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Original Article

Artigo Original

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Computer-assisted instruction in Speech-Language and Hearing Sciences: impact on motivation for learning about the Orofacial Myofunctional System

Educação mediada por tecnologia em Fonoaudiologia: impacto na motivação para aprendizagem sobre o Sistema Miofuncional Orofacial

Keywords

Speech-Language and Hearing Sciences
Anatomy
Physiology
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Motivation

ABSTRACT

This study aimed to compare the learning motivation of three learning methods as means of teaching Anatomy and Physiology of the Orofacial Myofunctional System of second-year Speech-Language and Hearing Sciences undergraduate students. The study was conducted with 36 students that participated after signing an informed consent form. Each student was randomly allocated to the groups: Group I (GI) – 12 participants using Interactive Method 1 (IM1); Group II (GII) – 12 participants using Interactive Method 2 (IM2); and Group III (GIII) – 12 participants using the Traditional Method (TM). The learning methods were applied during weekly complementary study schedule, following the discipline's lectures. Upon the conclusion of the learning methods application, the *Instructional Materials Motivation Survey questionnaire* was administered for evaluating the students' learning motivation. Data were analyzed using SPSS software version 21. Comparisons between groups were performed using ANOVA followed by Tukey post hoc test. The significance level was set at 5%. The groups differed in all evaluated aspects with the total score (F2,33 = 3691.17 p <0.001). The GII had the highest overall score (GI x GII = p = 0.015; GI x GIII = p = 0.115; GII x GIII = p <0.001). On attention (GII x GIII = p = 0.001) and confidence (GII x GIII = p = 0.003), GII had higher scores than GIII. There was no difference between groups on relevance. For satisfaction, GII had the highest score (GI x GII = p = 0.023; GII x GIII = p <0.001). Therefore, summatively, the 3D computer model was more efficient in enhancing students' learning motivation.

Descritores

Fonoaudiologia
Anatomia
Fisiologia
Instrução por Computador
Motivação

RESUMO

O objetivo deste estudo foi comparar três métodos de aprendizagem sobre Anatomia e Fisiologia do Sistema Miofuncional Orofacial quanto à motivação para a aprendizagem em Fonoaudiologia. Participaram 36 estudantes do segundo ano de graduação, após assinatura de termo de consentimento livre e esclarecido. Cada estudante foi alocado randomicamente nos grupos: Grupo I (GI) – 12 participantes do *Método Interativo 1 (MI1)*; Grupo II (GII) – 12 participantes do *Método Interativo 2 (MI2)*; Grupo III (GIII) – 12 participantes do *Método Tradicional (MT)*. Os métodos de aprendizagem foram aplicados durante horário de estudo complementar semanal, após aula expositiva de disciplina obrigatória. Concluída a aplicação dos métodos de aprendizagem, foi aplicado o questionário *Instructional Materials Motivation Survey* para avaliar a motivação. Os dados foram submetidos à análise estatística no *software* SPSS versão 21. A comparação entre os grupos foi realizada pela ANOVA seguida pelo teste post hoc de Tukey. O nível de significância foi de 5%. Os grupos diferiram em todos os aspectos avaliados e na pontuação total ($F_{2,33}$=3691,17 p<0,001). O GII teve maior pontuação geral (GI x GII = p=0,015; GI x GIII = p=0,115; GII x GIII = p<0,001). Com relação à atenção (GII x GIII = p=0,001) e à confiança (GII x GIII = p=0,003), o GII teve maior pontuação que o GIII. Não houve diferença quanto à relevância. O GII teve a maior pontuação para satisfação (GI x GII = p=0,023; GII x GIII = p<0,001). Neste estudo, foi observado que o modelo computacional 3D foi mais eficiente para motivar os estudantes durante a aprendizagem.

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INTRODUCTION

Knowledge of Anatomy and Physiology concepts is of extreme importance for both students and Speech-Hearing Sciences professionals in order to conduct assessments, make diagnoses, and provide therapy[1]. Because of the advances in information technology, computer-assisted educational objects have been used in order to link Anatomy and Physiology laboratories to strengthen learning of these contents. Positive results have been obtained in the expansion of knowledge and student interest[2].

Games developed for use in different educational levels are examples of computer-assisted learning objects[3]. Their use may foster the development of cognitive abilities, such as memory, attention, critical thinking and construction, and confirmation of hypotheses[4].

Nowadays, there is a lack of consensus on the effects of computer games on students' performance in general[5]; however, positive results have been found in its use in higher education[6]. We conducted a precursor study in the Speech-Hearing Sciences that has shown that the use of a computer game as a supplementary tool to the teaching-learning process has been beneficial for students as much as the traditional learning method has been, especially in relation to short-term theoretical knowledge retention: the traditional method was more efficient in long-term theoretical knowledge retention[7].

In addition to the aforementioned results of the use of computer games in teaching and learning, studies have also shown that the integration of computer simulators (e.g., animations, visualizations, and interactive laboratories) in these contexts may provide students with opportunities to foster their comprehension of non-observable phenomena in science and make abstract concepts visible[8]. In Speech-Language and Hearing Sciences, recent work on Anatomy and Physiology has suggested that there has been a substantial increase in students' theoretical knowledge after the use of computer 3D models, and that such models seemed to be more effective in learning than the exclusive use of the traditional methods[9,10]. There are few but recent studies in this area; for this reason, more studies are necessary to confirm that learning using simulators is comparable to traditional learning[11].

The motivation increase for learning has been revealed as one of the greatest benefits in the use of computer games in education as mentioned in literature[12,13] when compared to what has been obtained from the use of traditional methods[14]. Studies reveal that computer 3D models and virtual environments awaken and arouse student interest[15,16]. The extensive use of computer simulators has helped students become more engaged because they are then able to see the results of their decisions on basic concepts and clinical procedures that they have applied in a more concrete way, therefore improving their clinical skills[17].

One of the main models that has influenced the method and learning environment assessment in relation to motivational stimuli for students' performance[15-19] is the Attention, Relevance, Confidence, and Satisfaction (ARCS) model in motivational design[20]. All motivational strategies based on the ARCS model are devised to better expectations and values that influence students' learning behaviors[21]. The Instruction Materials Motivation Survey (IMMS)[19] that is validated internationally is based on the ARCS model, and it has been conducted in different learning contexts including computer-assisted learning[15,16,22,23]: This model was also used in this study.

There are still few studies that assess the motivational aspects for learning and consider all their components[17]: This occurs especially because of the lack of proper methodological support for the definition of indicators and reliable instruments for its measurement[22,23]. There are no published studies in Speech-Language and Hearing Sciences that have formally assessed the learning motivation of undergraduate students in computer-mediated learning contexts and consider all of their components. Thus, this indicates the need for specific studies on the topic.

The aim of this study consisted of the application and comparison of three learning methods for Anatomy and Physiology of the Myofunctional Orofacial System (MOFS), in which these three methods were used: the interactive method 1 (IM1— 2D computer game); the interactive method 2 (IM2— 3D computational model), and the traditional method (TM— summarized scientific texts associated to static 2D images). Subsequently, the learning motivation among undergraduate Speech-Language and Hearing Science students was investigated.

Considering the results in literature, the hypothesis of this study was that, firstly, the motivation for learning would be greater among students that participate in the interactive, 3D computational model and, secondly, among those that participate in the interactive, 2D computer method when compared to each other and with the traditional learning method.

METHOD

This study was conducted on Speech-Language and Hearing Sciences students at the School of Medicine at the University of São Paulo (FMUSP) in a formal course that includes a weekly supplementary study time in the classroom.

The selection and assessment criteria were performed only after the approval of the research project by the Ethics and Research Committee at FMUSP (Research Protocol no. 131/14) and the signing of the consent forms by the participants.

The subjects' inclusion criteria were: having concluded the basic courses in Anatomy and Human Physiology (part of the mandatory undergraduate FMUSP Speech-Language and Hearing Sciences syllabus for the first year – 1st and 2nd terms), and being proficient in reading and comprehension of English-language texts (confirmed by the students' performance on the university entrance exams).

Thirty-six students were selected as the study subjects, and all of them participated in all the study stages. Each student was placed at random in one of the three following groups: Group I (GI) – 12 students, who participated in the interactive model 1 (IM1 – 2D computer game); Group II (GII) – 12 students, who participated in the interactive method 2 (IM2 – 3D computational model); and Group III (GIII) – 12 students, who participated in the traditional method (TM – summarized scientific texts associated to pertinent 2D static images).

The interactive method 1 (IM1) consisted of the use of a quiz-format computer game, which is integrated into the *Anatesse 2.0* software[24], which features topics on OMFS Anatomy and Physiology. The students used the software during the supplementary study time where they were split in pairs or trios according to their choice, and they used a desktop computer for the supplementary study. On the first day of class, a brief tutorial was presented to instruct students how to use the software. The selected topics for the supplementary study in each week were related to topics approached in each formal class.

The interactive computer game is comprised of multiple-choice questions with static images and 2D animations. The students received feedback for each question answered on the screen. If the answer was correct, a picture with a happy green face was shown; if the answer was incorrect, a picture with a sad red face was shown. At the end of each section of the game, the total score was given.

Each part of the game was played twice; however, in the second trial, after the students' answers were finalized, the correct answer to each question was provided automatically to reinforce performance feedback and broaden content learning possibilities.

The interactive method 2 (IM2) consisted of the use of the *Primal Pictures*[25] software, which features topics on Anatomy and Physiology in a 3D computer graphics model. The students used the software during the supplementary study time. To do so, the students were split in pairs or trios according to their choice, and they used a desktop computer with Internet access for the supplementary study. On the first day of class, a tutorial was provided in order to instruct the students on how to use the software. The topics selected for the supplementary study each week were related to topics approached in each formal class.

The *Primal Pictures*[25] software is a computer model that is comprised of images associated to brief explanatory texts, animations, 3D graphics videos, and slides with brief integrated texts, and a dynamic 3D human anatomy model. The software is divided into areas of domain, including titles of medical specialties and other health areas. The following parts of this software were used in this study:

1. *Speech Language Pathology*: A field specifically designed for Speech-Language and Hearing Science that is comprised of images associated to brief explanatory texts, 3D graphics videos, and slides with brief integrated texts. Images and 3D animations of OMFS Anatomy and Physiology were used in this study. The software featured alterations of the visualization of static images according to the side that the user would like to visualize. One could also resume and forward the animation and video sequences according to the time and number of times the user thought were necessary. These contents were available in English;
2. *3D Head*: The human head model (featuring bones, muscles, fasciae, veins, lymphatic vessels, nerves, etc.) in the *Primal Interactive Human*, which shows the human body segments in 3D, thus allowing for real-time interactivity between the user and the model. This model allows user manipulation: rotating the image through 360º; altering visualization according to the side or angle the user wants to see; adding annotations for future study; exhibiting or hiding information; and emphasizing each part of his individual study. This model is available in English and Portuguese;
3. *Interactive learning activities for Speech-Language Pathology*: This feature of the *Primal Pictures* tool contains topic review and a quiz game with multiple-choice questions about each of the selected study items. Each week, during the last 15 minutes of the supplementary study time, the IM2 students reviewed their studies and answered the quiz questions. They received feedback on their performance on the computer screen as follows: Firstly, a text box appeared on-screen informing whether the provided answer was correct. Secondly, the correct answer was shown (in both situations) to reinforce performance feedback and broaden content learning possibilities. Finally, at the end of each game stage, the score was displayed. The content of this section is available in English.

The traditional method consists of the use of summarized scientific texts associated to OMFS Anatomy and Physiology 2D static images during the supplementary study time. The students were told to study the way they usually do—individually, in pairs, or in trios in the classroom. The selected topics for the supplementary study were related to topics dealt with during each formal class.

The use of learning methods was done within seven weeks, which is the total length of the formal course. The expository classes for both groups lasted for three hours, and the supplementary study lasted for an hour. The selected topics were the same for all groups. Each group was assigned a tutor who accompanied them during their supplementary study time.

To evaluate student motivation in both groups, the *Instructional Material Motivation Survey* (IMMS) was used immediately after the end of the application of the two learning methods. The IMMS is a motivational assessment tool based on the ARCS model[18,19], which was previously validated in a computer-assisted learning environment. This instrument has been utilized for the motivational assessment of instruction materials, especially in interactive teaching environments including computer-assisted environments and educational computer games[13,17,21,22].

IMMS is a tool that contains 36 sentences, whose judgment possibilities (alternatives) are presented in a Likert-like scale. The users are asked to assess each sentence according to the following archives: 1– not true; 2– slightly true; 3– moderately true; 4– mostly true; and 5– very true. Each sentence of the original instrument was created from the individual components of the ARCS motivational design model, consisting of 12 sentences that measure attention; 9 sentences that measure confidence; and 6 sentences that measure user satisfaction.

All the 36 IMMS original sentences were used in a Portuguese-translated version (they were devised specifically for this research), with small tweaks to adapt them according to the instructional materials. The translation and proofreading procedures are recommended in literature[15,19]. In addition, the original grammatical structure of each sentence was maintained to comply with the research questions.

Data analysis

The collected data were submitted to statistical analysis using the SPSS version 21 Software. The significance level used in this study was 5%.

To characterize the research subjects, their gender was described by the number of subjects and the equivalent percentage, and their age was described by the mean, standard deviation, minimum, maximum, median, and quartiles. The one-factor ANOVA was utilized to compare group ages. Descriptive analyses were also performed by using mean, standard deviation, minimum, maximum, median and quartiles values for the other aspects investigated in this study.

The IMMS motivation assessment has four different components. Each one of them features distinct minimum and maximum possible scores (considering the number of sentences used to assess each component). Thus, data standardization was done to compare the four components in each group. The *z score* was used for this conversion, that is, each subject's score was subtracted from the general mean for that domain, and the resulting value was divided by the general standard deviation. As a result, a zero z score corresponds to a value equivalent to the population mean, whereas other values associated to the plus or minus sign indicate how many standard deviations that value is below or above average.

The comparison of the domains was made by a repeated-measure ANOVA of a factor in each group from the data collected. The comparison between the groups in relation to the general and component score gathered in the motivation assessment was made using ANOVA, followed by the Tukey's post hoc test.

RESULTS

Regarding the characterization of study subjects, all groups had predominantly female subjects while there was no male subjects in GI (IM1) (Table 1). The average age was 22.0 (±4.7) years, and no statistical difference among ages between groups was observed ($F_{2,33}$=60,72 p=0,260).

The mean of the domains score in GI (IM1) was close to the population mean; only the relevance component had a more varied score. In GII (IM2), all scores were positive, with means above 0.5. GIII (TM) only showed negative mean scores and, except for the relevance, these were situated below 0.5. However, none of the groups showed a statistically significant difference among the z scores of the motivation components (Figure 1).

Table 1. Gender distribution per group

Group	Gender				Total
	Male		Female		
	n	%	n	%	
GI(MI1)	0	0.0	12	100.0	12
GII(MI2)	1	8.3	11	91.7	12
GIII(MT)	2	16.7	10	83.3	12
General	3	8.3	33	91.7	36

The three groups were different in both the total score and in the score attributed to each aspect of the motivation assessed by means of the students' answers to the IMMS questionnaire, as shown in the descriptive statistical (Table 2) and inferential analyses (Figure 2). The total score was greater for GII (IM2), and the maximum score for each of the four aspects was different for all groups. GII (IM2) reached the highest score in the attention, confidence, and satisfaction aspects. As for the relevance aspect, GI (IM1) and GII (IM2) reached the same maximum score.

In addition, we verified that for the attention and confidence aspects, GI (IM1) and GII (IM2) groups did not differ, and GI (IM1) did not differ from GII (TM) in both aspects. Regarding relevance, despite the difference in the ANOVA ($F_{2,33}$=122,89 p=0,048), this difference was not confirmed in the pairwise comparison. On satisfaction, GII (IM2) showed a greater score than the others did, and GI (IM1) did not differ from GIII (TM) (Figure 3).

DISCUSSION

In this study, three Anatomy and Physiology learning systems of the Myofunctional Orofacial System for Speech-Language and Hearing Sciences students were used and compared. Two methods were interactive (the first featured a 2D computer game, and the second featured a 3D computational model), and the third featured a traditional method (featuring summarized scientific texts with related pictures) to foster motivation for learning. Analyses were performed pertaining to the general motivation level, and each motivation component, according to the ARCS motivational design model[20,21] by means of the IMMS survey[19].

Few studies have investigated the motivational components as a whole in different learning contexts[15]. Furthermore, this is an unprecedented proposal in the Speech-Language and Hearing Science field for the few studies that have shown students' motivation level analyses were based on the use of different technological educational objects, and they were conducted in a general and simplified way; hence, these past studies have not considered all its aspects or used validated instruments for their research methods[10].

After the initial data standardization of the data related to motivation analysis and its analysis according to the group, we verified that, despite the fact that none of the groups have shown a statistically significant difference between the components' *z scores*, the students who played the computer game behaved similarly. Their motivation was close to the general population mean. The students who used the 3D computational model felt motivated in a level higher than the population mean, with positive results in all components, whereas the students who participated in the traditional method showed motivation below the population mean, with negative results in all components.

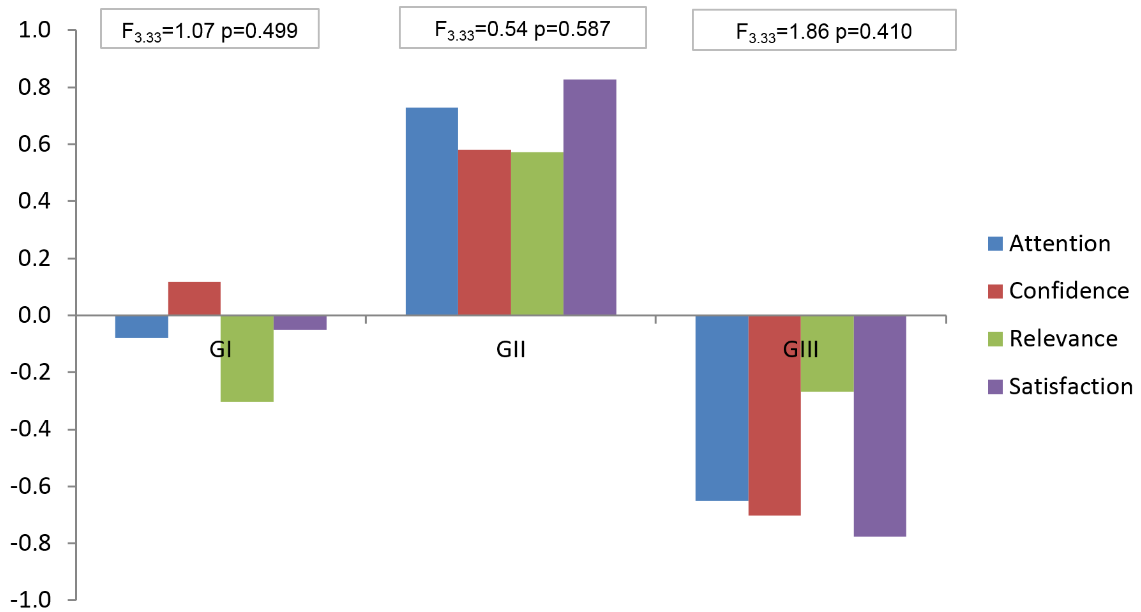

Figure 1. Comparison of motivation for learning component results according to the IMMS survey per group (z score)

Table 2. Descriptive statistics of scores in the IMMS survey per group

Aspect	Group	Mean	Standard Deviation	Minimum	Maximum	Median	1st quartile	3rd quartile
Attention	GI(MI1)	33.67	4.030	25	38	35.50	32.00	36.00
	GII(MI2)	37.33	3.985	31	44	37.50	33.50	39.75
	GIII(MT)	31.08	3.397	25	39	31.00	29.00	32.75
Confidence	GI(MI1)	25.33	2.387	21	29	26.00	23.00	27.00
	GII(MI2)	27.42	3.704	22	33	27.50	23.25	30.75
	GIII(MT)	21.67	5.087	14	31	21.50	18.00	25.25
Relevance	GI(MI1)	28.33	4.459	21	39	29.00	24.75	29.75
	GII(MI2)	32.33	3.939	27	39	31.50	29.00	35.50
	GIII(MT)	28.50	4.462	21	35	29.00	24.50	32.00
Satisfaction	GI(MI1)	16.83	4.239	9	28	16.50	15.25	17.75
	GII(MI2)	21.67	4.250	15	30	21.00	19.25	24.75
	GIII(MT)	12.83	4.239	7	19	11.50	9.25	17.75
Total	GI(MI1)	104.17	10.978	86	129	103.50	97.25	109.75
	GII(MI2)	118.75	13.363	102	144	117.00	108.75	128.75
	GIII(MT)	94.08	11.595	78	109	94.00	81.5	106.25

In the inter-group comparison for the general motivation for learning general level, the students who participated in the GII (IM2) also showed the best results. This could be linked to the degree of interactivity presented by the 3D computational model, which is greater than the one presented by the 2D computer game, and even greater than the one presented by the traditional method texts. The 3D computational model used in this study, which is similar to a previously presented model in the Speech-Language and Hearing Science field[10], allowed the students to manipulate the images freely by rotating them and visualizing them in different cuts and positions. This enabled a more detailed study of each topic, which was not possible with the other educational objects.

In this context, the research results support previous results for Speech-Language and Hearing Sciences students, who had learned about temporal bone anatomy from a 3D computational model. These subjects displayed higher levels of curiosity during the study, thus, increasing their motivation for learning and their study time. In addition, the results support the Veterinary Medicine study results in which students seemed to be more engaged during the learning process because of the use of a computer simulator[26].

According to the Motivation, Volition and Performance (MVP) theory[21], which takes into account the motivation components presented in the ARCS model, motivational processing helps students to set initial goals for their performance that are crucial in supporting the learning process. After that, they must transform their learning goals into concrete actions through their own free will. Then, the interface between motivation and information processing occurs, in which students apply metacognitive

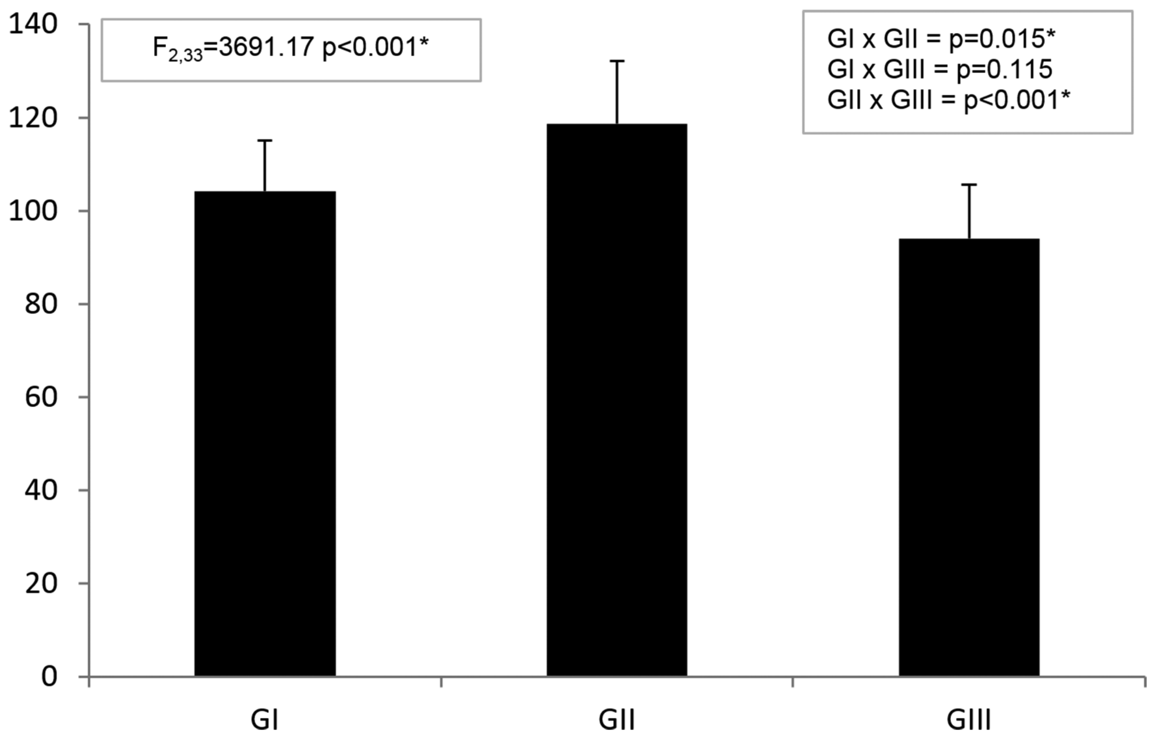

Figure 2. Comparison between the total average score of the groups in the motivation survey

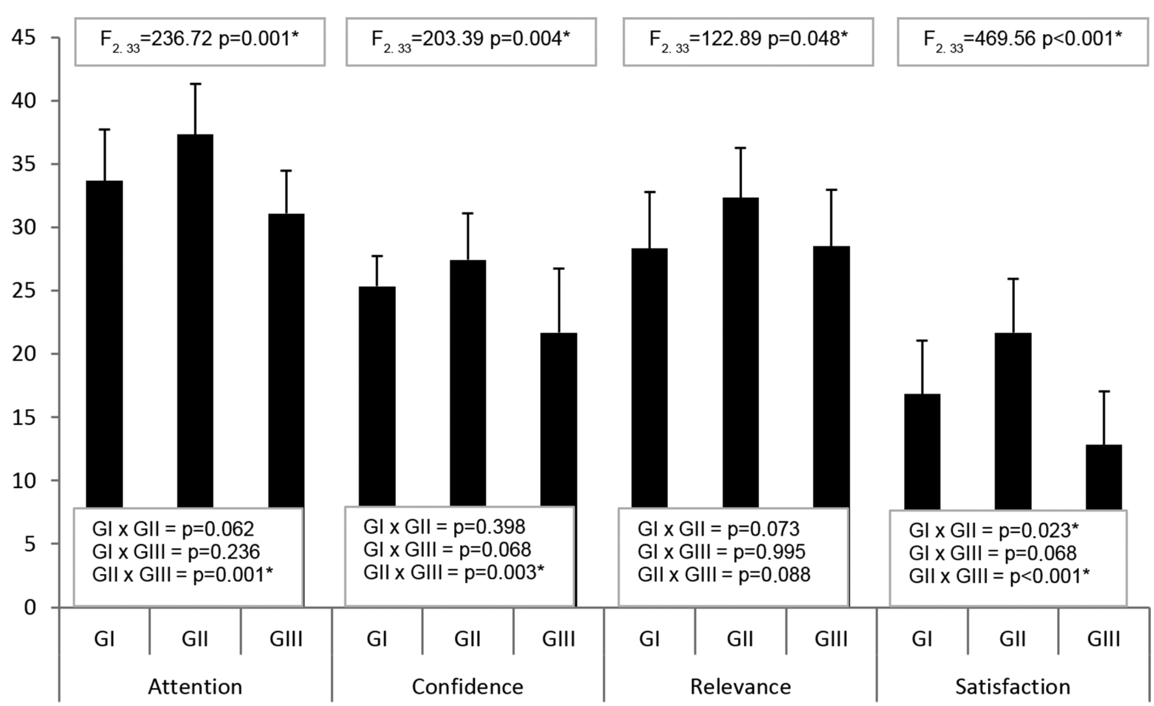

Figure 3. Comparison between the average score of the groups in the different components of the IMMS survey

strategies to manage their learning actively. To do so, the students' cognitive capacity must be taken into account, which is limited by the working memory and cannot be exceeded to provide information storage and new information transfer to the long-term memory, thus creating new mental models(15).

With regard to the motivation processing attention and confidence, the students, who utilized the 3D computational model, had the highest score in the motivation assessment. Nevertheless, no statistically significant difference was observed between the two interactive models used for these two components. Attention refers to students' response to a stimulus perceived during the learning process, which may enable them make greater effort to study; confidence is related to building up a positive expectation of the students on the possibility of obtaining good performance from the interaction with a certain object or learning task(15,18,21). Therefore, considering the results obtained in this study, we could notice that the two interactive methods proposed were efficient at fostering higher levels of attention and confidence among the students during the learning process, even with different levels of interactivity.

Both the computer game and the 3D computational model provided the students with the possibility of problem solving and immediate feedback on their performance. The possibility of a performance analysis as well as the subsequent display of correct answers allow students to reflect upon their mistakes, focus their attention on the most relevant topics, and attempt to study harder on the concepts that need to be better learned to facilitate knowledge acquisition(15,27).

In the 3D computational model, we asked students to investigate OMFS Anatomy and Physiology concepts first so that they could manipulate the images and animations freely. In the end, they were asked to complete the built-in quiz. The sense of freedom during learning triggers a feeling of personal control that is part of the confidence component(22). Having the opportunity to select how and when to learn and the possibility of choosing how to deal with a task based on personal preferences affect the students' intrinsic motivation. This may justify the fact that the highest scores attributed to attention and confidence were reached by the students that participated in the IM2.

In addition, IM2 appeared to be substantially more efficient than the traditional method in the motivational processing for learning. These results support literature data that demonstrate that traditional learning methods without the use of supplementary interactive tools have been criticized and deemed ineffective at motivating students since they foster passivity and low engagement in the learning process(17).

Differences in the ability to control attention and keep the information objects and goals presented to the students affect how much they may benefit from visual cues and information shown during the learning process(28). The novelty and allure of technology-assisted learning environments stimulate students' curiosity and improve their attention levels during learning(23). Nowadays, Cognitive Psychology state that the ability to control attention focus in relation to working memory capacity is an important starting point for future research that investigate how differences in working memory capacity may affect technology-assisted learning(27).

The relevance component in the motivational processing represents the students' ability in noticing the association between their previous knowledge and new information on a topic for them to use according to their needs(15). Furthermore, it has to correspond with the students' understanding of the educational object and the learning tasks proposed to them(21). In this study, the students attributed the same relevance level to the proposed topics, regardless of the learning method they have participated. It is possible that the students did not manage to fathom the immediate impact of the contents that had been studied in their own lives as future speech therapists, thus lowering the relevance level of these contents when they did the motivation assessment.

Considering the satisfaction aspect, students, who participated in the IM2, had the best results with a statistically significant difference when compared to the other groups of students. According to the MVP theory, satisfaction derives from the processing of results, in which students evaluate the balance between the effort that was made and the results noted in the end of the learning process based on the interaction with an educational object(21). Then, students determine if it is worthy to continue to make an effort to study the educational material that they use(16).

During the processing of results, the students reflect upon all the learning process stages emotionally and cognitively, thus reaching a satisfaction level(15). Therefore, according to the results of the present study, it is possible to say that the students that used the 3D computational model noted that the results obtained at the end of the IM2 application have compensated for the effort they had made during the learning process, thus giving them more satisfaction.

The results obtained by the group that used the 2D computer games in the motivational process were similar to the ones obtained by the group that used the 3D computational model (attention, confidence, relevance components). However, the processing of results outcome was not the most satisfactory, being equivalent to those presented by the group that participated in the traditional model. This result may be linked to a likely cognitive overload caused during the students' interaction with the game since during the whole supplementary study time the students should be answering the questions showed in the game. According to the MVP theory, the students are subject to reduction in motivation because of tiredness that may be caused by the cognitive processing of information for the accomplishment of some tasks(15).

The aspects pertaining to the cognitive effort that students had made during the interaction with the proposed learning methods were not investigated formally in this study, which could be a limitation. Such investigation is likely to be a research subject in this line of research.

Furthermore, the computational game used in this study is not as interactive and complex as the online games with 3D representations and elaborate settings with regard to graphics and interaction possibilities, which have shown considerable potential to motivate students during the learning process[15]. This may also be considered as a limitation to this study, because if the computational game we used had featured a greater interactivity level, that could have resulted in better subjects' evaluation of satisfaction (processing of results) in the motivation survey.

The potential of using computational games is considerable with regard to learning motivation and performance improvement in students. As for the knowledge acquired by the interaction with this kind of educational object, there is a lack of consensus in the literature about how computational games can influence each motivational component described in the ARCS model[29]. The same may be said about the learning motivation based on computational simulators[23].

CONCLUSION

The results of this study have shown that the students who used the 3D computational model showed greater motivation for learning in comparison to the subjects in the other groups in terms of motivational processing (with high levels of attention and confidence, followed by a moderate relevance level). This resulted in a greater satisfaction level in the processing of results. The students that used the 2D computational game showed the second highest levels of motivation. The students that participated in the traditional method showed the lowest motivation level. Both groups did not differ in levels of satisfaction. These results support previous study outcomes found in literature, and confirm the hypothesis of this study.

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Author contributions

SR-M has contributed to the development of the research method, data collection and analysis; discussion of results, and article writing, providing substantial scientific contribution; CRFA has contributed to the development of the research design and manuscript writing, providing substantial scientific contribution.