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SERIOUS GAME DIAGNOSTIC QUIZ FOR MEDICAL EDUCATION: CREATION, DEVELOPMENT AND VALIDATION IN THE AID TO THE DIAGNOSIS OF COVID-19

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ABSTRACT

The present research reports the process of development and validation of a digital quiz-type game, composed of radiological images of lung diseases, questions and answers, educational videocast, which allows the user to learn in a playful way the diagnosis including Covid-19, helping the continuing education of physicians at a critical moment for public health in Brazil in the face of the Covid-19 pandemic, With an increase in the number of cases and deaths, with low availability of serological tests, knowledge of tomographic patterns was imperative for diagnosis. The use of serious games is a strategy to offer digital, integrated and motivating learning, with flexibility of time and space for the construction of knowledge. Through the development of a tool that supports the use of active methodologies in medical education, with the creation of gamified mobile digital technology with immersive learning (Game Based Learning), the following research problem is presented: What is the process to create and validate a quiz-type digital serious game for learning pulmonary tomographic patterns and diagnostic imaging in the context of COVID-19? DiagRadQuiz is a game created in a master's research in Health Sciences Teaching, developed from 2019 to 2021. The game was created from a multidisciplinary team composed of a doctor specializing in radiology and diagnostic imaging, a pedagogue in the area of health technologies and an architect working in programming. It is a serious game for Android smartphones, which aims to assess previous knowledge and teach pathological patterns of the lung parenchyma defined in chest computed tomography. The DiagRadQuiz was validated by information technology specialists (games) and doctors specializing in radiology. All evaluators stated that they would indicate DiagRadQuiz as a pedagogical tool for teaching pathological patterns in tomography prevalent in Emergency Care services, including Covid-19.

Keywords: Gamification. Serious Game. DiagRadQuiz. Medical Education. Radiology.

INTRODUCTION

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In 2020, there was little availability of RT-PCR serological tests and the low sensitivity of rapid tests led the Ministry of Health to review the diagnostic criteria for COVID-19. According to the clinical-epidemiological criterion, confirmation would be based on the analysis of the patient's history, taking into account whether he had symptoms characteristic of COVID-19 and whether he had contact with infected people. On the other hand, the clinical-imaging criterion analyzes tomographic alterations of patients who have had contact with infected people. The final decision on the diagnosis is up to the doctor. In view of the pandemic situation that entered 2021, with an increase in the number of cases and deaths from COVID-19, the low availability of serological tests (which took up to a week to be ready when in high demand), knowledge of tomographic patterns related to COVID-19 was imperative for the diagnosis and management of patients in an assertive manner. The use of new methods or didactic strategies for teaching and learning in the Health Sciences is essential for the treatment of patients with diseases of the lung parenchyma.

The use of *serious games* is a strategy, linked to digital technologies and mobile devices, to offer new teaching-learning possibilities, with flexibility of time and space for the construction of knowledge, which is fundamental in times of social distancing. The present research reports the process of development and validation of a digital quiz-type game, composed of radiological images of lung diseases, questions and answers, educational videocast, which allows the user to learn in a playful way the diagnosis of Covid-19, helping the continuing education of physicians at such a critical time for public health in Brazil.

Through the development of a tool that supports the use of active methodologies in medical education, with the creation of gamified mobile digital technology that provides meaningful and immersive learning (Game Based Learning), the following research problem is presented: What is the process to create and validate a serious digital quiz-type game for learning pulmonary tomographic patterns and diagnostic imaging in the context of COVID-19?

DiagRadQuiz is a game created in a master's research in Health Sciences Teaching, developed from 2019 to 2021. It is a serious game for smartphones with Android and iOS operating systems and aims to assess prior knowledge and teach the main pathological patterns of the lung parenchyma defined in high-resolution chest computed tomography.

DIAGRADQUIZ PROJECT

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Game created from the joint effort of a multidisciplinary team consisting of a physician specialized in Radiology and Diagnostic Imaging, a pedagogue researcher in the area of health technologies and an architect working in programming. For the creation of the game, the five basic principles for creating adapted digital games from Awan (et.al., 2019) were followed, they are:

- Interactivity with informative feedback: engagement in the game is directly related to interaction and real-time feedback on your hits and misses, and it is necessary to provide means for the player to overcome these mistakes, since it refers to an educational game. The lack of specific knowledge about a certain standard can be overcome by accessing the explanatory videos.
- Specific objective: the player must be aware of the objective of the game. In DiagRadQuiz he is informed, right at the beginning, that it is a game to assess and learn specific patterns of diseases of the lung parenchyma, including Covid-19.
- Feeling of improvement: the number of correct answers should increase with the number of times the player accesses the game and this perception is of fundamental importance for student engagement.
- Sense of security: DiagRadQuiz is a safe environment in which the player can be mistaken about the pathological patterns of the lung parenchyma that cause harm to the diagnosis and management of patients, meeting the principles of simulation that are important in medical education (safe learning environment in which error is a didactic strategy).
- Engagement of the senses (vision): For a non-RDDI audience, the observation of specific nuances related to pathological patterns requires the activation of specific areas of vision and memory.

MULTI-PROFESSIONAL CREATIVE TEAM

Specialist in radiology and diagnostic imaging

Responsible for researching and defining the main lung diseases that lead the patient to seek emergency services. Since the objective of the game was to teach the pathological patterns observed in the lung parenchyma, including those observed in SARS-Cov 2 infection, priority was given to diseases that determine changes in the lung parenchyma observed in specific "windows" (interval corresponding to variations between

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black and white for images and level corresponding to variations in gray). Diseases that determine alterations that can be observed only in mediastinal "windows" were excluded.

To choose the diseases to be included in the game, references from the MSD Manual were used. The changes were divided into five groups:

- infectious processes: community-acquired pneumonias, atypical infections, pulmonary tuberculosis, fungal infections, and viral infections, including COVID-19, are addressed;
- dissemination of neoplastic diseases: lung metastases and carcinomatous lymphangitis;
- inflammatory processes: hypersensitivity pneumonitis, respiratory bronchiolitis related to smoking, and cryptogenic pneumonitis in organization;
- exacerbation of chronic processes: pulmonary emphysema and interstitial lung diseases.
- Pulmonary parenchymal alterations related to extrapulmonary pathologies: acute pulmonary edema and pulmonary congestion.

From the determination of the diseases to be addressed, the researcher specialized in RDDI selected images corresponding to the diseases to be addressed in the game, with relevant clinical data and with the diagnostic hypotheses to be included in the differential diagnosis for the game.

For the use of the images from the personal archive, the researchers obtained, according to the guidance of the Research Ethics Committee, an authorization for their use. The specialist in Diagnostic Imaging was also responsible for recording short explanatory videos to describe the changes observed in the exams. For the recording of these videos, we used as a reference the glossary of terms for lung imaging published by the Fleischner Society in 2008 (HANSELL *et al*, 2008). For descriptions related to Sars-Cov2 infection, the reference was the consensus published in March 2020 by the RSNA (North American Society of Radiology) that reports pathological patterns of COVID-19 (SIMPSON *et al*., 2020).

Education Professional Specialist in Information Technology

It brought to the project the theoretical framework regarding the pedagogical bases for the development of a Serious Game. For the development of the game, we started from the pedagogical paradigm of learning by experience (learning by active exploration and

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self-direction to the detriment of learning secondary to direct instruction), a paradigm that is dominant in the design of serious games. This paradigm derives directly from constructivism, formulated by Jean Piaget (PIAGET, 1976) in the 1920s, where the student becomes the protagonist in his learning ("playing" is the student's personal decision and will occur at the moment defined by the student himself, bringing autonomy to him), where the level of maturity of each student is respected (the passage of phases and the number of correct answers in quiz-type games reflect the degree of knowledge of the student). student and are determined solely and exclusively by the student), the learning process is dynamic, with broad interaction and participation of the student (allowing for greater engagement), learning is built gradually (again the passage of phases represents the gradual construction of knowledge, as well as higher scores in quiz-type games). In addition, the process of creating the game includes the concept that learning must be somehow related to the real world so that the student can correlate theoretical concepts with real events (DEWEY, 1916).

Amateur programmer

Being an architect and urban planner by training and having developed a series of works in computer graphics, the amateur programmer with experience in Python and C languages, searched the web, software available in the C language in a free version (free of cost). The software chosen was Unity, from the developer Unity Technologies, for its ease of creating and developing 2D games. In addition, the programmer chose Keynote, developed by Apple, associated with the video recorder included in the basic Ios software package for the realization of the explanatory videos. For eventual video edits, the programmer used the Windows video editor software, included in the Windows 10 basic package. To reduce hisses, and therefore improve the quality of the videocast audios, the Audacity equalizer was used, for audio editing, available in a free version on the internet.

For the animations used in the manual in the final version of DiagRadQuiz, Adobe Photoshop, developed by Adobe, was used. In the process of creating the game, we tried to use exclusively free software. However, after the analysis of the validators, it was noted inconsistency and difficulty in understanding the manual (to be explained in the section on validation) and it was decided to make an animation. To carry it out, it was decided to use Adobe Photoshop, in a version paid monthly by the programmer.

DEVELOPMENT OF THE SERIOUS GAME

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The DiagRadQuiz development process followed the steps proposed by Olsewski and Wolbrink based on an integrative review published in 2017 (OLSZEWSKI; WOLBRINK, 2017) in which they defined the theoretical-practical assumptions necessary for the development of a Serious Game for the medical area. Considering the recommendations, the following were carried out:

A. Team meetings: the professionals involved (the wide difference in the higher education of the professionals involved) in the development of the game held weekly meetings in order to establish the content to be addressed and the way in which this content would be developed. Each of the professionals brought to the meetings pertinent issues related to their expertise, in order to be discussed, reaching a consensus, since the knowledge is complementary and equally important for the success of the structure of operation of the serious game.

B. Transfer of medical concepts: considering that one of the main difficulties described in the process of developing a serious game in the medical field is the difficulty of transmitting medical knowledge to non-medical developers. As highlighted (MUNRO; CLARK, 2013) there are few professionals who are able to articulate knowledge of the IT areas within health, developing projects with developers who understand the challenges and nuances of the health area. DiagRadQuiz also has the educational dimension, making the software project even more complex. Specific meetings were held between the RDDI specialist and the programmer in order to establish specific criteria in relation to the quality of the images and their manipulation, both in the part related specifically to the quiz and in the part related to the explanatory videos. The programmer's previous knowledge in the health area, as he works with clinical engineering, was fundamental for the success of the proposal, which was put into practice with a fluid transit of information exchanges between the knowledge of medical education and the development standards of gamified mobile applications. To create applications, it is necessary to bring together a "multiprofessional team composed of health professionals (responsible for the technical-scientific aspects), designer and programmers (development of the graphic interface and application programming), other professionals with knowledge that contributes to the project" (MELLO, SOUZA, 2019, p.262).

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C. Content production: The RDDI specialist selected the diseases to be addressed, choosing representative images from a real image bank with authorization from a health service. Elaborating together with the education specialist the questions to be asked in the quiz, with the possible diagnostic hypotheses, and the creation of the descriptive content of the explanatory videos. For the production of this content, the RDDI specialist used her knowledge acquired in twenty years of practice as a specialist and data from the specific medical literature. The production of content for the serious game was based on the chaining of the images, of the diseases presented, with a gradual escalation in the level of complexity of the images/pathological patterns. In this sense, DiagRadQuiz enables the "chaining of content to be assimilated, in a gradual and correlated way. On the other hand, from the perspective of Behaviorism, it is understood that through these objects (gamified software), it is possible for the user to repeat tasks" (CELESTINO, 2019, p.25).

D. Learning process mapping: the RDDI specialist, the programmer, and the health information technology education professional discussed and collaborated in order to determine the characteristics of game functionality, layout, flow, feedback, and scoring based on the game development theory and the proposed game modeling. As pointed out by Awan (2019), the ability of a game to meet the proposed pedagogical objectives needs to be established from the process of creation and development of the game, considering everything from the design of the game to the scoring process, with well-established rules about the proposed challenges and the objectives to be achieved.

HOW THE GAME WORKS

DiagRadQuiz was developed for smartphones with the Android operating system and later adapted to the iOS operating system. It was developed using the Unity software, available for free on the web. To create the animations used in the game's manual, the Adobe Photoshop software was used.

The game consists of 50 images that represent the main lung diseases presented by patients who seek emergency medical services. DiagRadQuiz is aimed at physicians who are not specialists in RDDI and brings tomographic pathological patterns to be known even by non-specialists. The player is invited to rate an image and answer a question about the

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probable cause of that pattern presented. There are four possible answer alternatives. If the player hits the first option, he receives 2 points, if he hits the second option, he receives 1.5 points, if he hits the third option, he receives 1 pointand if he hits the fourth (hit by exclusion), he receives no points. The maximum total points to be achieved is 100 points. "Considering the potential of gamification in the context of digital education, such elements were incorporated into the platform. The incentive to participate in the platform is given by the distribution of points" (SANTOS, SZTAJNBERG, 2020, p.528). In addition to the score, when the user advances in the game and realizes the knowledge acquired with the videocasts, the motivation to learn and deepen knowledge increases engagement.

DiagRadQuiz is not only an evaluative serious game that aims to assess exclusively the degree of knowledge of physicians regarding pathological pulmonary patterns at CT scans. DiagRadQuiz has a formative function since for each image made available, there is an explanatory video in which the RDDI specialist describes the observed change in a very didactic way.

Several versions of the game were made and discussed among the members of the development team, before the beta version, which was forwarded to Information Technology professionals with experience in game development and RDDI specialists for validation, a process that led to the refinement of the initial version, and successive improvements until the final version.

DIAGRADQUIZ STRUCTURE (BETA VERSION)

This item details the screens of the application of its beta version as developed until September 2020 with a description of its purpose and functionality. This is the version that is available for evaluation with IT and RDDI specialists. It is important for the purpose of this research to present the original version to understand the changes made after the two validation processes. After this version, another, now definitive, was made available in February 2021 for the process of medical education as doctors who are not specialists in diagnostic imaging, by performing pre and post tests.

On the home screen, it is possible to click on the manual to receive instructions on how to use the serious game or start using it. It was decided to create a tutorial with icons (Image 2), which for semiology, are visual signs that represent another object by similarity (GREIMAS, COURTÉS, 2008), traditionally used in applications and video games, aiming at a full understanding of the general instructions for using the game, since the icons

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become intuitive throughout the use of information systems. The icons used were obtained from a public image bank with open copyright. The basic instructions were about the need to rotate the cell phone to a horizontal position to enlarge the images, use of the movement between the thumb and index finger to zoom in (as occurs in many applications), lateral movement with the fingers to move the images, icon to access the training content (videocast) regarding the radiological images and diseases presented, button to access the next image/disease.

Image 2 - Manual (first version)

Source: DiagRadQuiz, 2021

Image 2 refers to the layout of the main screen during the use of the application, in which the functionalities accessible when the user is playing are described, demonstrating the standard operation of the game for all images, clinical data, response options, access to the video with the explanation of each pathological pattern and diagnostic details of the image, in addition to the exit icon and the next image.

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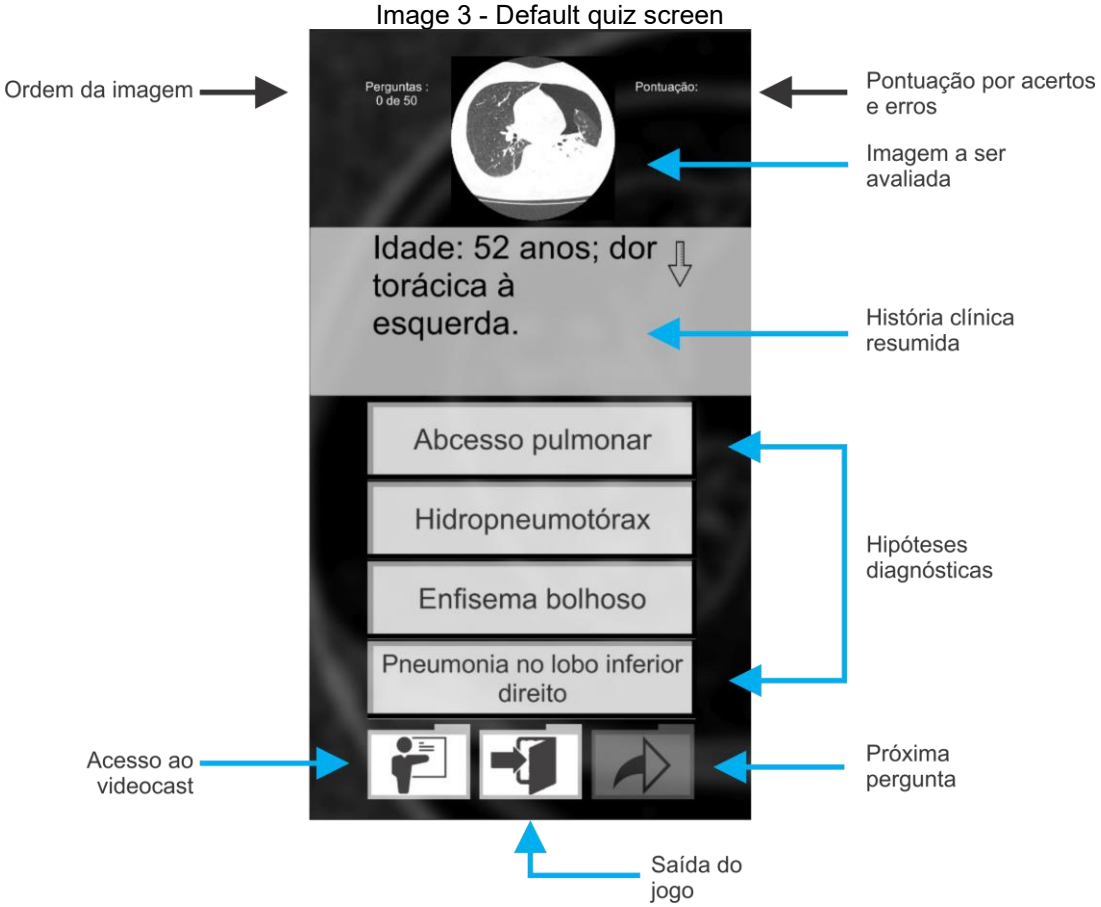
Image 3 - Default quiz screen



Source: DiagRadQuiz, 2021

DiagRadQuiz consists of 50 screens similar to Image 3, with different images, representing a wide range of diseases, including Sars-Cov2 infection. To complete the game, each image is evaluated and the correct diagnostic hypothesis is chosen. If the hit is on the first attempt, the player receives 2 points, if it is on the second attempt, it receives 1.5 points and if it is on the third attempt, 1 point. Access to the next question is only available with the correct diagnosis, hence the importance of access to the videocast that describes each image in detail, helping the autonomous learning of physicians who are not specialists in RDDI through anatomical, radiological and pathological description.

"The quiz makes a differentiated (higher) score for users who answer correctly" (BOTTENTUIT JR, 2017, p.1597) on the first attempt. The pedagogical rationale for the 50 videocasts created is detailed in item 4.2. On the standard DiagRadQuiz screen, the player can, by accessing a specific icon, access an explanatory video about the pathological pattern presented.

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4.2 VIDEOCAST FOR MEDICAL EDUCATION IN PULMONARY PARENCHYMAL PATHOLOGIES

The linking of a videocast to each tomographic image of the game brings the component of continuing education of non-specialist RDDI physicians. In addition to the mistakes and successes in the game, as it is a serious game, the purpose is to provide the user with a reflection on their more or less in-depth knowledge about the tomographic diagnosis of the diseases addressed. Thus, each image/disease is presented as a videocast with explanations for nonspecialists, providing training for the recognition of tomographic patterns that lead to the diagnosis of diseases of the lung parenchyma.

It is worth clarifying the didactic-pedagogical option for the use of videocast as a formative resource in the game. Videocast is a type of resource derived from the podcast, using the suffix cast to indicate the evolution from its predecessor. Podcast means:

mode of production/dissemination of musical content and/or focused on oral reproduction, distributed on demand [...], accessible via direct download or content subscription, for use at times and places of the users' choice (FREIRE, 2012, p. 202).

Understanding the podcast as a particular mode of reproduction of orality, the reported definition includes both audio podcasts that reproduce oral content, as well as videocasts in which, in addition to orality, images are used to contextualize the content. Videocast is "very similar to the podcast, the basic difference is that the file is made available in video when the presence of some images added to the audio is relevant" (COUTINHO, 2020), but it differs from video because the main content is in audio with complementary images, while in videos the audiovisual narrative has images as the main basis.

The proposal to create educational content through videocasts added to the game is based on the technological and educational characteristics of this type of resources: 1) Easy distribution through availability on open social networks such as Youtube, contributing to the democratization of access to content included in platforms such as open [4]educational resources; 2) Lighter and easier to share files, allowing you to study at any time and place

[4] Open Educational Resource (OER) - "teaching, learning and research materials, in any medium or medium, in the public domain, or openly licensed, allowing them to be used by third parties. The use of open technical formats facilitates access and reuse of digitally published resources" (CAPES, 2019).

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(multiplatform); 3) Democratization of knowledge through the use of formats that stimulate the production and sharing of information independently of publishers or institutions.

Among the added advantages of the use of videocasts in an educational context, especially continuing education of professionals, Santos (2014, p.31) highlights:

a) Greater interest in learning content: students and professionals do not recognize virtual media as a monotonous equivalent, novelties gain attention and podcasts/videocasts enable the use of platforms widely accessed on smartphones; b) Learning at the pace of each one: a support resource for different learning rhythms that can be heard countless times for a better understanding of the content covered. c) Accessibility: accessible audio explanation with the support of images asynchronously, allowing flexibility in a busy routine d) Possibility of learning outside formal education: adoption of pod/videocast allows students/professionals freedom of choice regarding the appropriate learning environment for moments of reflection in any place and time; e) Knowledge construction through a creative process: professionals, when adapting to the format of the resource, are also encouraged to create playlists and repositories to share this knowledge with their peers, and create their own.

The videocasts produced, linked to each image of the serious game are listed below, in chart 1, along with the theme and access link.

Chart 1 - List of 50 educational videocasts on diagnostic imaging of pulmonary parenchymal pathologies from DiagRadQuiz

Videocast Title	Access Link	Videocast Title	Access Link
Frosted glass with consolidation	https://youtu.be/DmB-iP7e2_E	Paramediastinal fibrotic changes	https://youtu.be/Ckof1HM2Oa4
Peripheral Frosted Glass	https://youtu.be/KIcvHfGBPHY	Node "in candle flame"	https://youtu.be/QZVkxG6ZKDg
Bronchiectasis	https://youtu.be/VQPzJmkTIWs	Consolidation with distal airspace injury	https://youtu.be/3pbEPU6WOrA
Grounded glass and cross-linked changes	https://youtu.be/u_Kt8azYhU4	Ground-glass halo nodule	https://youtu.be/vqEwqNkq6Vs
Smooth thickening of the septa	https://youtu.be/aSwc_luIQDs	Consolidation	https://youtu.be/1ZD5Ju8veT4
Distal airspace injuries	https://youtu.be/hhAqRpr3keo	Peripheral ground-glass with cross-linking	https://youtu.be/J9KR5Hhmfs8
Pleural changes	https://youtu.be/iorsyIrbAJ4	Diffuse frosted glass	https://youtu.be/xcS0HakAbCY

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Nodular septal thickening	https://youtu.be/UVLyik9e24k	Peripheral Grounded Glass with Consolidation	https://youtu.be/FnYB_LnAoHk
Radiolucent round lesion	https://youtu.be/GULKYL7NLhw	Rounded frosted glass with consolidation	https://youtu.be/1quD3KoQJXY
Rounded consolidation	https://youtu.be/yBcUS08CqY	Frosted glass with cross-linking	https://youtu.be/oW-FDwjP110
Consolidation with fissure bulging	https://youtu.be/85S5oH5vAVc	Rounded frosted glass and peripheral	https://youtu.be/EI3qetz7rL8
Ill-defined centrilobular nodules	https://youtu.be/hWv5QHCzrgo	Frosted glass with consolidation	https://youtu.be/8GbkAVyfE4g
Multiple pulmonary nodules	https://youtu.be/1Zw3B-28puE	Peripheral Frosted Glass	https://youtu.be/yOwypwCcE3s
Peribronchovascular and subpleural ground-glass	https://youtu.be/ajstg7sFHJo	Peripheral Frosted Glass	https://youtu.be/8mbDrEFVdAY
Diffuse frosted glass	https://youtu.be/fJMP-wpS8tc	Peripheral Grounded Glass with Consolidation	https://youtu.be/Yg6UJno0W24
Random micronodules	https://youtu.be/e1itT2E2Q20	Frosted glass with consolidation	https://youtu.be/zJkL7vd5sZM
Multiple pulmonary nodules	https://youtu.be/1z6Ehy0kqqg	Ground-glass with vascular ectasia	https://youtu.be/Df74awHO0eU
Ill-defined centrilobular nodules	https://youtu.be/YdoBQ8IBpXI	Peripheral and rounded frosted glass	https://youtu.be/0vgPLo6lIII
Multiple pulmonary nodules	https://youtu.be/CAk09w6dVM	Rounded frosted glass	https://youtu.be/QnWceJ7PaH4
Fibrotic changes	https://youtu.be/PnpzWUCHrMI	Frosted glass with consolidation	https://youtu.be/pH6sX--HgE8
Ill-defined centrilobular nodules	https://youtu.be/WBlp3RY2dIU	Peripheral Frosted Glass	https://youtu.be/i6Nmhy7rRjM
Multiple pulmonary nodules	https://youtu.be/ttk_N0guqa8	Peripheral Consolidations & Ground-Glass	https://youtu.be/REmpPZgjC8g
Nodular thickening of the interlobular septa	https://youtu.be/OTDpz2kIe-s	Rounded and Peripheral Frosted Glass	https://youtu.be/yydZNKAlybo
Diffuse ground-glass with cysts	https://youtu.be/7Qib3V9q6Ww	Lung Base Flaveling	https://youtu.be/DJGXhlUoztk
Glove-finger injury	https://youtu.be/KD4z93xUUWw	Bronchiectasis with Mucoid Impaction	https://youtu.be/Xv2GGLBi1Fw

Source: survey data, 2021

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VALIDATION BY EXPERTS

Expert validation covered two groups. The first was formed by Information Technology professionals with experience in game development. The validation with these experts took place between October and November 2020. The second group was RDDI specialists and the validation took place between December 2020 and January 2021. The DiagRadQuiz validation process adapted the criteria created by Graafland, Schraagen and Schijven (2012) shown in table 2:

Chart 2 - Validity criteria for games designed for radiology

Validation Type	Criteria for Validation
Content validity	The content of the game must adequately cover the medical knowledge it aims to impart, as determined by the expert in that content (medical)
Interface validity	The medical construct presented in the game must be sufficiently similar to reality, determined by the medical specialist.
Construct validity	The game metrics must demonstrate significant differences between players according to the level of previous and acquired knowledge
Concurrent Game Validity	The game design should correlate the result with the choice of an alternative, as well as direct an established training method for the construction of the proposed knowledge.
Predictive Validity	The development of the game provides for post-training performance, with the construction of knowledge to be used in the real life of the trained doctor. The acquisition of this knowledge must be correlated with a well-explained scoring system.

Source: prepared by the authors based on Graafland et.al. 2012.

Considering the types of validation and criteria proposed, two specific validation instruments were developed. One of them for doctors specializing in RDDI and the other for Information Technology professionals with experience in creating and developing games. These validation instruments were sent to the experts through the GoogleForms platform along with a free and informed consent form for participation in the research project according to the guidance of the CEP of Faculdades Pequeno Príncipe.

VALIDATION BY INFORMATION TECHNOLOGY SPECIALIST

Six specialists in Information Technology participated in the validation of the Application, who analyzed the DiagRadQuiz from the point of view of programming, usability, design and production models of internet applications. Of these specialists, there

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were five men and one woman, aged between 25 and 48 years, with an average age of 39 years. 66.7% of these professionals had already developed or participated in the development process of a game. The criteria evaluated by the Information Technology experts were:

- User interface (by the definition of Rogers, Sharp and Preece, in 2013, it refers to the link between the game and the player, as it allows the player to take control of the action to be performed, navigate the environment and make decisions in the game, its elements range from the controls, keys and mouse to the features that appear on the screens, as important information for the players' decision-making), and the DiagRadQuiz was approved by 50% of the evaluators.
- Gameplay (defined by Sánchez *et al* in 2009, as the set of characteristics that describe the player's experience when using a game, whose main objective is to provide fun and entertainment, and, in the case of serious games, the achievement of a specific pedagogical objective) with approval by 50% of the evaluators.
- Quality of the images made available, considered regular by 66.7% and excellent by 33.3% of the evaluators. - Video quality considered regular by 100% of the evaluators. - Quality of the audios made available being evaluated as excellent by 66.7% and regular by 33.3% of the evaluators.

A field was also opened for criticism and suggestions to improve the game. Among the relevant criticisms, the absence of introductory content dealing with the objectives of the game stands out, as highlighted by participant 2 "There was a lack of an introduction talking about the objective of the Quiz in the tool itself". Caveats were also made regarding the scoring system, as explained by participant 4 "The score is not accounting correctly. I didn't identify the score at the end of the game (sum of points and final total points)". This position is important, since Werbach and Hunter, in 2012, pointed out that in the process of developing a Serious Game, it is essential to create reward mechanisms that stimulate the player's sense of fun, curiosity and competition with himself or with his peers, thus leading to greater adherence to the game (WERBACH; HUNTER, 2012).

Participant 4 took a position on the audio quality of the videocast explanatory videos "In the explanatory video I thought that the audio has a little interference in the background, maybe if you apply a noise filter at the time of recording it will improve the quality". To solve this issue, the audio was treated to reduce noise and make the volume in the foreground

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more comfortable. The developers of DiagRadQuiz are fully aware that sound quality is an important dimension within audiovisual media and have opted for the recording of videocast audios in mp3 format, despite the lower quality of this format compared to high definition recordings, since the game was created to be used on smartphones whose audio system is low resolution (McELHEARN, 2016). To improve the quality of the audios, they were equalized using the Audacity software.

There was no specific manifestation regarding the quality of the images made available, although these were considered regular by most of the IT expert evaluators. It should be noted that the images used were exported directly from the computed tomography machines, in JPEG format and are, therefore, of a different quality, due to their compression, from those used by RDDI specialists to perform the diagnoses (VARMA, 2012). However, the resolution matrix of the images used in DiagRadQuiz remains the same as that used by RDDI specialists to perform diagnoses (512 x 512 pixels), serving the images used for the purpose of the game.

The images used in the DiagRadQuiz followed the quality standard of the Diagnostic Imaging Accreditation Program (PADI) of the Brazilian College of Radiology (CBR, 2018) and were acquired with a thickness of 1 mm, with Kv and mAs variables according to the patient's thickness, and the AUTO mAs technique was used (where the device automatically calculates the value of the mAs to be used). It is noteworthy that the images used are real, obtained with authorization from a health service and, therefore, for learning the radiological pattern of the diseases addressed by DiagRadQuiz, real images equivalent to those that the physician has access to in practice in health services were made available.

Some criticisms regarding the game are beyond the scope of the game. For example, the statement of participant 1: "Evaluating it as a quiz, in which I do not master the content, the visual design can improve, the scoring rules are not clear, I cannot select questions that might be interesting, only a linear process, no return, repetitive, low background music, without any other sound effect. Monochromatic". This type of criticism was not accepted, since DiagRadQuiz is not an instrument made within commercial game standards, having not had financial support or a dedicated development team. Therefore, a game of commercial standard is not expected. An educational game was developed for the teaching of basic tomography patterns. Therefore, even the color palette and elements on the screen were thematic in line with the area of origin (radiology).

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5.2 VALIDATION BY MEDICAL SPECIALISTS IN DIAGNOSTIC IMAGING

Eleven RDDI specialists, ranging in age from 28 to 50 years old, evaluated the DiagRadQuiz. The average length of experience in the specialty was 9 years, and none of the doctors had experience in creating games. The criteria evaluated by the specialists in Diagnostic Imaging were:

- resolution of the images from a technical point of view, with 72.7% of the evaluators fully agreeing with the quality of the images.
- adequacy of the images for the target audience (physicians who are not specialists in RDDI), having been fully approved by 72.7% of the evaluators.
- correlation between images and diagnoses, with approval by about 72.7 % of the evaluators.
- relevance of the diseases presented for medical training with approval by 100% of the evaluators.
- Pedagogical content, structure and quality of the explanatory videos with approval by 100% of the evaluators
- ease of understanding and self-explanatory character of the game manual: 63.6% of the evaluators agreed with this statement.
- possibility of recommendation as a pedagogical tool for medical training: 100% of the evaluators recommend DiagRadQuiz.

In the game validation process, in the open field for "Suggestions for DiagRadQuiz improvement". Among the suggestions, there were complaints about the size of the images from 3 experts: participants 2 "The resolution of the images in the quiz is good, but I found it a little small, I would like to be able to increase them", participant 5 "Small image" and participant 8 "Increase the size of the images". It can be concluded that it is not usual for RDDI specialists to read the explanatory manual that clarifies how to enlarge the image (by rotating the cell phone and enlarging it with the movement of the thumb and forefinger).

The difficulty in accessing the clinical history mentioned by 2 participants was also mentioned, such as the contribution of participant 3 "Include, in the manual, an explanation for reading the clinical history", participant 7 "Does not inform the clinical picture". Regarding access to the clinical history, it was observed that there was no icon in the manual that showed how to access these data, which was corrected.

Another point mentioned was the difficulty among users to understand the scoring system, as explained by participant 10 "Scoring system a little confusing". There was also

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criticism of the scoring system, as said by participant 6 "The quiz score is not counting correctly". In view of these observations, it was decided to include in the explanation manual an item referring to the scoring system in order to make it clear to the player how the score would be, depending on the order of the correct diagnosis. The algorithm for scoring was also revised, and it was corrected in the final version of the game.

In view of the issues highlighted, the developers concluded that it was necessary to reformulate the tutorial for using the serious game, since part of the information was contained in it, but was not understood by users generally because they did not access the manual. Information not available in the first version of the explanation manual (such as access to the clinical history) was included in the final version.

As a suggestion, the creation of a menu with the diseases was indicated so that the clinical doctor could access and consult the images in a situation of doubt in his daily practice, without having to enter the game. The suggestion was noted for later versions of serious games.

CHANGES AFTER VALIDATION WITH EXPERTS

After analyzing the suggestions and criticisms, the final version of the game prototype was reached, with the following changes in relation to the beta version (table 4.3):

Chart 3 - Changes in the DiagRadQuiz after validation with experts

Changed aspects	Description
Access to the Game's tutorial (manual)	Access was optional as a menu item and became mandatory. The home screen now automatically displays the usage tutorial for all game users on first access
Game manual structure	The manual was static and used internationally renowned icons, as well as succinct texts, to guide the main commands of the game. The manual became dynamic, with videos explaining exactly how to proceed to achieve a certain goal, such as enlarging the image
Lack of introductory content	In the manual of the final version, an item was added explaining what the DiagRadQuiz is about
Access to the patient's medical history	An icon on how to access the clinical history has been added and explained in the manual
Difficulty understanding the scoring system	An explanation about the score was added to the manual, demonstrating the difference in points achieved according to the order of correct answers
Error in the accounting of the hits	The scoring system was reviewed and reprogrammed and it was correctly counted in the final version.
Hissing in the audio of the explainer videos	An equalization software (Audacity) was applied in order to reduce the background noise in the available audios

Source: the authors, 2021.

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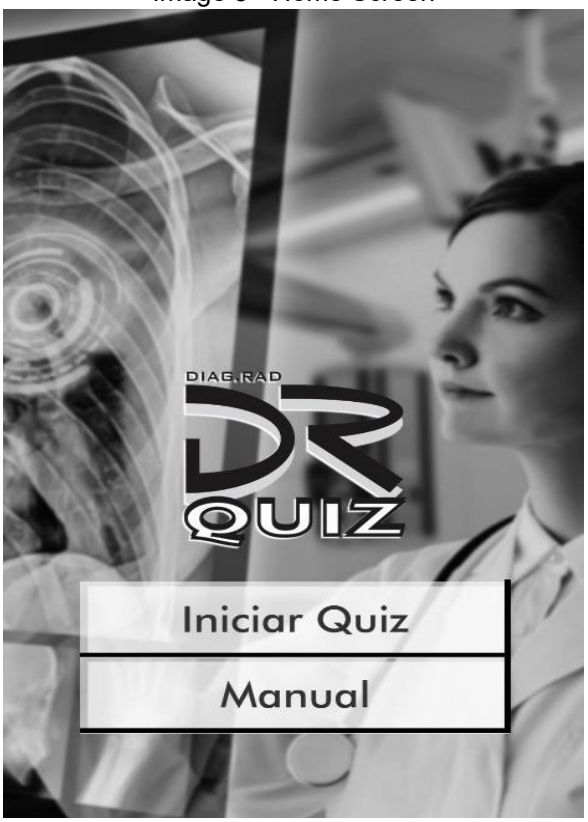
Chart 3 shows the changes made in the structure of DiagRadQuiz after the evaluation of Information Technology professionals specialized in game creation and RDDI specialists, who validated the use of DiagRadQuiz for pedagogical purposes.

The modifications made between the beta and definitive versions were about access to the game manual, as well as the structure of this manual, and an icon was included in the definitive version that guided how to access the patient's clinical history and clarified the scoring system. It was also revised in the definitive version, as suggested by evaluators, the algorithm for scoring was corrected. As a final adjustment, a filter was applied to reduce noise in the videocast audios on the image patterns presented on the various screens of the game.

POST-VALIDATION VERSION OF DiagRadQuiz. The definitive version of the DiagRad Quiz can be accessed through the following link: https://drive.google.com/file/d/1HVZf-21F3akwCbTnpTXLe-Z9wLZDrA3S/view?usp=shari

Image 3 - Home Screen



Source: DiagRadQuiz, 2021

Image 3 represents the opening screen (cover) of the definitive version, and no changes were made in relation to the beta version, whose particularities were described in

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a previous item (item 4). The manual was reformulated to be dynamic, in video, with succinct texts to support the images. Screenshots of the topics covered in the manual follow.

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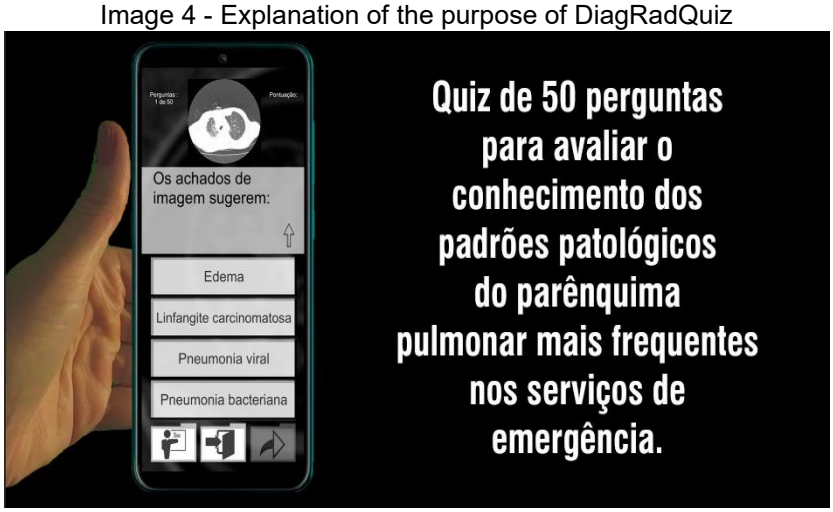
Image 4 - Explanation of the purpose of DiagRadQuiz

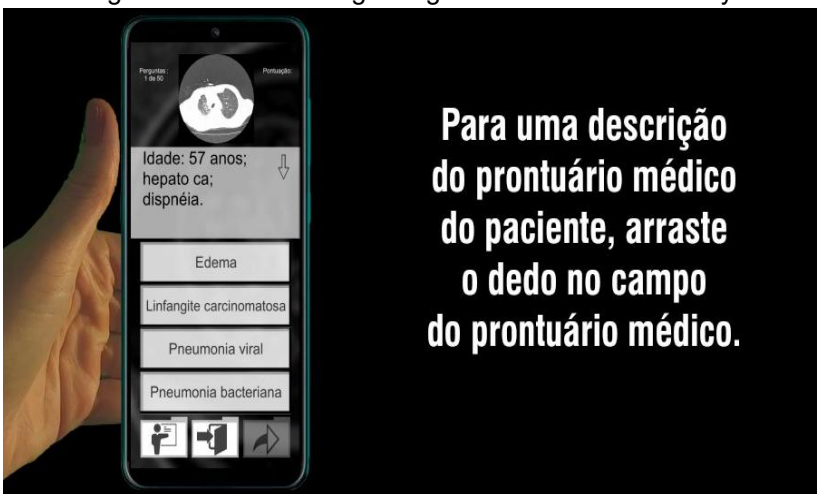


Source: DiagRadQuiz, 2021

Image 4 shows an introduction about the objective of the DiagRadQuiz as suggested by the evaluators. This screen did not exist in the beta version of the game, having been added in order to establish the specific objective of the game, fundamental to player engagement. The pedagogical objective of the game is highlighted, since educational games should help students acquire skills that are directly transferable to patient care (most frequent diseases). Therefore, the practice and application of the skills learned should be the focus of the curriculum (AWAN, *et al*, 2019).

1) Guidance for access to the clinical history (absent in the beta version):

Figure 5 - Guidance regarding access to clinical history



Source: DiagRadQuiz, 2021

The evaluators also pointed out the lack of an icon that showed how access to the patient's clinical history was given. This flaw has been fixed with the addition of Image 5.

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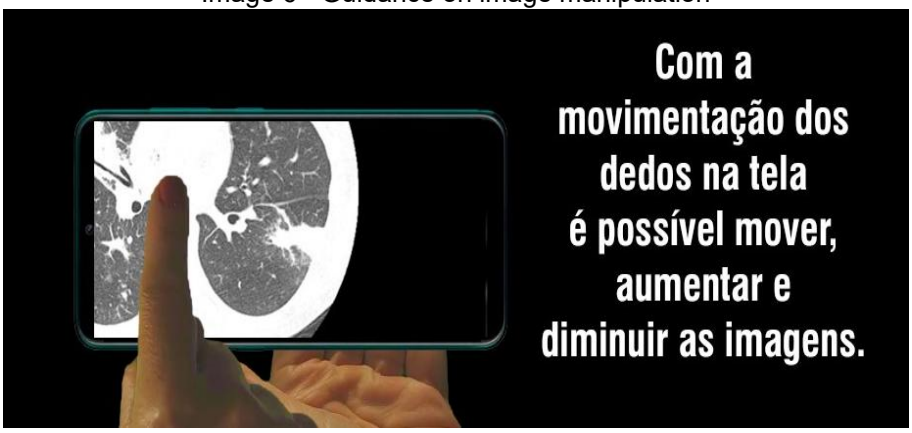
Chest computed tomography is a complementary exam, and correlation with clinical data is always necessary in order to reach a correct diagnosis.

2) Guidance on image manipulation (improved compared to the beta version):

Image 6 deals with the guidelines regarding the possible ways of enlarging and manipulating the available images, as requested by the evaluators. The images can be automatically enlarged by rotating the smartphone in the horizontal plane and by moving with your fingers it is possible to increase, decrease or move them.

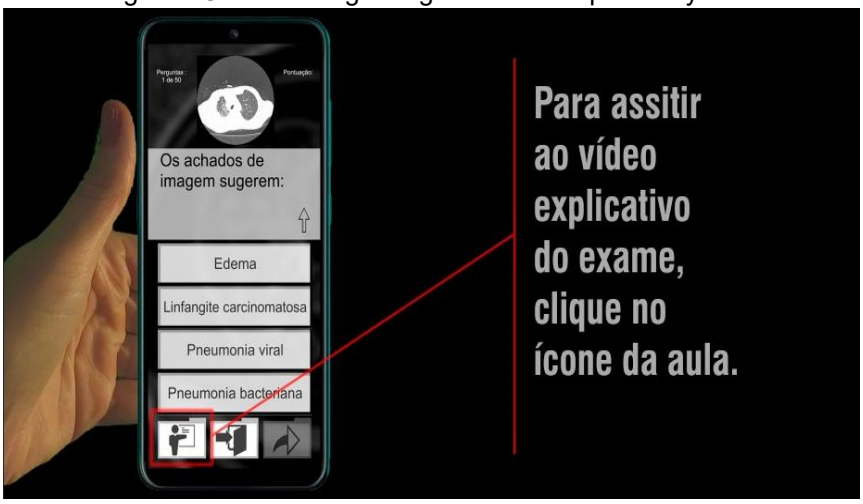
Image 6 - Guidance on image manipulation



Source: DiagRadQuiz, 2021

3) Guidance regarding access to explanatory videos (improved compared to the beta version):

Image 7 - Guidance regarding access to explanatory videos



Source: DiagRadQuiz, 2021.

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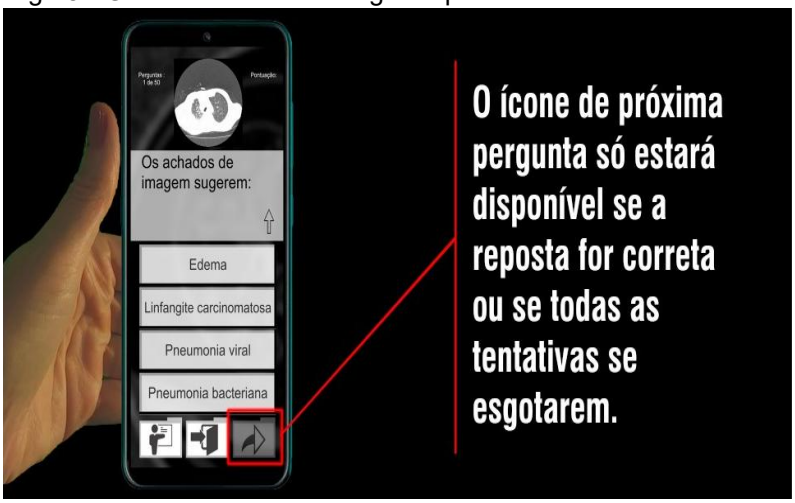
Image 7 shows how access to videocasts on the pathological patterns related to each image presented in the 50 questions addressed is given.

4) Guidance regarding the obligation to answer a question to access the next one (absent in the beta version):

Image 8 - Guidance on answering the question to access the next one

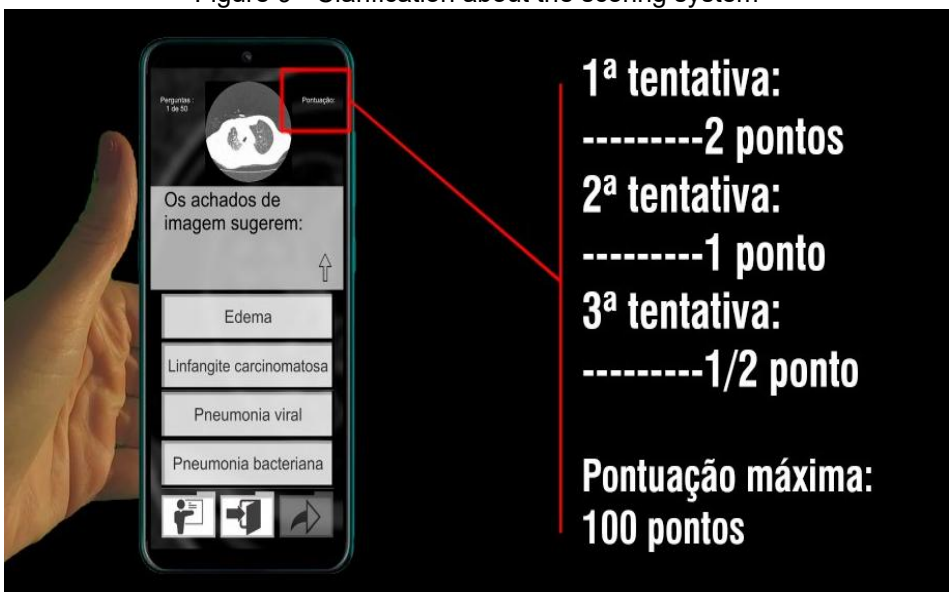


Source: DiagRadQuiz, 2021

In the beta version of DiagRad Quiz there was no guidance regarding the need to get the answer to the question right or to exhaust all alternatives before having access to the next question. This flaw has been fixed in the definitive version as explained in Image 8.

5) Clarification about the scoring system (absent in the beta version):

Figure 9 - Clarification about the scoring system



Source: DiagRadQuiz, 2021

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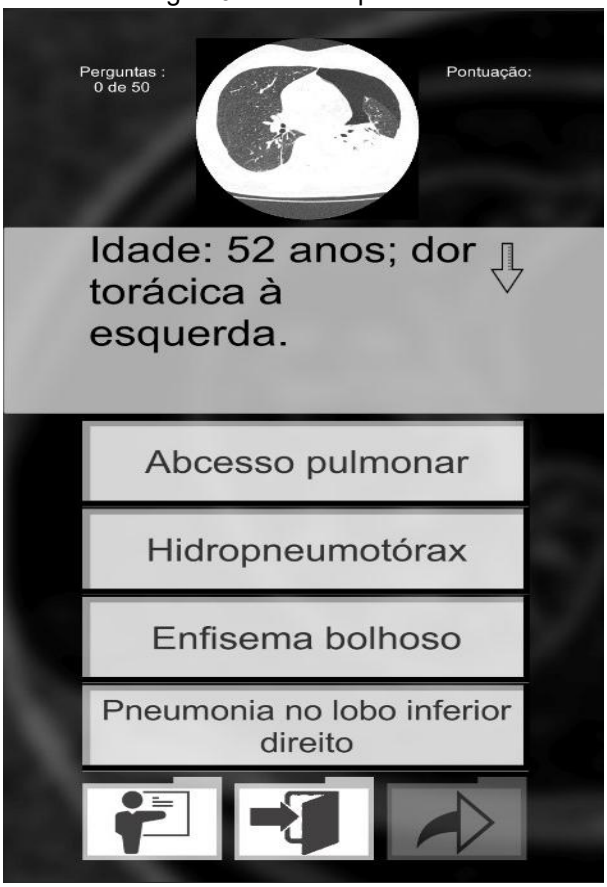
Image 9 deals with the explanation of the DiagRadQuiz scoring system, showing the number of points to be achieved according to the order of the correct answers. That explanation was absent in the beta version and raised doubts among the evaluators and was therefore included in the definitive version. On the standard quiz screen there was no significant change compared to the beta version, except for a centering of the image made available.

Image 10 - Default quiz screen



Source: DiagRadQuiz, 2021

Image 12 shows the standard DiagRadQuiz screen. The game consists of 50 screens similar to this one, with different images representing the most varied pathologies.

FINAL CONSIDERATIONS

The use of *serious games* as an educational platform meets numerous learning objectives in Health Sciences. These resources share the same advantages as the use of simulators for student training and continuing education of professionals, allowing practice in safe environments without exposing patients to risks, standardizing training and

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stimulating the acquisition of well-defined specific knowledge, in a more economical way and with a greater reach (WANG *et al*., 2016).

Despite the propagated advantages of the use of *serious games* for medical education, their development is complex and there are many obstacles to be overcome. The development of a serious game for medical education requires knowledge in the areas of medicine, education and information technology (web development for mobile devices) to create a product that meets the basic requirements of a game: modeling, specific design and scoring system (OLSZEWSKI, WOLBRINK, 2017).

The creation and development of DiagRadQuiz, without external financial support or a dedicated team of developers, was possible due to the proximity between the professionals involved in the development who collaborated, sharing specific knowledge of their expertise, in order to achieve a common goal, in addition to the necessary process of technical validation by physicians specialized in Radiology and Diagnostic Imaging and by Information Technology professionals for substantiation scientific product developed.

The quality of DiagRadQuiz has been validated by specialists in Information Technology and physicians specialized in Radiology and Diagnostic Imaging. All medical evaluators stated that they would indicate DiagRadQuiz as a pedagogical tool for teaching pathological patterns in chest computed tomography prevalent in Emergency Care services, including those related to Covid-19.

The next step of the research is to evaluate the pedagogical effectiveness of DiagRadQuiz for the target audience, by conducting a pre-test of knowledge before using the game, use of the tool, and post-test to assess knowledge acquired after use.

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