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Player Engagement Analysis of a Business Simulation Game from Physiological, Psychological and Behavioral Perspectives: A Case Study

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Abstract: To obtain an accurate understanding of player experience (PE) in serious games that simulate organizational environments, many factors must be considered and intertwined, psychological, physiological and related to the game performance itself. Such elements can be analyzed using experimental techniques such as recording attentional aspects or monitoring brain waves and subjective methods such as questionnaires. The objective of this work was to analyze the possible benefits of using a business simulation game (BSG) as a resource to stimulate learning based on the measurement of engagement in its different dimensions, using a hemoencephalogram (HEG) device to monitor cortical activation and the eye tracking (ET), for measuring pupillary dilation, both used concomitantly, in addition to pre- and posttest questionnaires, to record participants' expectations and perceptions of the game experience. Data collection was carried out with 10 students and professors in the computer engineering course at the University of La Laguna, Spain. The results indicate that critical situations and recurring ethical decisions in the game are important elements of the involvement of participants. In addition, the two devices proved to be suitable as a source of important information in determining the flow and attentional level for BSG.

Keywords: human-computer interaction; business simulation game; hemoencephalogram; eye tracking; player experience; engagement

Citation: Ferreira, C.P.; González, C.S.G.; Adamatti, D.F. Player Engagement Analysis of a Business Simulation Game from Physiological, Psychological and Behavioral Perspectives: A Case Study. *Appl. Sci.* **2022**, *12*, 10143. https://doi.org/10.3390/app121910143

Academic Editors: Miguel Ángel Redondo Duque, Ana Isabel Molina and Carmen Lacave

Received: 13 September 2022
Accepted: 3 October 2022
Published: 9 October 2022

1. Introduction

BSGs have become an e-learning strategy widely used in organizational training environments, as it is recognized by its users as an excellent tool for supporting the development of skills such as critical thinking and decision making and the ability to deal with uncertainties and paradigms that involve managing a company [1,2], through risk-free simulation resources [3]. By offering different possibilities of the visualization of scenarios inherent to corporations, and with an interactive and stimulating approach, the experience with the game itself contributes as a motivating factor for business learning [3,4]. In addition, a BSG can present market trends and corporate behaviors that allow for fixing concepts and establishing important relationships in the contribution of knowledge in the management area [5–7]. Cognitive complexity theory [8] proposes that BSGs are more effective than other traditional interaction methods in helping students develop effective decision-making ability for dealing with dynamic and complex problems presented to them. Another relevant aspect is that the use of BSGs in the classroom can promote the inclusion of students through stimulating, experiential and participatory learning, motivated by gamification elements, as well as helping them to develop self-control in learning core and soft skills [9].

In terms of design, multitasking interaction is one of the main features of the games. In a BSG that consists, for example, of managing an entire logistical chain of a product, the player needs to develop his attention and quick response capacity in the face of situations that present themselves simultaneously, such as the stock of raw materials, production itself, or the client's needs and also taking care of the financial health of the business. Some gaming research reveals the power of games to develop the multitasking ability of players [10,11].

Complex game scenarios require the coordination of cognitive activities, and the game has its role of collaborating with elements that "catch" the user's attention efficiently and effectively, under penalty of being labeled boring or, even worse, not contributing to the learning process. Complementarily, in the domain of cognition, games that involve multitasking strategies can offer a very interesting experience regarding the involvement with the game, known as the flow state, which means the complete engaging state of mind when immersed in an activity [12,13]. Some experiments prove that the allocation of the player's visual attention to certain elements of the game scenario can reveal cognitive strategies and pattern establishment, using human-computer devices [12–14].

Whether to ensure entertainment and/or learning, serious games, including BSGs, are often enriched by features and elements that make it difficult to analyze and evaluate their effectiveness through traditional methods commonly used in interactive systems. Developing and improving mechanisms that allow us to assess the user experience (UX) and PE in games is a key factor in ensuring success in an increasingly competitive market with a wide range of products. Thus, the existence of models that characterize aspects such as engagement and provide mechanisms for monitoring it throughout the game experience, enabling the improvement of the game, becomes essential [14,15].

Although there are studies using integrated methodologies to understand engagement as a part of PE, there is little consensus among researchers about which specific techniques should be applied [16,17]. The hypothesis considered in this study is that the analysis of engagement with serious games for simulating business can be an excellent indicator of design aspects of the tool that contribute to the player's learning process, when using a proposed model of experiment that combines the techniques of experience monitoring from physiological, psychological and behavioral perspectives. To obtain the expected results, this work uses a multiple methodology to observe the performance of players with BSG The McDonalds. Quantitatively, the experiment simultaneously monitors the physiological and behavioral signals of the participants, respectively, through the HEG and ET devices. Qualitatively, the study contemplates the player's perceptions about the game and the experience. At the end, the results of all collection instruments are analyzed in an integrated way to identify possible elements that contribute to player engagement.

The article is organized as follows: Introduction (1) makes a brief contextualization of the theme and presents the research hypothesis, followed by Background (2), which identifies related concepts and investigations as references for the study. Materials and Methods (3) describes the path traced for the execution of the experiment, and Results (4) brings an organized view of the information obtained in the collection, which in turn feeds the Discussion (5), designed to provide a sense of the investigation and obtain the answers to the questions that guide it. Finally, Conclusion (6) synthesizes the subject and study contributions.

2. Background

2.1. Engagement in the PE

Engagement can be defined as a meta-construction with behavioral, affective and cognitive components that vary both situationally and dispositionally [18,19]. Effort and persistence in a task constitute some of the behavioral components of engagement, while interest, curiosity and identification of value are part of the affective component. The cognitive component includes concentration and then the use of learning strategies [19].

The study and monitoring of engagement are used in investigations related to UX as an indicator of positive aspects in the interaction between the user and the product [20,21]. In the gaming context, engagement stands out as an important category that structures the understanding of the PE, together with the analysis of gameplay, usability and immersion. This process involves a heuristic evaluation in monitoring the efficiency and effectiveness of games, offering more opportunities and contributions to a design that is more suited to the needs and perceptions of those who use them [22].

Reaching a certain level of engagement means that the player is captivated and feels motivated by the game. For a serious game to be successful, the game is not only used: players also invest a portion of time, emotion and attention in the game [20,23]. Research on engagement in the context of serious games relates flow as an indicator of the ideal experience based on a balance between skill and challenge [20,24]. For this, the activity needs to be challenging; set clear objectives; include direct and immediate feedback and present a sense of control, a relative loss of self-awareness and high concentration, factors that align with the results of research on what contributes to the game effectiveness [24–27]. This means that when a player experiences flow, their engagement with a game is likely to be high. Thus, a considerable level of engagement is necessary for a serious game to be able to achieve the objectives outlined in its conception. Greater user involvement will lead to players increasingly interested in the purpose of the game, which can lead to a change in attitude and behavior in real-world situations [28], which is one of the purposes of the BSG.

2.2. Measuring Player Engagement in Serious Games

Understanding aspects involving the interaction between humans and games is a complex and challenging area of ongoing game research. To gain an accurate understanding of the PE, a multitude of factors must be considered in relation to psychological characteristics, game performance and human emotion. The exploration of this field normally involves an experimental analysis promoting the manipulation of characteristics of the game system (such as difficulty levels, control flow and feedback) and its context (environment). Through careful manipulation of these variables, it is possible to identify and quantify the specific effects of any design change or decision on a game. A classification of the methods used in research with game users defines three different groups: physiological, psychological and behavioral [29].

The measurement of physiological activity is used to evaluate games using sensors that, in contact with the surface of the human skin, make inferences about the cognitive or emotional states of the players. The psychological method is based on the evaluation of the player's experience through surveys or post-game interviews, but despite its being the easiest and least expensive approach, information can be lost in the delay between action (gameplay) and recall (interview or questionnaire). Behavior analysis includes monitoring the action and interaction with the game [30]. Figure 1 presents examples of instruments that can be used in an investigation of user experience with games [30]:

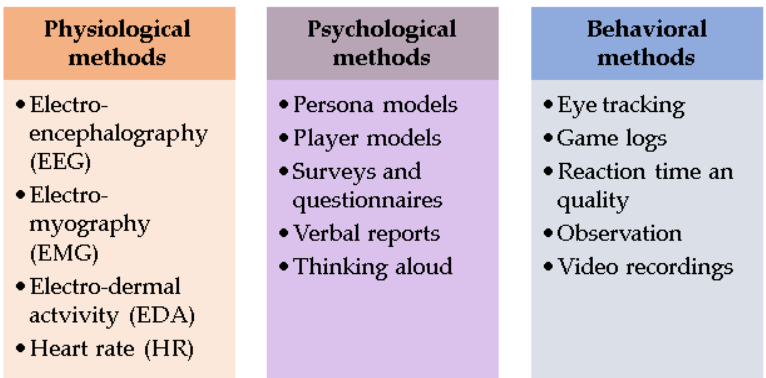

Figure 1. Examples of methods to assess player experience in Serious Games.

Approaches to measuring user engagement can be divided into three main groups: self-reported engagement, cognitive engagement and behavioral metrics [20]. In the first group, questionnaires and interviews are used to obtain attributes and assess user engagement. However, these methods have known drawbacks based on user subjectivity. The second approach uses task-based methods and physiological measures to assess cognitive performance, using devices to measure signals such as EEG, heart rate and HEG. The third and final approach studies user engagement through real-time behavior metrics. Through devices such as ET, the depth of engagement is related to information that comes from, among other sources, the click-through rate, time and number of views invested in the analyzed game.

A large part of investigations uses only one tool in their experiments to obtain results in the analysis of the PE with serious games, using physiological/behavioral information for quantitative analysis [17,31–36] or psychological data for qualitative assessments [37–39]. To a lesser extent, some experiments use up to two methods, typically combining one measuring device with pre- and posttest questionnaires [40–42].

The use of physiological and neuroscientific techniques has supported several studies that seek to deepen the understanding of people's interactions with technologies, including learning through games. In the context of serious games, simulators and BSGs, studies based on the PE monitored by devices such as EEG, HEG and ET have provided more accurate analyses of the elements, functionalities, limitations and possible contributions to the design and optimization of these learning tools [15,38,43–45].

A recent field of research called games user research (GUR) combines research on human–computer interaction (HCI) and game development [22,46]. Based on the observation and understanding of the individual and personal experience maintained by the player before, during and immediately after the game, the methodology aims to provide insights into the design of games that meet the expectations of its users. Through information-gathering devices and tools, the user researcher applies methods inspired by psychology and user-centered design to monitor and evaluate the player. The communication channel is multi-way, allowing the interpretation of player reactions, and often seeks to determine which game features can be improved by game designers [46]. This flow of information between those involved in the GUR is shown in Figure 2.

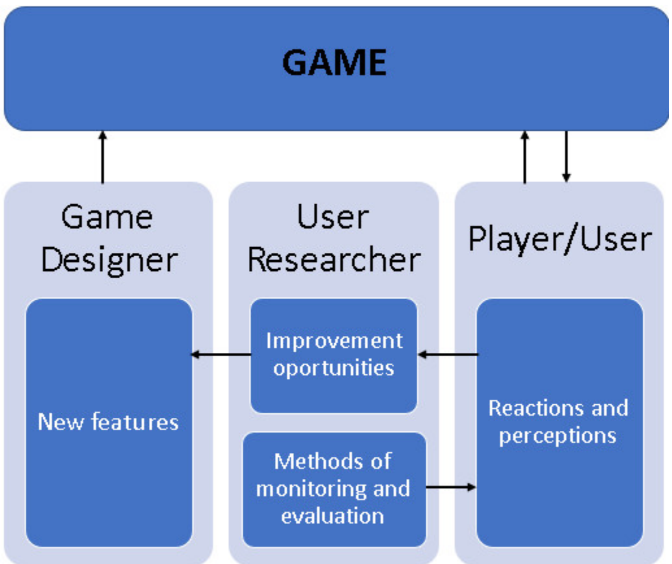

Figure 2. Flow of information between game designer, user researcher and game player/user.

An appropriate GUR methodology considers player involvement to be crucial in the game development process regardless of its application as entertainment or education [22]. In this way, the level of engagement of those who use the game needs to be monitored in such a way as to accurately reflect their needs and expectations. To analyze and evaluate player experiences, experts have been leveraging many tools, including game testing protocols, gameplay heuristics and monitoring devices. Utilizing an increasingly valuable mixed-methods approach, the present researchers leveraged the benefits of each technique and complement its limitations. The great challenge with each study on serious games is, based on the objective proposed in each experiment, to identify which instruments are most suitable for providing the most efficient and effective result.

3. Materials and Methods

3.1. Participants

The experiment took place at the University of La Laguna, La Laguna, Spain, involving seven students and three professors from the computer engineering course. Of the 10 participants, 7 were men and 3 were women, aged between 21 and 39 years (M = 31.50; SD = 8.54). All subjects participated voluntarily and declared that they had no learning deficits. To carry out the activities, the BSG and all the tutorials were made available to the participants in their native language. Although the data collection was noninvasive, this research was presented to the Ethics Committee for Research and Animal Welfare (CEIBA—ULL), obtaining favorable authorization for its realization, according to code 2019-0356.

3.2. The BSG

Any game that presents an organizational setting and incorporates features of the "business world" is considered a BSG and should be categorized as a "simulation game" or "serious game" unless it offers the wrong educational approach or manifests deliberately unrealistic reactions to the choices of their users [47]. Based on this characterization and on previous studies citing games as possible support tools in the learning process of soft and hard skills related to the business environment [48–50], BSG McDonalds emerged as an interesting alternative for the application of the experiment. In one of these studies [49], based on an exploratory study of the different uses of games for educational purposes, BSG MacDonald's, among others, is cited as a means of highlighting or interrupting social behavior or positions through rule-based representations and interactions. Thus, by not only approaching aspects of the production chain but also presenting itself as a persuasive game, adding aspects of awareness on topics such as ethics and sustainability, which can influence the conduct of a business, even if in a playful way, but without losing its characteristics of a serious game, McDonald's was identified as the best option.

Better describing the BSG selected for the experiment, the McDonald's is a serious strategy video game designed by Molleindustria (http://www.molleindustria.org/, accessed on 1 may 2021) that provides knowledge on managing a company in a more playful way: The player assumes the role of director of the McDonald's corporation and has control from the production process to the sale of products, always looking for the best result. The business sustainability is achieved through multitasking decisions that are made on four screens, shown in Figure 3, that represent different process environments, briefly described in the following:

- Screen 1: Agricultural section. Beginning of the supply chain, where the planting of grains and cattle raising, raw material for supplying the stores, are defined.
- Screen 2: Feedlot. Stage in which the cattle are fattened and slaughtered and, in the sequence, the hamburger is produced.
- Screen 3: Fast Food. Represents the chain of stores, comprising the process of production and sale of the snack.
- Screen 4: Headquarters. Place where the player gets to know the most detailed information of the business and makes decisions at a strategic level that are reflected in the whole process.

Although decisions are made individually on each screen, the impact of changing variables is reflected in other environments as it is a production chain. In addition to the normal day-by-day decisions of the organization, the player has other options that involve ethical aspects. The screens have in common a bar with the company's financial results in real time and a bar of tips.

Figure 3. Screen of the four environments of decision in the game The MacDonalds.

3.3. Data Collection Devices Used in the Experiment

3.3.1. Hemoencephalogram (HEG)

The device developed by ALPHA company is an open-source brain training that reveals brain metabolism through a direct relationship with the use of oxygen by the brain. Its mounting form consists of a headband adaptable to the size of the person and totally noninvasive, containing a near-infrared (nIR) transmitter and an optical receiver. The interface takes advantage of the fact that more oxygenated blood has a more reddish color. The equipment sends pulses of red and infrared light through the skull to the cortex below and measures the level of oxygen in the blood by comparing the intensities of red and infrared light. The lights emitted by the red and infrared LEDs are sent alternately at a sampling rate of 480 Hz [51]. For the data acquisition was used the Free Software Delobotomizer (https://www.hegalpha.com/product-page/hegduino-2-0-the-delobotomizer, accessed on 10 May 2021), the official repository.

3.3.2. Eye Tracking (ET)

Pupil Core eye tracking are is a modifiable, secure and lightweight (~23 g) device, used in conjunction with the open-source platforms for data collection (Pupil Capture) and visualization/analysis (Pupil Player), developed by Pupil Labs (https://github.com/pupil-labs/pupil/releases, accessed on 10 May 2021). The equipment consists of 2 individual ocular cameras (200 Hz each) and a scene camera (60 Hz) for tracking the field of view. A real-time tracking algorithm is used to detect the shape and position of the pupil. This ET device uses a model-based approach to estimate gaze that fits image-detected pupil parameters in optical modeling and estimates the optical axis orientation of the eye relative to the RF ocular camera. To estimate the relative position of the three cameras, a calibration is needed, where markers are displayed around the screen at a distance where the user moves his head slowly while fixating on a marker [52].

3.4. Player Engagement Research Model Adopted for the BSG Experiment

The definition of the model for the development of the experiment with the BSG considered the use of data collection instruments that could simultaneously characterize user engagement [19] and the methodologies that cover studies on playing serious games [30], as shown in Table 1.

From the definition of the instruments and their application, it was possible to create the research model, represented as shown in Figure 4. Its application foresees that the HEG and ET devices are used concomitantly during the experience with the BSG so that the data can be synchronized and cross-referenced accurately. In order for the players' perceptions to be as reliable as possible, the pre- and posttest questionnaires should, respectively, be carried out immediately before and after the game. The analysis takes place in the convergence between the results from the three perspectives.

Table 1. Composition of research instruments for definition of a model experiment with BSG based on the player's experience.

Instrument	Instrument Deliveries	User Engagement Component	Player Experience Method
HEG	Flow tendency	Cognitive engagement	Physiological
ET	Attention aspects	Behavioral Metric	Behavioral
Pre- and Posttest	Value perception	Self-reported engagement	Psychological

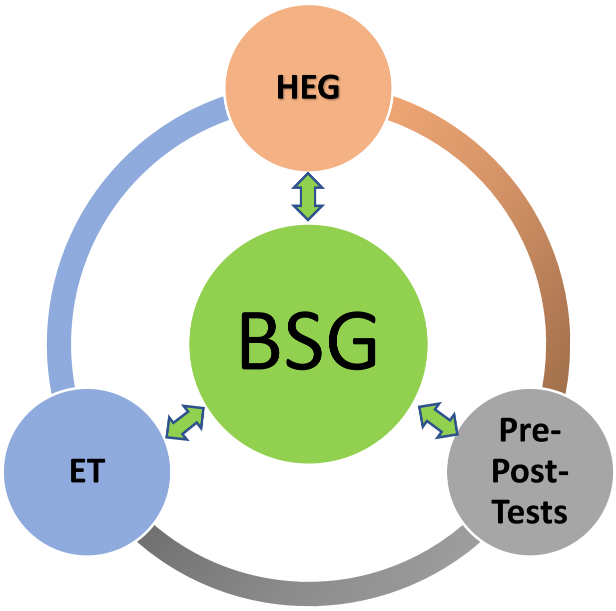

Figure 4. Screen of the four environments of decision in the game The MacDonalds.

3.5. Metodology of the Experiment

This investigation adopted a mixed method, with the generation of quantitative and qualitative data, defined as the verification and comparison of data obtained through different informants, through different collection instruments, applied at different times [53]. Using multiple methods, it is possible to mix, invert and explore different types of data to better understand the event under study. While many questions or problems are of a type that presuppose one form of research rather than another, not all problems preclude multiple approaches, and some lend themselves positively to using a mixed approach [54]. The tasks during each collection carried out with each player consisted of:

- Answer a pretest questionnaire containing questions about the participant's profile and their perceptions about using the BSG;
- Position the two devices and make calibrations/adjustments for the tests;
- Read a tutorial introducing the basic principles of the game operation and features;
- Carry out the proposed activity using the BSG;
- Answer a posttest questionnaire, with questions about the learning experience after using the BSG as well as aspects related to the features and design elements perceived in the tool.

For each participant, right after the positioning and adjustments of the devices, the game and the simultaneous collection of data were started, monitoring from the reading of the tutorial and the start and finish the game.

The gaming time and subsequent data collection was limited to 20 min, including tutorial reading time (expected between 4–5 min). If the game ended during this time, the player started again, repeating its execution as many times as necessary, respecting the maximum time limit of the experiment.

The questions created for the pre- and posttest questionnaires can be seen in Table 2. In the case of Yes/No answers, when negative, respondents were encouraged to argue their choice.

Table 2. Questions created for the pre- and posttest questionnaires.

Pretest Questions	**Posttest Questions**
Genre	(I) Did the devices, room or other elements used to perform the data collection make it difficult to run the test?
Age	(II) Did the in-game tutorial seem appropriate for you?
(I) Have you had any previous experience with business simulation games?	(III) Did the game environment help you to understand the aspects involved in running a company?
(II) Do you often have fun with computer games?	(IV) Was the speed of the game adequate for the understanding of the problem presented?
(III) Do you have any professional experience or knowledge taken in Business Management?	(V) Was the number of variables you could modify adequate to understand the proposed problem?
(IV) What do you consider most important in a simulator or game? Images, Interaction, Difficult Level, Unexpected situations, User scenarios, Results after change variables	(VI) What did you consider most important in the experienced game? Images, Interaction, Difficulty Level, Unexpected situations, User scenarios, Results after change variables
	(VII) How would you describe or main problem to solve in this game to keep the company running and financially balanced?
	(VIII) What was your strategy to solve the problem described in the previous question?

4. Results

The data organization took place from three sources, HEG, ET and the pre- and posttest questionnaires, for later the cross referencing of information. Likewise, for both signal sources, HEG and ET, initial filtering was performed discarding isolated points. The parameter analyzed from the collection with the HEG was the ratio, which represents the relationship between red light waves (variable) and infrared light (little affected by oxygenation). Following the same criterion adopted for the ET, from the data collected from each participant, the ratio moving average (MA for $n = 50$) and the respective deviation (SD) were calculated, represented in the form of an individual graphic, which allowed for identifying the general behavior of the prefrontal cortex throughout the game (including reading the tutorial) and moments of relevant rise and fall of blood flow. However, to provide a general and grouped view of the behavior of the ratio HEG of each player, Figure 5 was created.

The pupil diameter was the parameter chosen to analyze, from the data generated with the ET, considering studies that claim that the human pupil diameter changes under the influence of stimuli that involve visual difficulty and limitations for task resolution and can be used as a direct measure of activity [55,56] and a useful metric for assessing when an individual has transferred information into long-term memory [57]. From the file in .CSV format generated by the Pupil Capture software, an Excel spreadsheet was used for filtering and analyzing the data. As this was not a medical experiment and considering that several studies assume the proportionality of the variation in dilation between pupils and use the average diameter between the two pupils as a metric [58–61], the same procedure was adopted for the treatment of this variable. The Pupil Labs device collects approximately 25 measurements per second of each variable, and for the purpose of this analysis, for each participant, the moving average (MA for n = 50) and the respective standard deviation (SD) were calculated and plotted in individual graphs. Filtering was performed considering as noise all isolated points that exceeded 3xSD, disregarding them from the analysis. In order to provide an overview of the behavior of the pupil diameter variation throughout the game, Figures A1 and A2 were developed including the behavior of the variable of all participants; additionally, a tendency line was included to facilitate the interpretation. It is important to highlight that with the aim of analyzing and comparing the data and the possible relationships between the HEG ratio and the pupil dilatation diameter (PDD), from the generated tables and graphs, the time interval between the measurements of the two devices was adjusted to correct the small differences of synchronization in each collection.

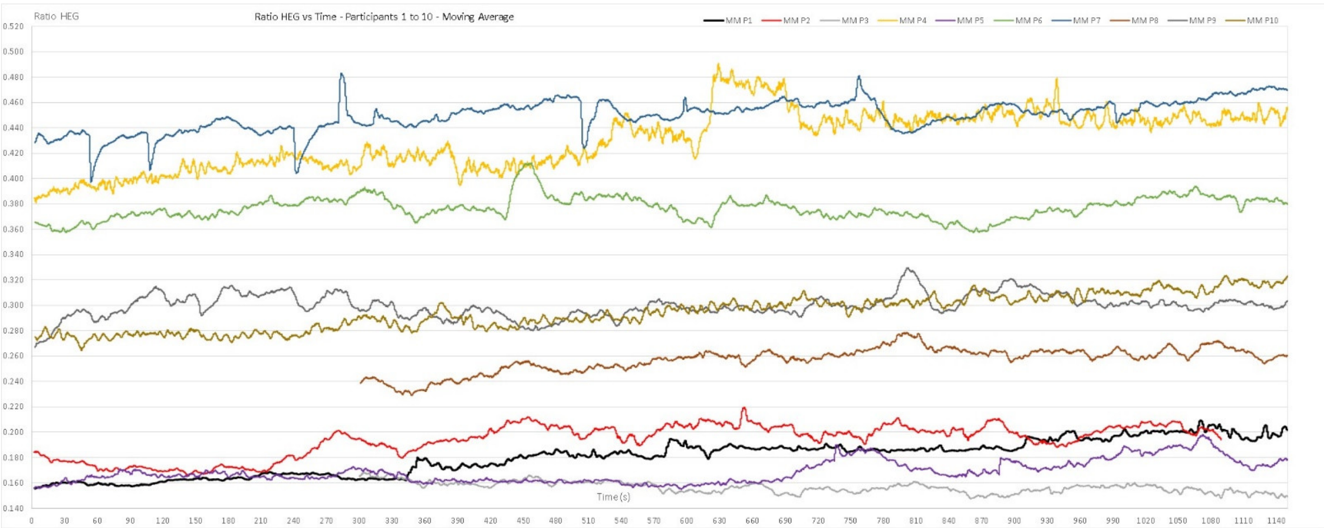

Figure 5. Ratio HEG variation during the tutorial reading and playing time for the Participants P1 to P10.

In addition to personal characteristics of age and genre, the pretest was designed to identify the participants' previous knowledge and experience so that during the analysis, it was possible to assess whether or not these factors could influence the performance of the game. The answers to the pretest question detailed in Table 2 were: I) previous BSG player experience, which only 1 affirmed (10%), and if games normally amused the participant, to which 9 said yes (90%); II) have fun with computer games: 9 said yes (90%) and only 1 (10%) said no; III) previous professional experience in the field of business management: 6 participants (60%) said no and 4 participants (40%) said Yes. Another question (IV) on the pretest was related to the player's perception of which elements were most important in the game's design. The results, shown in Figure 6, point to the following classification: interaction—40%; images—30%; different levels of difficulty—10%; unexpected situation—10%; activity-based scenario—10%; and identification of results after changing the variables—0%. The same question was asked later on the posttest in relation to the BSG in the experiment to assess possible changes in perception from the experiment with BSG. In the open-response field for freely describing other elements, respondents added sound and atmosphere, immersibility and realism.

About the posttest, whose questions are detailed in Table 2, the first part (questions I to V) was initially designed to identify possible interference from the devices in the experiment. In question I, none of the participants declared any external interference that hindered their experience with the game, despite a comment (P10) that the use of the mask during the experiment caused him slight discomfort (it was mandatory personal protective equipment for all participants due to the COVID-19 pandemic). In sequence, questions

II to VIII were elaborated to identify the player's perceptions of the characteristics of the experienced BSG. About the tutorial, in question II, 6 participants declared it suitable (60%), and 4 people (40%) said No; 3 of them reported that it was too long and unrelated to the BSG itself, and another player identified not specifying the different parts of the game. Regarding the BSG's contributions to adding knowledge in the business area, question III, 8 participants (80%) said they learned from the game; 1 participant stated that he had the feeling of lack of control over the game even though he learned marketing concepts; the other player expected greater complexity of concepts related to the topic. In respect of the speed of the game, question IV, 7 (70%) participants declared it was adequate, and the claim of those who did not agree was that the game required a very quick response. Regarding the number of variables, question V, 8 (80%) said they were sufficient and the 2 participants who disagreed cited excessive entries.

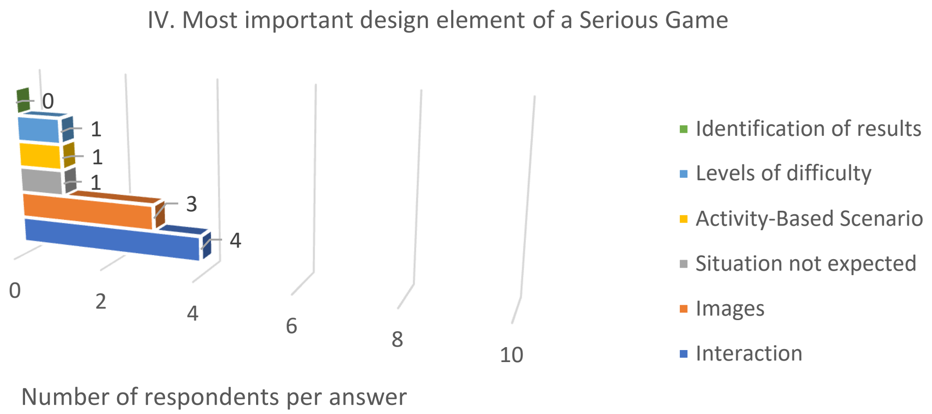

Figure 6. Question IV of Pretest responses.

The last three questions (VI to VIII) were related to the strategy adopted by each one in executing the game. Question VI, represented in Figure 7, related to the design aspects prioritized in the pretest but identified now after experiencing the BSG. The answers were: interaction—40%, images—20%, levels of difficulty—20%, results after change variables—20%, unexpected situations—0%, user scenarios—0%.

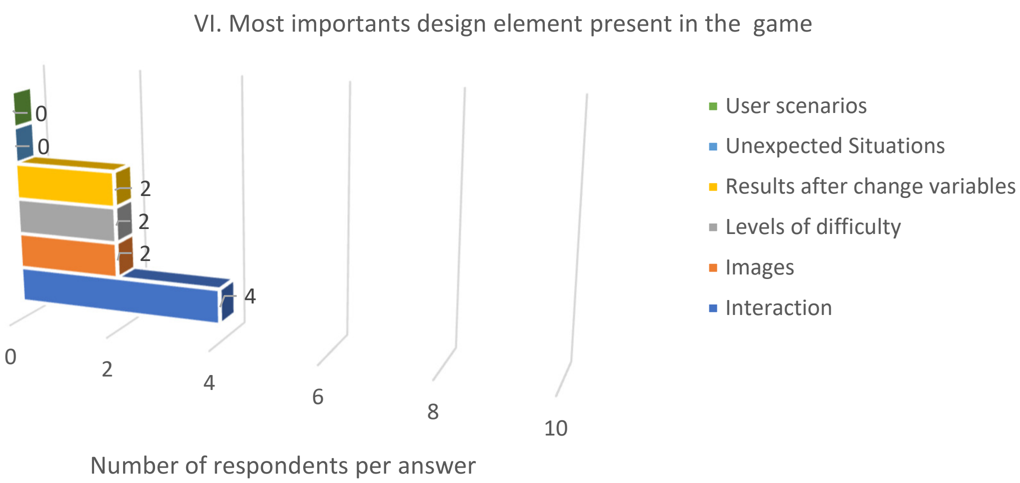

Figure 7. Question VI of Posttest responses.

Regarding the participants' perceptions of the main problem to be solved in the BSG, according to question VII, represented in Figure 8, 7 participants (70%) declared that it would be to maintain a balance between production and sales. In the other responses, representing 30%, 1 participant (10%) identified that it would be keeping control so as not to go bankrupt, 1 participant (10%) reported that it would be acting so as not to enter a dead-end loss loop and 1 participant (10%) specified that it would seek profit and satisfy customers synchronously.

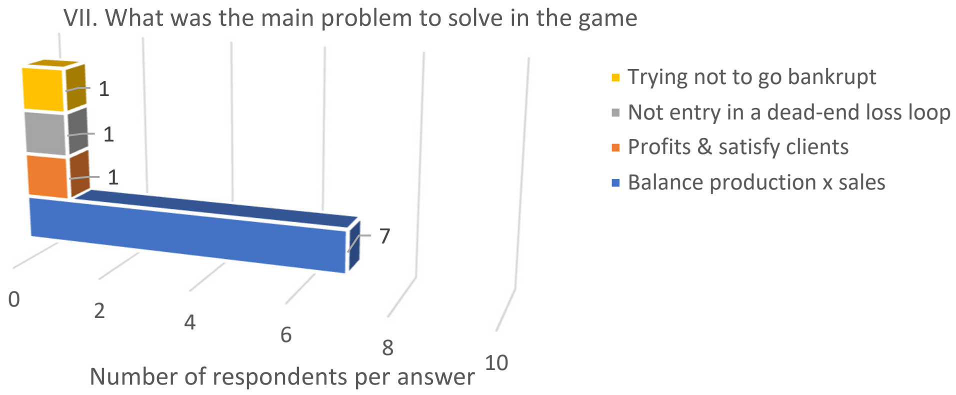

Figure 8. Question VII of Posttest responses.

With respect to the strategy to be adopted for success in the BSG, according to the answers from question VIII, represented in Figure 9, 6 participants (60%) understood that it would be maximizing production, 3 participants (30%) declared it to be keeping the chain in balance and 1 participant (10%) reported making changes gradually.

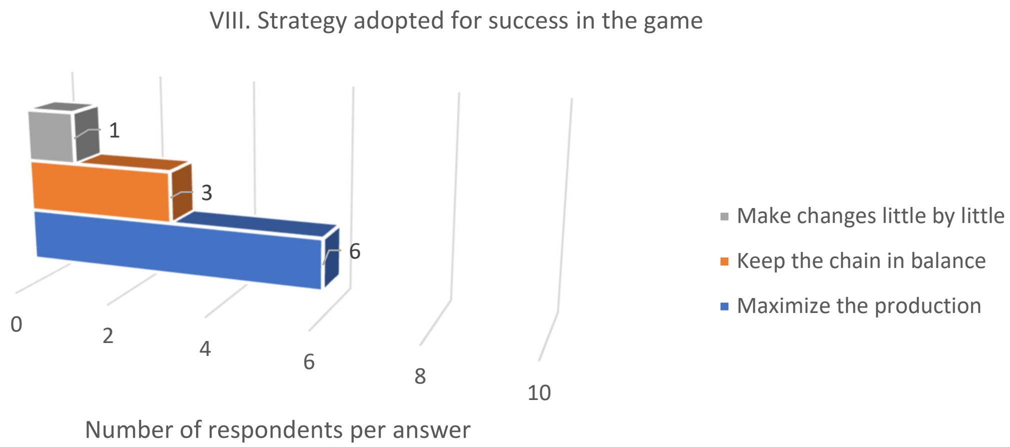

Figure 9. Question VIII of Posttest responses.

Despite the tutorial being viewed before the beginning of the BSG, the experiment also monitored participants with HEG and ET devices during access to this resource as a source of complementary information in the analysis of the game, to identify possible behavioral state changes in the initial activity, engagement, proper use of features and interlocution with posttest responses. Over the time available for the game, the moments in which the company went bankrupt and a new game was started were also identified. In addition, zones for analysis of HEG data were defined considering:

- Intervals of at least 10 s where there is an up/down of the moving average of the oxygen rate with more than 80% of the points in the interval.
- Variation of the moving average of the oxygenation rate $\geq$20 (up or down) recorded at time intervals $\geq$5 s. These criteria allowed for the selection of five to nine moments of the game with a significant rise and/or fall in the HEG rate for each participant. Subsequently, these periods were used as references to identify the corresponding average pupil dilatation diameter (PDD) in addition to the minimum and maximum diameter and the variation between these two values, provided by the ET, in the different intervals. The situation experienced by each player was also identified and classified into one of seven different categories: game start (GS); critical situation (CS);

game over (GO); ethical dilemma (ED); operational decision (OD); strategic thinking (ST); or insight (IS). All these results from the 10 players were grouped to provide cross-referencing and critical analysis of the information and can be seen in Table A1. It should be noted that although the 10 participants underwent complete collection, 2 of them (P3 and P8) had problems capturing the signals while reading the tutorial, and this period was discarded. In these two cases, it was decided not to require the participant to reread the tutorial, as it would have been exhausting and could have compromised motivation and, consequently, their performance in the game, considered the most important source of information for the experiment. The other data from P3 and P8, referring to the game period, were normally used in the research.

In defining the variables for further analysis and the comparison of the results of the experiment obtained from human–computer devices, the following aspects were considered:

- The HEG ratio is not an indicator of the greater or lesser activation of the prefrontal cortex that allows for comparing it in isolation between different people, considering that each human being has a different level of cerebral oxygenation, in addition to the influence of other aspects. Therefore, the experiment monitored this variable from the point of view of its behavior throughout the game for each participant, and allowed, through the individual graphs and later grouped according to Figure 5, to analyze possible trends that allow inferring patterns adopted by the players.
- The variable monitored by the ET, which was the pupil dilation diameter, varies from 1.5 mm to 8 mm, and is influenced by aspects such as age and ambient light, which means that each participant has a range of variation [62]. This does not mean that a higher pupil dilation diameter than others indicated a higher level of attention. Therefore, the experiment individually analyzed the trend of the variable over time, and a subsequent comparison of these trends as a reflection of visual behavior from the beginning to the end of the game suggested patterns associated with engagement in the activity.

5. Discussion

In the analysis of the results, a first behavior that draws attention is in relation to the temporal increase in the individual HEG ratio of the participants throughout the game, according to Figure 5, suggesting that players could be in the process of developing a flow state, wherein as an activity begins to make more sense, brain connections continue to occur along hierarchical pathways, and full convergence appears to occur in the dorsolateral prefrontal cortex, involving executive functioning and allowing for higher functionality, such as self-reflective awareness and abstract thinking [63]. The exception is for P3, who showed a subtle drop in the HEG ratio, especially in the last three minutes of the game. When considering the player's answers on the posttest, this result may be related to his dissatisfaction with the tutorial (question II), whose results from the reports indicate that the tutorial was extensive. This is in line with research findings that tutorials integrated into a game's progression, different from the format presented for the tested BSG, are less tiring and more effective, offering elements for the construction of the player's strategy without negatively impacting engagement [64] using tutorial levels [65].

Another piece of information that contributes to inferences of a possible flow experience comes from the pupil diameter variation. Figures A1 and A2 show through the traced trend line that this variable has ascending behavior when the experience is analyzed from beginning to end, revealing a high level of concentration, one of the components essentials associated with the flow state [40]. Other associated elements that define the flow experience, presented in sequence, may have been evoked by the game [12], identified from the players' responses in the questionnaires: (a) The activity is intrinsically rewarding: The increase in the level of pupil dilation and activation of the HEG ratio during the game occurred even for the two participants (P5 and P9) who stated, in response to posttest question III, that the game environment did not add to the understanding of the processes that involve the management of a company. It is important to point out that these same players are among the four who declared having experience and/or knowledge in the area in response to question III on the pretest, which could represent a demotivating factor that was not confirmed by the results observed by monitoring with the two biometric devices, probably because the respondents descriptively revealed some other hard and soft skills insights that kept them connected to the game. What can be seen is that, in one way or another, the game seems to leverage knowledge and offer elements for its conduct, which can also be observed by the result represented in Figure 8, which shows that the vast majority managed to identify the main problem to be resolved in the game (balance between production and sales). There was also clear feedback and balance between skill level and challenge: 80% of players declared that the 3 most prominent elements of the game were the immediate results after changing variables, the levels of difficulty and the interaction, according to Figure 7.

The periods of the HEG ratio showed in Table A1 (column II), identified as relevant (77 in total), according to the selection criteria adopted, occurred in the form of increase (56%) or decrease (34%) of the indicator. This higher percentage of the ranges of increased activation of the prefrontal cortex, in relation to reductions, which makes sense from the perspective of the construction of the flow state provided by the BSG. This may be an important sign that the dynamics and design of the analyzed BSG were responsible for this result, considering the aspects that most attracted attention in the game by its participants highlighted in the posttest, as shown in Figure 7, question VI, led by the interaction, in line with research that relates this construct as one of the game design elements that most contribute to engagement [20,26,66]. When expanding this selection considering the two main elements of the individual classification, interaction and immediate results after changing variables represent 60% of the players' perception, meaning that this last con-struct may also have been a relevant factor of engagement.

Associating the HEG ratio with the corresponding situation experienced by the game, according to the Figure 10, it is important to analyze each result presented.

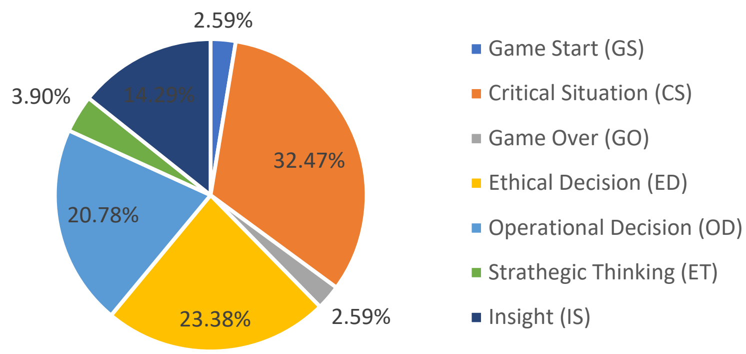

Figure 10. Situation experienced in BSG during the greatest periods of rise and fall of Ratio HEG.

Starting with the less representative indicators that add up to 9.1% of the most prominent behaviors of the HEG ratio (GS, GO and ST), it is possible to see very significant aspects, even more when we cross these data with the players' posttest responses, as described below: (a) GS = 2.59%. Although the tutorial presents relevant information for a good performance, 40% of the participants revealed that it was not adequate because it was too long. In general, the problem reported was not enough to interfere with the construction of the player's flow state, as we see in Figure 5, but occasionally it brought negative reflexes in the activation of the prefrontal cortex at the beginning of the game, since only one player (P1) was satisfied with the tutorial and showed a significant increase in HEG ratio at the beginning of the game (2.59%). Still considering the player's attentional aspect, none of them presented their highest levels of PDD variation in this early stage of the game. Studies on pupil dilation show systematic changes in pupil size with the practice of a task. It is possible that situations in which there is a reduction in pupil diameter in moments of learning may be related to the transfer of information to long-term memory, which leads us to infer that the tutorial, despite being extensive, fulfilled its role of correctly guiding the player in the initial phase until elements that instigated reactions were presented [57,67]. (b) GO = 2.59%. The end of the game in the analyzed BSG occurred with the culmination of a sequence of decisions made that were not adequate to deal with the problems that the management of the business demanded and that over time led the company to bankruptcy. Depending on how many bankruptcies occurred for each player (which in the experiment was 1 to 3), this time could vary from approximately 5 to 15 min, with continuous decision-making, which tended to generate a certain level of stress, especially when decisions did not produce results. The default behavior of players when they realized that they would no longer be able to change the company's situation was to move between the four game screens in a more passive attitude and without a coherent decision strategy, a behavior that we can infer as a cause for a lower activation of the prefrontal cortex in relation to other moments of the game, in line with studies that claim that the feeling of control over the game is an influencing factor in player engagement [36,68]. Extending the discussion, in an accurate analysis of this singular behavior from the point of view of the visual behavior identified by the ET, it is noticed that each player presented intense pupil activity, seeking to continuously reverse the situation until the game is over and then their attention is suddenly affected. Crossing these data with the posttest responses, the reason for this behavior may be related to the fact that two participants declared that the speed of the game was adequate: That is, they were able to follow everything that was happening in the game environment, and they also had an equivalent strategy, which was to keep the production chain balanced. (c) SD = 3.90%. This result illustrates that in the moments involving more specifically strategic thinking, normally in situations of the headquarters screen (screen 4), they were not the ones that contributed most significantly to the increase or decrease in the HEG ratio. This behavior is also reflected in PDD variation, which can be explained by the fact that a strategic decision involves other areas of the cortex dividing brain activity and is much more a moment of thought reorganization than a situation that requires a level visual attention, corroborating studies that relate brain behavior during games that involve strategic behavior [69,70]. In addition, the posttest responses reveal that everyone developed a strategy, such as P7 who reports having tried to keep the production chain balanced, which leads us to believe that moments of strategic thinking effectively occurred for everyone, but they were built according to the situations and insights offered by the game, their own memories and concepts, previous experiences, and knowledge [69,71].

The other results associating the HEG ratio to the corresponding situation experienced by the game, presented in Figure 10, show that: 32.47% of these moments occurred during critical situations in the game (CS), when the result was being significantly compromised by 1 or more variables; 20.78% in operational decisions (OP) made between the 4 available screens and 23.38% in game moments that mentioned the importance of ethically questionable conduct or decisions (ED) as an easier path to business success. The greater activation of the prefrontal cortex in these situations seems to have collaborated with good player engagement, as they constitute elements that influence engagement, already highlighted in the background, in a stimulating relationship between skill and challenge provided by the game [20,23,24]. This behavior seems to be related to the strategy of maximizing production, adopted by most players (60%), as shown in Figure 9, as it involves a series of risks that may have stimulated the player.

Calculating the PDD variations, presented in Table A1 (column VII) calculated from the difference between the minimum PDD (column V) and maximum PDD (column VI), also made it possible to establish, at first, relationships between the players' greater attention and the situations experienced in different moments of the game and contributions of the HEG signal. When selecting the 2 periods of greatest variation of PDD for each player, it was identified that the critical situations (CS) are one of its biggest activators (35%) according to Figure 11, also highlighting that this activation always occurred in the moments rise of HEG ratio, corroborating studies that indicate that changes in pupil diameter are indicators of increased levels of cognitive demand in a task, including the frontal area of the cortex and central executive functions [72,73], in this case activated by the risky situations in the game.

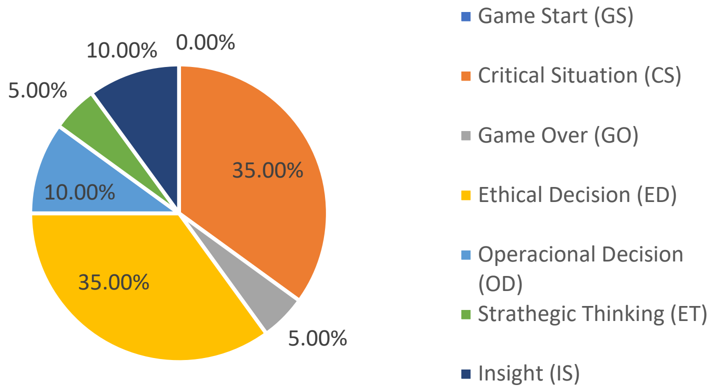

Figure 11. Situation experienced in BSG during the greatest periods of Ratio HEG and highest PPD variation.

Ethical decisions represented another 35% of the moments with the highest level of attention of the players, represented in Figure 11; however, the HEG ratio behaved in a relation of 56% (fall) and 44% (rise) of the total periods identified in Table A1, and this seems to be directly related to previous concepts on the subject and their convictions, including in the game, when we identify that players who have a reduction in the activation of the prefrontal cortex are those who decline or delay making a decision unethical. At the same time, regardless of your beliefs, concepts and what the game represents for you (simulation of reality or mere fun), this type of theme attracts attention, confirmed by the greater variations in the diameter of the pupil. On this issue, it is important to highlight P9′s comment in the posttest that the "BSG should present more clearly the ethical reflection and its consequences, even before starting to play". Specifically on this topic, one study reveals that tasks that involve ethical aspects involve high levels of attention and, at the same time, highlights the ET as an appropriate device for monitoring this theme [74]. Therefore, it can be inferred that the "dose of ethics" inserted in the BSG may have contributed, in general, to positive player engagement.

An important aspect observed is that in critical situations or ethical decisions such as those provided by the game, as they involve a strong emotional appeal, there seems to be a direct influence on the HEG result, in line with a study that shows that activation of the prefrontal cortex varies from according to the task, decreasing when there is a negative emotional impact or increasing when not [75].

Figure 11 also reveals that operational decisions and insights (whether positive or negative) are individually responsible for 10% of the highest PDD variation. These results show that at certain times, these elements have meaning for the player with regard to the level of attention, and also, together with the HEG ratio, how much he can associate them as a possibility of success (rise curve) or failure (fall curve) in the game, in line with research associating pupil diameter with motivation in tasks [57,67].

6. Conclusions

Serious games, such as BSGs, demand many attentional sources, and they can prove to be potentiators of visual and cognitive abilities. In this way, knowing how the player receives and processes information can be the key to identifying how the contributions, elements and moments in this tool can stand out as a learning resource.

This article showed the results of the experience in the context of player engagement when using a BSG for learning. From a model that considers three different perspectives of player monitoring, different data collection tools and information of physiological, psychological, and behavioral origin provided the results. As part of the adopted methodology, the variables generated by the HEG (HEG ratio) and ET (PDD) devices were not only suitable for the experiment to measure engagement, but were also able to:

- Indicate trends in the flow and attentional behavior of the game as a whole;
- Establish not always direct relationships between the variables in the different situations proposed, as was the case of moments involving strategic thinking;
- Provide analysis of specific periods, relating the results of variables with pre- and posttest data, mainly to justify situations in which players' behaviors are different.

Finally, the crossing and complementation of data provided a much more complete analysis of the experience and, consequently, of the game, such as the negative aspects related to the tutorial, and the identification of situations related to critical situations and recurring ethical decisions, as a factor of high player–game connection.

It is believed that this work was able to provide important insights, both for the definition of experimental models for monitoring the player's experience with BSG and for the proposition of significant elements for the design of this type of tool, as support for the process of teaching knowledge of the business world.

Considering that the physiological device used (HEG) only provides cognitive information from the prefrontal cortex, although there are scientific studies that indicate its relationship with other brain regions in specific situations, this study has limitations because it does not consider an analysis in more detail and in real time of the other cortical areas, mainly regarding the emotional reactions of the player. Thus, new experiments are recommended adopting the proposed methodology, using other noninvasive devices, such as the electroencephalogram (EEG), to further explore the player–game interaction process and the potential of BSG as a learning tool. Other possibilities for experimental studies applying the proposed methodology include the analysis of other types of serious games, entertainment games, smartphone games, simulators and even monitoring the experience on web pages.

Author Contributions: C.P.F., C.S.G.G. and D.F.A. conceived the study. C.P.F. performed the database search and prepared the first draft of the manuscript. All authors wrote this SR collaboratively, including Introduction, Background, Methodology, Results, Discussion, and Conclusions; All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Universidad de La Laguna (protocol code CEIBA 2019-0356 and date of approval: 9 October 2019).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Acknowledgments: We would like to thank the Universidad de La Laguna (ULL) and the Universidade Federal do Rio Grande (FURG), which through a cooperation agreement between the two institutions has allowed us to advance research on the user experience with serious games through the support of biofeedback interfaces. We would also like to thank the Instituto Federal de Educação Ciência e Tecnologia do Rio Grande do Sul (IFRS), which has enabled the author Cleiton Pons Ferreira to integrate and contribute to this group of studies.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

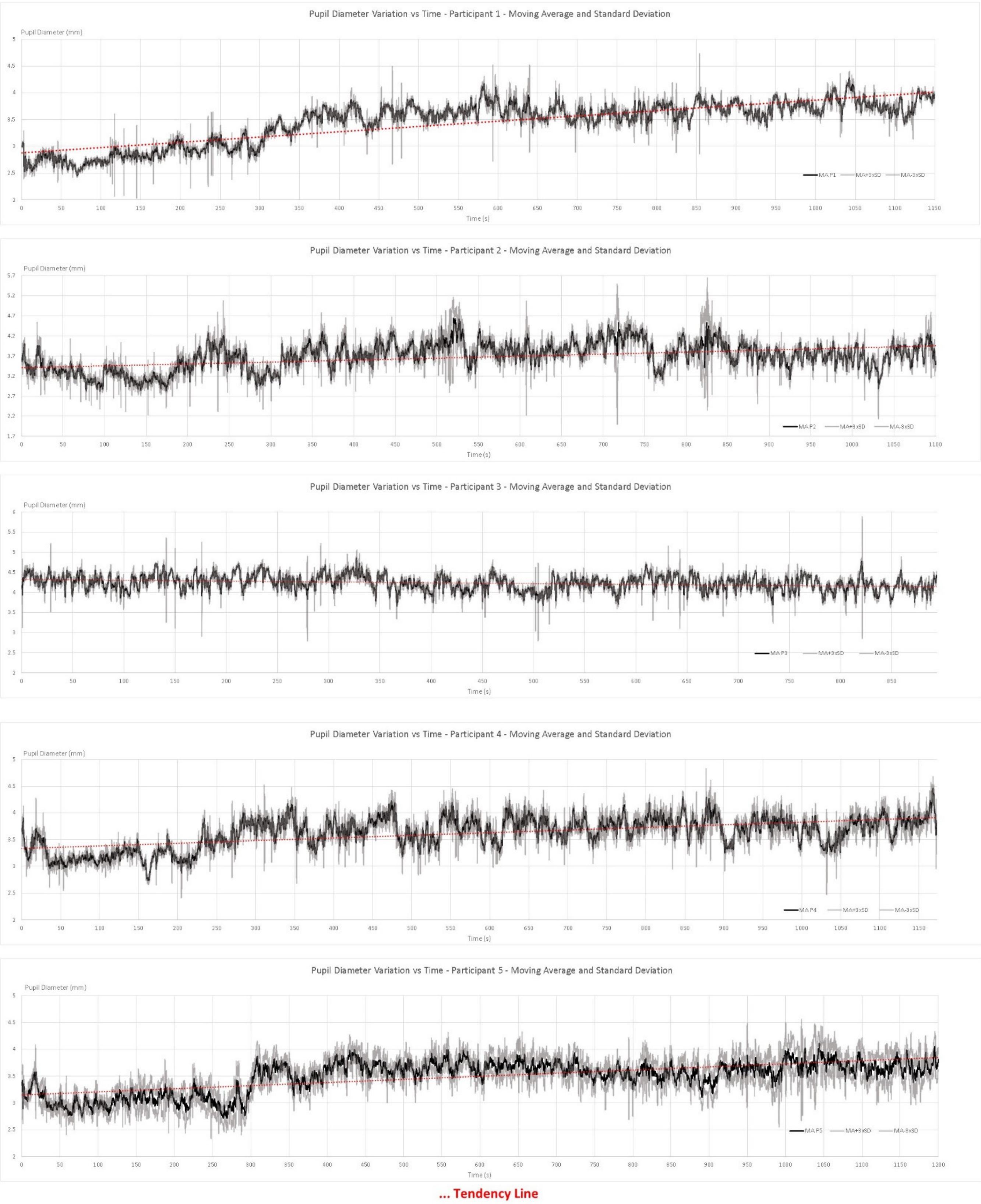

Figure A1. Pupil Diameter Variation during the tutorial reading and playing time for the Participants P1 to P5.

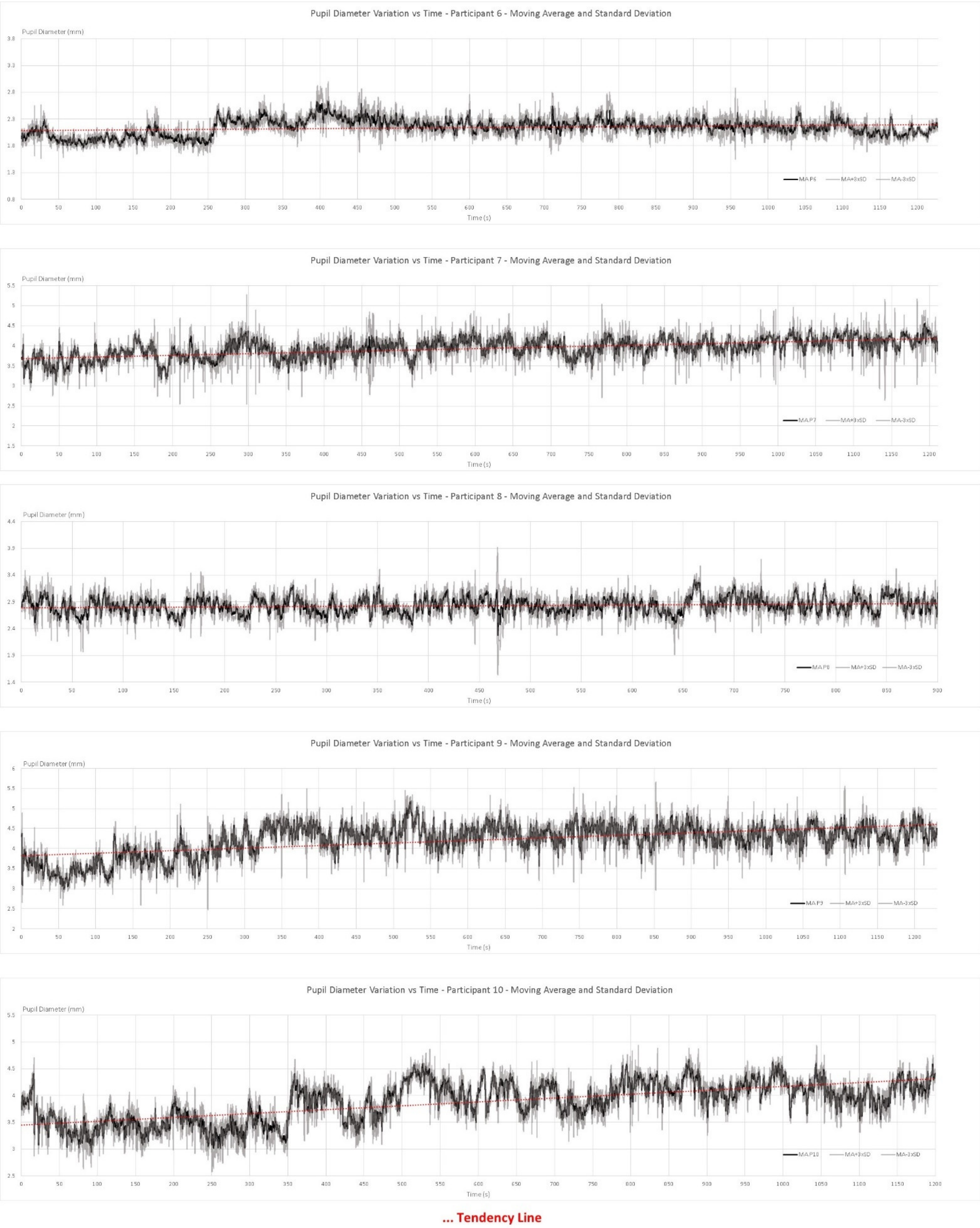

Figure A2. Pupil Diameter Variation during the tutorial reading and playing time for the Participants P6 to P10.

Appendix B

Table A1. HEG and ET cross referencing information table.

Player	Time	(I) Time Period (s)	(II) BSG Situation during the Play	(III) HEG Ratio Behavior	(IV) PDD min (mm)	(V) PDD máx (mm)	(VI) PDD avg. (mm)	(VII) PDD Variation (mm)
P1	1	273–283	ED	Fall	2.9155	3.3187	3.1372	0.4032
	2	342–354	GS	Rise	3.2588	3.4870	3.3779	0.2282
	3	432–443	CS	Rise	3.2150	3.4557	3.3532	0.2407
	4	523–590	ED	Rise	3.4468	4.1689	3.6972	0.7221
	5	609–621	CS	Fall	3.4892	3.9327	3.7390	0.4435
	6	628–640	OD	Rise	3.3810	3.9618	3.6737	0.5808
	7	1118–1131	ST	Rise	3.3550	4.2808	3.7544	0.9258
	8	949–960	ED	Fall	3.5320	3.9697	3.7820	0.4377
	9	1099–1111	CS	Fall	3.4877	3.9375	3.7071	0.4498
P2	1	6–18	IS	Fall	3.1539	3.7445	3.3722	0.5906
	2	161–175	ST	Rise	2.8378	3.2531	3.0526	0.4153
	3	213–265	ED	Rise	3.2034	4.2710	3.7751	1.0676
	4	327–339	ED	Fall	3.2694	3.9066	3.6250	0.6372
	5	424–441	OD	Rise	3.5927	4.2246	3.8863	0.6319
	6	506–518	ST	Rise	3.7283	4.3915	4.0462	0.6632
	7	652–664	CS	Fall	3.6455	4.3097	3.9654	0.6642
	8	762–879	CS	Rise	3.1114	4.5328	3.8237	1.4214
	9	885–899	OD	Fall	3.2337	3.9946	3.6891	0.7609
P3	1	347–359	CS	Fall	3.9083	4.5551	4.3327	0.6468
	2	419–431	OD	Rise	4.1199	4.7076	4.4349	0.5877
	3	564–582	ED	Fall	3.8330	4.4401	4.1846	0.6071
	4	631–642	OD	Rise	3.9843	4.5652	4.2976	0.5809
	5	669–684	CS	Fall	4.0768	4.3559	4.2131	0.2791
	6	808–864	ED	Fall	3.7910	4.5412	4.2144	0.7502
	7	1064–1115	CS	Fall	3.7347	4.4502	4.1382	0.7155
	8	1145–1165	CS	Rise	3.7093	4.7729	4.1600	1.0636
P4	1	350–380	CS	Rise	3.2175	4.1204	3.5652	0.9029
	2	381–392	OD	Fall	3.3601	3.9655	3.6127	0.6054
	3	608–623	ED	Rise	3.2416	4.0911	3.6229	0.8495
	4	924–936	CS	Rise	3.4552	3.8541	3.6516	0.3989
	5	937–945	OD	Fall	3.5924	4.0267	3.8347	0.4343
P5	1	182–193	ED	Rise	2.9232	3.3531	3.1506	0.4299
	2	336–352	OD	Fall	3.4259	3.7923	3.6682	0.3664
	3	699-709	CS	Rise	3.5561	3.8322	3.7310	0.2761
	4	773–784	OD	Fall	3.3534	3.7958	3.6067	0.4424
	5	989–1001	CS	Rise	3.3372	3.9779	3.6532	0.6407
	6	1060–1072	CS	Rise	3.6029	3.9547	3.7961	0.3518
	7	1072–1117	OD	Fall	3.3994	3.9522	3.6580	0.5528
P6	1	20–46	IS	Rise	1.8887	2.2917	2.0491	0.4030
	2	81–112	IS	Fall	1.7663	1.9910	1.8942	0.2247
	3	321–332	ED	Fall	2.1713	2.4799	2.3547	0.3086
	4	430–450	GO	Rise	2.1277	2.3878	2.2697	0.2601
	5	455–474	OD	Fall	2.1560	2.5897	2.3195	0.4337
	6	587–597	CS	Fall	2.0899	2.3438	2.2236	0.2539
	7	621–640	CS	Rise	2.0154	2.3149	2.1499	0.2995
P7	1	53–124	IS	Rise	3.2747	4.0762	3.6520	0.8015
	2	240–266	IS	Rise	3.4729	3.8900	3.6503	0.4171
	3	282–298	GS	Fall	3.7925	4.4462	4.1296	0.6537
	4	504–599	CS	Rise	3.2993	4.4773	3.9932	1.1780
	5	747–870	CS	Rise	3.4226	4.3826	4.0142	0.9600
	6	1192–1204	CS	Rise	3.6641	4.5744	4.1327	0.9103

Table A1. *Cont.*

Player	Time	(I) Time Period (s)	(II) BSG Situation during the Play	(III) HEG Ratio Behavior	(IV) PDD min (mm)	(V) PDD máx (mm)	(VI) PDD avg. (mm)	(VII) PDD Variation (mm)
P8	1	329–340	ED	Fall	2.5513	3.0386	2.7272	0.4873
	2	422–432	OD	Rise	2.6842	2.9737	2.8389	0.2895
	3	507–518	OD	Rise	2.5505	2.8084	2.6714	0.2579
	4	653–674	ED	Rise	2.5631	2.9446	2.7385	0.3815
	5	720–780	CS	Rise	2.2761	3.1305	2.8778	0.8544
	6	810–827	OD	Fall	2.5783	2.9157	2.7406	0.3374
	7	887–899	OD	Fall	2.5756	3.0623	2.8596	0.4867
	8	906–924	IS	Rise	2.6040	2.9818	2.8087	0.3778
	9	1109–1130	ED	Fall	2.6283	3.1873	2.9087	0.5590
P9	1	10–41	IS	Rise	2.9835	3.9353	3.4411	0.9518
	2	117–156	ED	Fall	3.2328	4.3639	3.7994	1.1311
	3	156–177	IS	Rise	3.3948	4.0034	3.7315	0.6086
	4	256–267	IS	Rise	3.4911	4.1965	3.9241	0.7054
	5	535–550	CS	Rise	3.8763	4.9207	4.3356	1.0444
	6	703/719	CS	Rise	3.9724	4.6468	4.3417	0.6744
	7	784–795	CS	Rise	3.9978	4.7905	4.4542	0.7927
	8	803–833	GO	Fall	3.8058	4.8136	4.3551	1.0078
	9	890–950	OD	Fall	3.9966	4.8885	4.3823	0.8919
P10	1	46–58	IS	Rise	3.2025	3.6066	3.4473	0.4041
	2	377–386	ED	Fall	3.6790	4.1176	3.8990	0.4386
	3	354–376	IS	Rise	3.6627	4.4119	4.0856	0.7492
	4	528–538	ED	Fall	3.8645	4.5475	4.3724	0.6830
	5	737–750	ED	Fall	3.5468	4.1789	3.8123	0.6321
	6	827–837	ED	Fall	3.8669	4.4601	4.2183	0.5932
	7	851–865	CS	Rise	3.8447	4.2299	4.0697	0.3852
	8	1082–1092	CS	Rise	3.8339	4.1826	4.0054	0.3487

Legend: BSG Situation along the game

GS	Game start	Watching the Tutorial
CS	Critical situation	
GO	Game Over	Playing the Game
ED	Ethical Dilemma	
OD	Operational Decision	
SD	Strategic Thinking	
IS	Insight	

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