, with only the classes, I would not be able to understand: 8 (20); Fun, because it provided an informal moment of collective discussion of the content in working groups: 33 (8%); Unnecessary; lecture lessons would be enough for the understanding of the content, without necessity of a game: 0 (0); | 33 (8%)                     |
| 5. In your opinion, the use of games in the Human Physiology course.... (Check as many alternatives as you want.) | To verify students’ opinion about use of games in Human Physiology course | Is interesting: 29 (73); Allows for a better understanding of the contents worked in class: 36 (90); Is funny: 30 (75); Instigates curiosity and the desire to understand more about physiology: 29 (73); Is boring: 0 (0); | 33 (8%)                     |
| 6. Would you recommend to other teachers the use of educational games in their classrooms? | To verify students’ perception about the games’ applicability in other courses | Is boring: 0 (0); Yes: 38 (95); No: 1 (2.5); No response: 1 (2.5); | 33 (8%)                     |
| 7. Assign a grade for the use of the SBG, considering a scale from 0 to 10. | To evaluate the SBG in the participant’s view | Good: 25 (63); Regular: 13 (33); Bad: 0 (0); | 33 (8%)                     |

Values are n, no. of responses (with percentage in parentheses). Results are given as absolute and relative frequency for the closed questions (questions 1–6). In question 7, the mean ± SD is given. SBG, synaptic board game; ST, synaptic transmission.

leagues (28), a card game was used to teach the subject; students commented that this methodology was able to emphasize the material and helped the memorization process. The undergraduate students affirmed that the EG is important to complement the theory taught by the professor in a lecture class, and they also consider it as an important tool to provide a funny and sociable moment. In fact, EGs have been showing their importance in the area of education: they are capable of changing the behavior of students in the classroom, stimulating them to be more active and sociable. In research realized by Rose (33), the students related that the fact that the game was fun and enjoyable motivated them to learn more about the subject; they got enthusiastic. These data match with the opinion of the students who participated in this research: most of them think that the SBG is interesting, funny, allows a better understanding of the theory, and instigates them to search to increase their knowledge about the subject.

In general, the studies recommend the use of EG as strategy to facilitate teaching. This is because the games can be a powerful tool to use in the classroom, instigating the students to get a better performance (33). They also enable student-to-student interaction, which can produce team learning (33). In this study, a BG for ST content for physiology classes was designed and tested with students to find out their opinion about this teaching strategy. Their opinion was extremely positive, which makes us excited. We expect that the SBG can be a way to make synaptic physiology learning easier and more fun.

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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

A.D.C., D.F.P., C.F.K.d.R., and P.B.M.-C. conceived and designed research; A.D.C. and D.F.P. performed experiments; A.D.C., C.F.K.d.R., and P.B.M.-C. analyzed data; A.D.C., C.F.K.d.R., and P.B.M.-C. interpreted results of experiments; A.D.C. and P.B.M.-C. prepared figures; A.D.C. and P.B.M.-C. drafted manuscript; A.D.C., D.F.P., C.F.K.d.R., and P.B.M.-C. edited and revised manuscript; A.D.C., D.F.P., C.F.K.d.R., and P.B.M.-C. approved final version of manuscript.
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