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## A puzzle used to teach the cardiac cycle

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**Marcondes FK, Moura MJCS, Sanches A, Costa R, Lima PO, Groppo FC, Amaral ME, Zeni P, Gaviao KC, Montezor LH.** A puzzle used to teach the cardiac cycle. *Adv Physiol Educ* 39: 27–31, 2015; doi:10.1152/advan.00116.2014.—The aim of the present article is to describe a puzzle developed for use in teaching cardiac physiology classes. The puzzle presents figures of phases of the cardiac cycle and a table with five columns: phases of cardiac cycle, atrial state, ventricular state, state of atrioventricular valves, and pulmonary and aortic valves. Chips are provided for use to complete the table. Students are requested to discuss which is the correct sequence of figures indicating the phases of cardiac cycle. Afterward, they should complete the table with the chips. Students of biology, dentistry, medicine, pharmacy, and nursing graduation courses from seven institutions performed the puzzle evaluation. They were invited to indicate whether the puzzle had been useful for learning about the subject by filling one of four alternatives. Of the students, 4.6% answered that it was not necessary but helped them to confirm what they had learned, 64.5% reported that although they had previously understood the cardiac cycle, the puzzle helped them to solve doubts and promoted a better understanding of it, and 30.9% said that they needed the puzzle to understand the cardiac cycle, without differences among courses, institutions, and course semesters. The results of the present study suggest that a simple and inexpensive puzzle may be useful as an active learning methodology applied after the theoretical lecture, as a complementary tool for studying cardiac cycle physiology.

graduate education; educational games; active learning; physiology; heart

IN PHYSIOLOGY COURSES, students are expected to learn a large amount of information and to integrate the morphological and physiological concepts. Knowledge about the cardiac cycle, an important topic in the physiology of the cardiovascular system, is required by students of healthcare careers, such as biology, dentistry, medicine, and nursing. Considering the amount of information involved in the study of cardiovascular physiology, student-centered teaching is necessary, because it provides active involvement of the student in the teaching-learning process, resulting in effective learning (22). In this context, supplementation of lectures and practical classes with educational games can be a useful teaching strategy.

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Educational games may increase students' interest in the subject under discussion and increase the retention of knowledge (23). An educational game may be a competitive activity with rules and procedures in which learning results from interactions and behaviors of the players. It can also be a simulation based on reality or a structured noncompetitive activity. In these types of games, learning results from the subject matter (1). Educational games allow students to learn by doing, develop their creativity and ability to solve problems, and improve their communication and negotiation with peers (5). Games can be used at the beginning of a class as a motivational tool, during a class as a teaching tool, or after a lecture for the revision of concepts (23). Educational games have been used in life sciences careers, in different disciplines and subjects, such as obstetrics (2, 19), gastrointestinal physiology (3, 18), psychiatry (4), immunology (8), pharmacology (5), and practice in hospital wards (24).

We developed a puzzle of the cardiac cycle (7, 13) to help students to understand how the heart pumps blood continuously. In addition, we intended to provide a way to make it easier for them to integrate the concepts of morphology and physiology in both normal and pathological states of the heart. The aim of the present article is to describe the cardiac cycle puzzle and to present perceptions of students about its use after a traditional lecture-based learning in undergraduate healthcare courses.

### MATERIALS AND METHODS

This work was performed with undergraduate students ( $n = 327$ ) in Biology ( $n = 32$ ), Dentistry ( $n = 115$ ), Medicine ( $n = 124$ ), Pharmacy ( $n = 25$ ), and Nursing ( $n = 31$ ) courses from 7 different universities. Students were in their second (dentistry, medicine, and nursing), fourth (medicine), and seventh (biology) semesters, which are the periods when physiology lectures are conducted.

After a presentation of the principal concepts of the above-mentioned cardiac cycles during a 50-min theoretical class, students were divided into groups of 5–7 students/group. Dentistry, medicine, and nursing students were advised to study clinical topics related to the pathology of the cardiac system, such as angina pectoris, myocardial infarction, and ventricular fibrillation, 48 h before the practical activity with the puzzle.

The puzzle was developed (7, 13) based on the figures and tables of the Moffett et al. (16) physiology textbook. The puzzle presents pictures of the cardiac cycle phases (Fig. 1) and a table and chips for use to complete the table (Figs. 2 and 3). The pictures show the path of the arterial and venous blood in the heart as well as contraction and relaxation of the atria and ventricles. The table (Fig. 2A) has five columns and six rows. The columns indicate the phases of cardiac

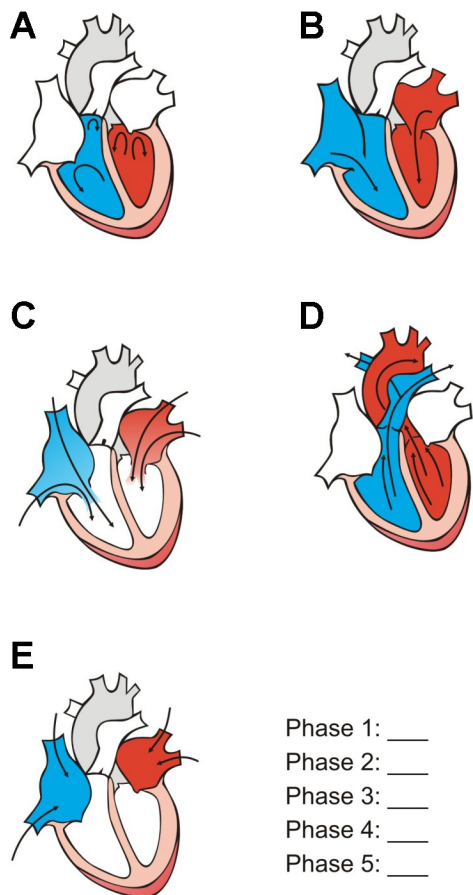


Fig. 1. Figures of the phases of the cardiac cycle in the cardiac cycle puzzle.

cycle, atrial state, ventricular state, state of the atrioventricular valves, and state of the pulmonary and aortic valves. The chips (Fig. 2B) indicate the names of the cardiac cycle phases, atrial and ventricular relaxation or contraction, valves opening and closing, and heart sounds. The figure board and table were 29 cm wide and 20 cm high. The figure board was printed in color on 120 g/m<sup>2</sup> paper of A4 size and was laminated with transparent plastic. The table and pieces were printed in black and white, on a similar type of paper, and were also laminated. Each piece measured 5.7 × 2.5 cm.

At the Piracicaba Dental School, activities with the puzzle were coordinated by a professor and three graduated students as monitors. At the Araraquara University Center, the activity was coordinated by a professor and four undergraduate medical students. Each monitor guided two groups, by moving from one group to the other group alternatively. At the other institutions, one professor supervised all groups simultaneously, by discussing doubts and giving instructions to one group at a time. Each group of five to six students received a set consisting of a checkerboard and pieces to assemble the puzzle. During assembly of the puzzle, students were expected to organize each piece on the board according to the respective phase of the cardiac cycle. Subsequently, the teachers analyzed every group's board to check if they had been correctly organized. If the pieces were not correctly organized, students were encouraged to find and fix their mistakes, and the instructors then reevaluated the boards. During the activity, instructors also discussed each student's choice of chips. In addition, students were asked the following questions during the activity: 1) When and how do the cardiac valves open and close? 2) When are the cardiac sounds heard? 3) How is the electrical stimulus transmitted through the heart during each phase? 4) How do the gap junctions participate in conducting the cardiac electrical stimulus? 5) What role does atrioventricular delay of action potential play in the

cardiac cycle? and 6) What is the importance of Hiss and Purkinje fibers for the transmission of electric stimulus in the ventricles?

The instructors evaluated each step completed (ordering the figures of cardiac cycle phases and filling out the table) and proposed some questions to make the group of students reevaluate what was not correct. Students had to arrive at the correct answer by comparing the different opinions in their group. They had to complement some information presented by a colleague about cardiac anatomy and histology, and the group was instructed to integrate what they knew about cardiac morphology and its function. Students were allowed to work in groups in periods lasting 70–100 min.

Once all groups had accurately completed their puzzles, the instructors finalized the activity with a discussion concerning the main events of the cardiac cycle as proposed by the game in addition to a debate on the major issues raised by the students during assembly of the puzzle. This discussion with the entire class took 20–30 min. The complete activity lasted ~90–120 min.

Considering the course in medicine, a discussion was encouraged about the medical correlations between normal and pathological states of the heart that had been studied. Taking the medical students into consideration, a debate about medical correlations was also illustrated by videos from the Apple 3D Medical Heart Pro III for iPad. This part of the activity lasted ~15 min/group.

Students' evaluation of the usefulness of the puzzle was assessed by the following question in a later class: "In the physiology class, a puzzle of the cardiac cycle was used. Please indicate if this material was helpful in learning about cardiac function by checking one of the alternatives below:

A. The material was not necessary for me to understand the studied topics and did not need to be used. I had understood the heart cycle events based on the theoretical class about the basis of cardiac physiology.

B. The material was not necessary for me to understand the studied topics, but it was useful since it helped me note I had understood the content.

C. The material was useful to enable me to gain a better understanding of the topics studied. Although I had understood the cardiac cycle, the material helped me by clarifying some items and/or by allowing me to clear some doubts.

D. The material was necessary to enable me to understand the topics covered. By attending only the theoretical class, studying the book and the notes alone, I had not understood the cardiac cycle, and the puzzle method helped me understand the topics addressed.

Students did not identify themselves with the response to this question.

## RESULTS

Students' answers to the question about the usefulness of the cardiac cycle puzzle for learning purposes showed that for the majority of students (64.5%), the puzzle was useful to enable them to gain a better understanding of the topics studied and to clarify items. For 30.9% of the students, the puzzle was necessary to enable them to understand the topics covered ( $P < 0.05$  by  $\chi^2$ -test). Only 4.6% of students answered that the material was not necessary for understanding the studied topics, but it was useful to confirm what they had learned. These percentages did not differ among the courses, semesters, and institutions ( $P > 0.05$  by  $\chi^2$ -test).

## DISCUSSION

The results of the present study express the value of using the puzzle as an active methodology applied after the theoretical class, as a complementary tool for the study of the cardiac

**A**

Cardiac Cycle Phase	Atrial state	Ventricular state	State of Atrioventricular valves	State of Aortic and pulmonary valves

Fig. 2. Table (A) and chips (B) in the cardiac cycle puzzle.

**B**

closed	open	relaxed	relaxed: filling	passive filling
relaxed: filling	relaxed	ejection	ventricular isovolumetric relaxation	contracting
atrial contraction	isovolumetric contraction	isovolumetric relaxation	ventricular isovolumetric contraction	contraction: ejection
*1 <sup>st</sup> sound heart	*2 <sup>nd</sup> sound heart	relaxed	relaxed	closed
closed	closed	closed	closed	closed
open	open			

Fig. 3. Table of the cardiac cycle puzzle filled with chips.

Cardiac Cycle Phase	Atrial state	Ventricular state	State of Atrioventricular valves	State of Aortic and pulmonary valves
Passive filling	relaxed	relaxed: filling	open	closed
Atrial contraction	contracting	relaxed: filling	open	closed
Ventricular isovolumetric contraction	relaxed	isovolumetric contraction	closed *1 <sup>st</sup> sound heart	closed
Ejection	relaxed	contraction: ejection	closed	open
Ventricular isovolumetric relaxation	relaxed	isovolumetric relaxation	closed	closed *2 <sup>nd</sup> sound heart

cycle physiology by students of biology, dentistry, medicine, pharmacy, and nursing courses. Although their learning outcomes were not assessed, students found that the combination of the theoretical class followed by the puzzle activity was useful for them to gain a better understanding of the subject, clear doubts about the topic, and integrate the concepts proposed.

It has been previously reported that educational games decrease stress during student activities (5). Although we did not evaluate the relationship between students' stress levels and the use of the puzzle, in spontaneous manifestations, many students pointed out that they liked the activity with the cardiac cycle puzzle because it was stimulating and promoted cooperation among the students, since it involved teamwork. In addition, students said that it was an entertaining way to learn.

During the activity, the teachers realized that the students were curious. Since this curiosity was associated with the relaxed atmosphere, the activity with the puzzle may have increased their intrinsic motivation to learn (25). This interpretation was supported by some spontaneous comments by students who pointed out that the puzzle was challenging; the discussions in the groups were interesting, and the activity with the puzzle allowed one student to explain some subjects to another, which facilitated their understanding. In addition, when the work environment is pleasant, people interact better with each other, are more alert and critical, and are more productive (17).

It is important to emphasize that the activity with the puzzle promoted active participation of the students, who were at the center of the teaching-learning process. Previous investigations have suggested that students' perceived understanding and performance can be improved by promoting active learning (11, 20). Therefore, the cardiac cycle puzzle used in the present study represents an active learning strategy that transformed students into active players in the learning process, in agreement with other authors who have used different games in education (6, 14, 21).

In the present work, the professors also observed that some topics that students generally did not understand so easily seemed to become more understandable. For example, students frequently think that only after the atria have been filled with blood will the atrioventricular valves open, and then the atria will contract. We observed that during the completion of the puzzle, it became clear to them that almost 80% of the blood goes passively from the atria to the ventricles and that atria contraction completes filling of 20% of the ventricles. This information is presented in the books; however, it seems that the students did not understand what this means. Considering this, it became clearer to them why alterations in ventricular function compromises cardiac inotropism at a higher level compared with dysfunction in atrial contraction. In addition, the role of the cardiac pacemaker became clearer because, while filling out the table, students had a discussion about the time when the action potential is generated and why its delay in the atrioventricular node is important.

Considering that students have different styles of learning, it is necessary to use different teaching strategies to address the diversity of students and improve the retention of knowledge and effective learning. Some students have better auditory skills, so they prefer to listen, whereas others prefer tactile stimulation and others may learn more easily while talking

about the subject after reading and taking notes (9, 12). During a traditional lecture, it is not possible to promote the same degree of engagement of students. Whereas auditory-oriented students, who like to learn by listening to someone, will pay attention and learn, kinesthetic students, who prefer a hands-on approach to learning, will not (15). Using active learning strategies, the teacher is able to promote the engagement of students with different learning styles. In the activity presented here, this probably occurred because students had to analyze the figures, talk, listen, pose questions, and touch and change the placement of chips. Thus, different skills were required and different learning styles interacted to perform the activity, resulting in positive perceptions by the students about the use of the puzzle to learn the cardiac cycle.

The fundamental role of the university, apart from communication, is to generate knowledge by providing an institutional space for questioning and producing human resources to respond to the needs of the society that maintains it. In the era of information technology and telecommunications, in which information circulates rapidly and generates the dispersion and superficiality of data and reason, educators no longer play the role of information transmitters. They have to assume a role as facilitators of learning, helping students to construct their own knowledge (10). This task is easier if we use different teaching strategies, which may include educational games.

In conclusion, the present article indicates that the combination of the theoretical class and an educational game, used as an active learning tool, could be useful for students to gain better understanding and clarification of misconceptions about the cardiac cycle.

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#### DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

#### AUTHOR CONTRIBUTIONS

Author contributions: F.K.M. and M.J.C.S.M. conception and design of research; F.K.M., M.J.C.S.M., A.S., R.C., P.O.d.L., M.E.C.A., P.Z., K.C.G., and L.H.M. performed experiments; F.K.M. and F.C.G. analyzed data; F.K.M., M.J.C.S.M., A.S., R.C., P.O.d.L., F.C.G., M.E.C.A., P.Z., and L.H.M. interpreted results of experiments; F.K.M. prepared figures; F.K.M. and L.H.M. drafted manuscript; F.K.M., M.J.C.S.M., A.S., R.C., P.O.d.L., F.C.G., M.E.C.A., P.Z., K.C.G., and L.H.M. edited and revised manuscript; F.K.M., M.J.C.S.M., A.S., R.C., P.O.d.L., F.C.G., M.E.C.A., P.Z., K.C.G., and L.H.M. approved final version of manuscript.

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