Game Design and Neuroscience Cooperation in the Challenge-Based Immersion in Mobile Devices as Tablets and Smartphones

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Abstract. The significant number of digital game applications for mobile devices, such as smartphones and tablets, motivates the concern of designers regarding the impact that the application of design elements may have in the construction of the gameplay experience. This concern is intensified when involving children on the stage of brain and cognitive development. This scenario is favorable to the cooperation between Game Design and Neuroscience, which are discussed in this article from the proximity between the elements of Challenge-based Immersion and attention mechanisms, decision-making, emotional and cognitive processing, and voluntary motor action. Among the main results obtained in the evaluation of two focus groups aged between 7–8 years-old and 9–12 years-old, there is the directly proportional association between cognitive involvement of the player with the game; the player control of the charts and navigation through the digital game objects; and the player motivation to overcome the challenges in this context.

Keywords: Game design · Neuroscience · Challenge-based immersion · Mobile devices

1 Introduction

The cooperation between Design and Neuroscience is proving to be a prolific field of research [1–5] in view of the significant and mutual contributions that these areas provide by enhancing, extending and converging their respective scopes of activity; and the positive impact that this synergy represents to the users of products, services and environments designed from this interface and transdisciplinary confluence.

The context of the games especially in mobile platforms is presented as a universe even more challenging to this cooperation between the fields of Design and Neuroscience, since the large number of digital game applications available and accessed through mobile devices, such as tablets and smartphones, increases the designers concern about the role that the projective elements used in the design of these games may have in the user experience during gameplay and the impacts, both positive and negative, in this context and resulting from these projective choices.

Meanwhile, for neuroscientists, such concerns are consistent with those that involve the dynamics of the brain and cognitive processes directly involved in the construction

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of this research and the behavioral reverberations arising from it. "There is a widespread opinion that human behavior cannot be globally understood only based on external and observable facts. To be fully understood it is necessary to take into account the thoughts, cognitions and beliefs of the subject, as it is these that determine and give meaning to the behavior and structure and organize the world" [6].

Such concerns, in both perspectives, are extended when this scenario involves children on the stage of brain and cognitive development. In this context, this research presents and discusses the cooperation between Design and Neuroscience from the results obtained during the gameplay evaluation of Time Tremors Infinity, a game available for mobile devices - tablet and smartphone. The evaluation was conducted with 56 school children in the age groups of 7–8 years-old and 9–12 years-old, 28 boys and 28 girls. This article will be specially focused on the game design elements, evaluation and results specifically related to Challenge-based Immersion (control, challenge, cognitive involvement).

Time Tremors Infinity consists of a "digital treasure hunt" in which players must hunt, gather and exchange "Time Treasures" in different media platforms. There is a collaboration relationship between the players. They have to share the findings and solutions to the puzzles and mysteries of history, but there is also competition, because each player is challenged to find new treasures and, as a consequence, to stand out during the game. "Time Treasures" have a value directly associated with historical facts of humanity and can be, for example, a Marie Antoinette's dessert fork or Titanic guard's binoculars. Players are given assignments that can force them to solve puzzles and mysteries, or even to overcome a challenge in order to find and collect new and more time treasures. At every treasure they find, there is a new historical cycle revealed to players.

The data collection was conducted from video recording of the above-mentioned sessions as well as through semi-structured interviews with the target-population of the research and a socio-demographic questionnaire filled in by the parents/guardians of students. Among the main results observed from the perspective of cooperation between game design and neuroscience, there are: (1) the directly proportional association between the player cognitive involvement and the game; the player control of the charts and navigation through the digital game objects; and the player motivation to overcome the challenges in this context; (2) the absence of a direct relationship between the technological device - tablet or smartphone - and the elements of control, challenge and cognitive involvement of the player; (3) the identification of the body posture assumed by the player during gameplay as a determining factor to the results obtained under the game control; (4) the player engagement when facing the game challenges that was directly related to the novelty provided by the action of playing, regardless of the game content in question.

2 Immersion in Games

Among the several factors involving gameplay experience, during and after playing, such as fun; flow; thriller; competence; frustration; control; challenges; social presence; and from a wide variety of approaches to gaming experience [7–19], immersion is an important and positive component of the experience players seek from games.

In general, the concept of immersion can be understood as the player engagement or involvement during their experience of playing a digital game, which suggests the expression “a person feels as if they are in the game” [20]. Nevertheless, it is important to emphasize that this feeling of being “in the game”, in this particular context, does not refer to a spatial or social location in the game, but to the player cognitive status during the action of playing and experiencing the situations proposed by the game.

This cognitive experience can reveal different levels of engagement and involvement in the game, which constitute one of the different approaches dedicated to research of the immersion in digital games. In this perspective, the different levels of involvement and engagement with the different aspects of the game are responsible for moving the player attention, consciousness and thoughts, dissociating the aspects related to the physical world and concentrating them only in events occurring inside the game [20].

In this regard, Brown and Cairns [7] propose three levels of immersion. The first level is the necessary engagement so the player invest their time and effort to play the selected game. The second level is defined by the high degree of attention and emotional involvement during gameplay. Lastly, the third level comprises the total immersion or complete involvement with the game. This is where the sense of being “in game” emerges, and nothing but the very context created by the game will be relevant to the player. Although Brown and Cairns called this level as presence, it is important to note that the concept of total immersion is not associated with a spatial or social location in the game, and therefore this terminology does not seem to be the most appropriate to express this condition.

Another approach presented by Ermi and Mayra [21] establishes three types of immersive experience: sensory, challenge-based and imaginative. This approach comprises an experiential perspective aiming to characterize the immersion attributes as an experience lived by the players. In this context, the concept of sensory immersion complies with the presence in which the game, as a digital environment, can offer high quality and realistic audiovisual representation; aspects that are able to stimulate the player to the perception of their “physical” presence in the game. The concept of challenge-based immersion concerns the challenges proposed by the game and the skills required from the player to overcome them while the imaginative immersion relates to the player emotional involvement during gameplay.

Also within an experiential perspective, but with a different approach, Adams [11] proposes another model for the concept of immersion in digital games, but it is also structured on three pillars: tactical, strategic and narrative. The definition of tactical immersion comprises the immersion built, moment by moment, during the act of playing the game while a strategic immersion relates to the player strategic thinking throughout the game. The narrative immersion refers to the player emotional involvement during the game.

Among the definitions introduced by Brown and Cairns; Ermi and Mayra; and Adams, it is also possible to identify overlapping of the immersion concept in digital games. For example, the first level of immersion proposed by Brown and Cairns convergences to the context of challenge-based immersion defended by Ermi and Mayra, as well as the tactical and strategic immersion presented by Adam’s model.

In this regard, a tactical immersion corresponds - in part - to the ‘challenge’ factor and – fully - to the ‘control’ factor, which are described by the Brown and Cairns’ first-level immersion model. It is also possible to notice a clear correspondence between the strategic immersion and the cognitive involvement, which are also an integrating factor of first level. The Brown and Cairns’ second level of immersion is directly related to the imaginative immersion proposed by Ermi and Mayra, as well as the narrative immersion of Adam’s model. In relation to the concept of total immersion, while Brown and Cairns’ model mentions the third level of immersion, Ermi and Mayra’s model presents the sensory immersion associated with the idea of presence in the game, but without specifying a direct correlation between this and the dimension of total immersion; Adam’s model considers that the emergence of a true immersive experience is only possible from the harmonious collaboration among tactical, strategic and narrative immersions [11].

Another possible approach to the immersion concept is brought by the technological perspective comprising a “physical” presence in the game, or the sensation of being in that (digital) environment [22]. This approach involves directly the technologies able to create representations of the player in the game digital environment.

This brief review does not intend to exhaust the discussion about immersion in digital games, but to present a brief overview of the main approaches that are dedicated to this concept. This brief mapping is essential to the identification and construction of potential connections between the fields of game design and neuroscience. In this article, the contribution will be restricted to the proximity between the concept of challenge-based immersion proposed by Ermi and Mayra [21], and referred to the challenges proposed by the game and the skills required from the player to overcome them - and the attention mechanisms; decision-taking; emotional processing; cognitive processing; and voluntary motor actions, clarified by the neuroscience perspective.

3 Articulations Between Neuroscience Approach and Challenge-Based Immersion Elements

As a start, it should be noted that the intended proximity between attention and decision-making mechanisms, emotional and cognitive processing, and voluntary motor actions, explored from the neuroscience perspective, and the concepts of control, challenge and cognitive involvement, discussed in the game design as Challenge-based Immersion, does not aim to create a reductionist and restrictive approach of cause and effect between brain phenomena, design elements and choices made by the player. Rather, the aim of this research is to explore the expansion of perspectives to the game design that the neuroscience reflections can bring to the design Challenge-based Immersion. The understanding of neuroscientific background that engender the connections between the above-mentioned mechanisms, processing and intrinsic actions to the human body can provide relevant assistance and be able to identify sustainable and more favorable ways to the conception and definition of the design elements related to the challenges posed by the game, given the cognitive and sensorimotor skills necessary and required from the player to overcome them. It is believed that the dialogue between these design elements and the associated cognitive and sensorimotor skills can contribute significantly to the game design regarding the motivation increase, frustration reduction and strengthening the player cognitive involvement in the gameplay experience.

The highest point in brain plasticity takes place in early childhood. This can be seen when one hemisphere of a child's brain is removed, and the other hemisphere creates interconnected networks in order to enlarge their tasks and assume the operation of the functions hitherto exclusive to non-existent hemisphere. On the other hand, there are areas of the brain that take years to reach their full maturity. For example, the core with the important role of maintaining the attention, called reticular formation, is in general fully myelinated in the puberty or after it while the frontal lobes only reach full myelination after adulthood [23]. The brain design developed over time explains the behavior. That is, the more intense level of emotion and impulsivity identified with higher incidence in younger adults than in older adults denotes a possible and proportional association between these behaviors and neuronal maturation of the individual.

Every thought the player has when facing a challenge and, consequently, a decision-making in a game requires some attention. That is, it requires the focus in the context of the activity and disposal of stimuli not related to it. There are two types of attention in this case: (1) the automatic bond of senses when information captures the attention of the individual; (2) when the mind is deliberately dedicated to a topic of interest. In both scenarios, attention is the result of the connection between neurotransmitters in brain areas and, only from those, they are directly involved so these mechanisms occur. Many brain regions work in guiding and controlling attention taking into account three elements required for this function: (a) excitement; (B) orientation; (C) focus. The (a) excitement is dependent on a group of midbrain nuclei - the top of the brainstem - called the reticular activating system. The stimulation of this group of reticular neurons creates alpha brain waves - activity fluctuations in the range from 20 to 40 Hz - associated with the alert status. The (b) orientation involves neurons in the superior colliculus and the parietal cortex. The superior colliculus move the eyes to the new stimulus, while the parietal cortex decouples the attention from the current stimulus. While the focus is executed by the lateral pulvinar - a portion of the thalamus - which operates similarly to a spotlight that turns on the light according to the stimulus and further transfers the information about the focused context to the frontal lobes, which are responsible for retaining and maintaining the attention [23].

In other words, the human body has the neurophysiological mechanisms that support the processes of attention, choice and decision-making; elements and situations that will integrate or not their game context and if they will invest or not their time. In the decision-making, two complementary pathways of neurophysiological communication set up this mechanism. The first is responsible for causing the appearance of images related to the particular situation, such as action options and preview the future consequences. Several reasoning strategies act with this knowledge in order to make a decision. Meanwhile, the second pathway operates in parallel to the first; it is responsible for activating previous emotional experiences associated to situations comparable to what happens at the moment of decision-making in the game. This parallel mechanism influences the decision-making process by interfering with reasoning strategies or leading the attention to the representations of future consequences.

This second pathway can also operate in foreground and directly lead to a decision, for example, when an immediate choice is made from an intuition [24]. It is true that the degree of participation of both pathways in the decision-making process will depend exclusively on the individual who decides, from their previous experiences as well as the circumstances that make up the current situation experienced in the context of the game.

Any and every experience lived in this area is accompanied by some degree of emotion. The emotions and feelings play an important role in the reasoning that supports the decision-making in a game. Feelings trigger mental alerts about good and bad circumstances and thereby prolongs the impact of emotions by lastingly affecting attention and memory. Furthermore, the feelings, by combining memories of the past, imagination and reasoning, lead to the emergence of preview capacity and problems forecast and to the possibility of creating new and nonstereotyped solutions [24].

In this context, the amygdala acts as an interface between emotions and cognition, as well as it plays an important role in modulating motivated behavior. It is known that it receives information from more than one sensory modality, in addition to the direct reception to exteroceptive and interoceptive information arising respectively of the thalamus and visceral afferent receptors. In it, the information is integrated and receives an affective nature. The amygdala may also influence both the mnemonic and cognitive processes due to their direct projection to the hippocampus and the various associative polymodal neocortical areas. It can also directly modulate autonomic, neuroendocrine and behavioral responses related to motivated behavior due to its communication with the hypothalamus and limbic mesencephalic structures. That is, the amygdala provides the link between the cognitive and emotional processing - related to emotional experience in the game - and, on the other hand, modulates hypothalamic and mesencephalic sites responsible respectively for orchestrating and expressing several motivated and related behaviors, thus, to this emotional expression [25].

The nucleus accumbens, also called the ventral striatum, is considered a key element in the integration of emotions with voluntary motor actions taken by the player. This nucleus receives a convergence of information from various brain regions involved in emotional processing, learning and memory, such as the amygdala, the hippocampus and the prefrontal cortex. Furthermore, neurons of the nucleus accumbens - through projections for the ventral globus pallidus - can control the somatic movement [25].

As well as other cognitive systems, the human movement is built from the dynamic rules of brain development and their interactions with their own body and the environment. Perception, motivation and action in the game are subject to body biomechanical states. These states change throughout life. It is, therefore, important to point out that the motivation arising within the gameplay is essential both for the formation of new motor behaviors and for the preservation of the established behaviors. Children usually feel fulfilled with their new motor skills, and these skills are the results from new neural connections, new perceptual gains and biomechanical changes [26], for which the motivation contributes meaningfully.

4 Materials and Procedures

Time Tremors Infinity (TTI) consists of a transmedia game, that is, it is available for different converging media, and Alternate Reality, which uses the physical world as a platform to offer an interactive narrative. Alternate Reality Games are characterized by involving players in the stories, encouraging them to explore the narrative in order to solve the challenges and interact with game characters. This format is defined by the intense involvement of the players with the story that is built in real time and evolves according to their participation. The players interact directly with the characters in the game, helping them to solve puzzles and challenges, collaborate in real time with an online community that discusses and analyzes the activities in the game.

TTI's narrative is about two characters: the Max brothers, who are 14-years-old and Medie, who is 10 years-old. They are sent to the gloomy boarding school Ranksome Academy after the mysterious disappearance of their parents. The school is located on a secluded island, and built in a 'time tremors', unstable point in the time-space line in which objects, animals and people appear and disappear mysteriously. The leading character is represented by 'Hector, the Bear', a timekeeper. The enemies are the dangerous 'sleepy forest' and 'Miss BuGly', a wily biology professor.

In Time Tremors Infinity, the player must explore different pathways searching time crystals, which allow the time-space journey, with the aim of collecting various objects lost in the history; they are called 'time treasures'. There is also the 'celestial atlas', a kind of book that acts as a map and reveals highly relevant pieces of information. Only by bringing together all 'time treasures' and 'completing the celestial atlas', the player can unveil the mystery in Time Tremors Infinity.

In the game, there are 63 'time treasures' distributed in seven distinct stages of the narrative. Each stage has nine levels. The treasures can only be collected when the player captures the required amount of 'time crystals' in that particular level. By completing each level, only one 'time treasure' is released.

One of the main goals of TTI is to pass on cultural and educational information to the public, especially children, by covering areas as geography, history, science, physics and arts. This information is contained in the 'time treasures' and, as they are collected, the players are able to access details about the content, for example, tridimensional interactive and explanatory replicas on the operation or the context in which particular object ('treasure') fits into the historical period.

The age rating system is appropriate for children. For this research, the collection of quantitative and qualitative data focused on Challenge-based Immersion (control, challenge, cognitive involvement) was conducted with two main groups of players (A and B) consisting of members of both genders in the age groups from 7–8 years-old (group A) and 9–12 years-old (group B). The sample had a total of 56 individuals, with homogeneous distribution: group A – 14 boys; group A′ – 14 girls; group B – 14 boys; group B′ – 14 girls. They are all students at the Municipal School Miguel Ferreira Vieira, located in São Paulo, Brazil.

The group classification considered the stages of human development proposed by Piaget [27], indicating features that define differences in the configuration of cognitive structures and, thus, the process of cognitive development of children in the respective phases: sensorimotor; preoperatively; concrete operational; and formal operations. The research focused on the 'concrete operational' and 'formal operational' stages, because they are considered as the most suitable for the intended evaluation, as the 'concrete operational' stage marks a decisive change in the mental development of the child, which consists of the capability of concrete organization of thought in addition to the maturation of socialization behavior and social relations through games; while the 'formal operational' stage is marked by the abstraction ability and mathematical cognitive acquisitions.

The methodology for the collection of quantitative and qualitative data considered: (1) the application of a socio-demographic questionnaire filled in by the parents/guardians of students; (2) the individual experience of TTI gameplay on the smartphone, with the maximum duration of 10 min; (3) the semi-structured interviews held in a maximum of 10 min with each student after gameplay on mobile phone; (4) the individual experience of TTI gameplay on tablet with a maximum duration of 10 min; (5) the semi-structured interview held in a maximum of 10 min with each student after gameplay on tablet; (6) the video recording of steps (2), (3), (4) and (5). It should be noted that the sequence of steps (2) and (4) was alternated with the groups in order not to induce the preferred use of the mobile device by the students analyzed during the data collection.

5 Results

The data collected from the groups (A); (A′); (B) e (B′) were systematized and analyzed according to parameters related to Challenge-based Immersion: control, challenge and cognitive involvement. For the 'game control' parameter, the focus was given to: (1) graphics; (2) time; (3) navigation; (4) smartphone device; (5) tablet device; (6) body posture – playing while seated; (7) body posture – playing while standing. With regards to the 'cognitive engagement with the game' parameter, the focus was given to: (1) game main goal; (2) character; (3) treasures; (4) colors; (5) setting; (6) music. Finally, regarding the 'game challenges' parameter, the focus was given to: (1) tasks; (2) individual challenge - focus on playing; (3) individual challenge - focus on winning; (4) collective challenge - focus on the competition; (5) collective challenge - focus on collaboration. The results showed (Table 1):

Table 1. Results of 'control' parameter obtained from the two groups

Game control				
Parameters	Group A	Group A′	Group B	Group B′
Graphics	65 %	36 %	57 %	57 %
Time	79 %	36 %	86 %	50 %
Navigation	72 %	43 %	50 %	36 %
Smartphone	50 %	43 %	15 %	15 %
Tablet	50 %	43 %	50 %	72 %
Body posture – playing while seated	60 %	64 %	50 %	64 %
Body posture – playing while standing	13 %	29 %	7 %	7 %

The group A (7–8 year-old boys) demonstrated greater control of graphics and game navigation on the smartphone when compared with the other groups analyzed. The 'more control' was shown to be associated with the ability to play while seated.

The group A′ (7–8 year-old girls) showed better control of graphics, navigation and time playing while seated, regardless of the type of the mobile device used.

The group B (9–12 year-old boys) demonstrated greater control of the gameplay on the tablet when compared to the other groups. The 'more control' was shown to be associated with the ability to play while seated.

The group B′ (9–12 year-old girls) showed better control of graphics, navigation and game time when playing while seated and using the tablet device (Table 2).

Table 2. Results of 'cognitive involvement' parameter obtained from the two groups

Cognitive involvement with the game				
Parameters	Group A	Group A′	Group B	Group B′
Game main goal	100 %	72 %	72 %	58 %
Characters	93 %	87 %	64 %	64 %
Treasures	86 %	72 %	50 %	7 %
Colors	93 %	72 %	71 %	73 %
Setting	86 %	69 %	64 %	57 %
Music	72 %	73 %	72 %	64 %

The group A (7–8 year-old boys) demonstrated greater cognitive involvement with the game in respect to the main goal, character, treasures, colors and setting when compared to the other groups.

The group A′ (7–8 year-old girls) demonstrated greater cognitive involvement with the game as regards to the music when compared to the other groups (Table 3).

Table 3. Results of 'challenge' parameter obtained from the two groups

Game challenges				
Parameters	Group A	Group A′	Group B	Group B′
Missions	79 %	43 %	65 %	65 %
Single player - focus on playing	54 %	64 %	14 %	22 %
Single player - focus on wining	15 %	22 %	22 %	7 %
Multiplayer - focus on competition	29 %	14 %	14 %	50 %
Multiplayer - focus on collaboration	21 %	57 %	29 %	7 %

The group A (7–8 year-old boys) demonstrated greater motivation when facing the existing challenges in the missions proposed by the game when compared to the other groups. This motivation for the challenges was associated to the desire to play and compete, regardless of the final result.

The group A′ (7–8 year-old girls) demonstrated motivation when facing the existing challenges in the missions proposed by the game when associated with the desire to play and collaborate, regardless of the final result.

The group B (9–12 year-old boys) demonstrated motivation when facing the existing challenges in the missions proposed by the game when associated with the desire to win and collaborate.

The group B′ (9–12 year-old girls) demonstrated motivation when facing the existing challenges in the missions proposed by the game when associated with the desire to compete, regardless of the final result.

6 Discussions

By understanding Challenge-based Immersion as a game design domain that links the following elements: control, challenge and cognitive involvement of the player during the gameplay, it can be said that only the group A, consisting of 7–8 year-old boys, has shown the most suitable percentage range to the connection between these factors.

This result provides the diagnosis of a directly proportional relationship between the player cognitive involvement with the game; player control of the charts and navigation through the digital game objects; and the player motivation to overcome the challenges in this context. That is, as seen in the results obtained from the groups A′, B and B′, any kind of influence on one of these aspects, whether from the player's body or the physical environment, consequently results in impacts to other evaluated elements.

This result allows us to validate the hypothesis presented by this article that aimed to demonstrate the close connection between the following concepts: control, challenge and cognitive involvement and attention mechanisms, decision-making, emotional and cognitive processing, and voluntary motor action, addressed from the neuroscience perspective.

Given the results obtained from group A′, consisting of 7–8 year-old girls, it is not possible to establish a direct relationship between technological device in which the game is played - tablet or smartphone – and the elements of control, challenge and cognitive involvement. On the other hand, it is possible to consider the body posture assumed by the player during gameplay as a determining factor to the results obtained under the control of the game. Postural adjustments occur during voluntary movement in anticipation of disruptions caused by the movement execution plan. These anticipatory postural adjustments are part of the selected motor plans to perform a certain action [26]. Therefore, they work on what is observed as a result of this motor action.

It was also found that the difference between all the percentages observed in the comparison between the genders of the groups proved to be directly proportional to the habit of playing. This diagnosis supports the direct relationship between the decision-making mechanisms and previous experiences of the individual.

The results also showed that, in the context of the challenges presented by the game, the player engagement was directly related to the novelty provided by the action of playing, regardless of the game content in question. This finding confirms the pleasure and the consequent cognitive involvement in the use of new motor skills, usually seen in children.

It is important to emphasize that these discussions do not exhaust the still possible interpretations of the results. Rather, they are intended to explore other perspectives for many other discussions open to dialogue and integration.

7 Conclusion

The objective of this article was to find a proximity between the fields of knowledge of Games Design, especially from the concept of Challenge-based Immersion, and Neuroscience, especially of attention mechanisms, decision-making, emotional and cognitive processing and motor action. Its main objective was to raise the cooperation between these fields of knowledge in order to create game design taking into account the cognitive and sensorimotor needs of the intended target-audience and, therefore, more motivating to the cognitive involvement and to reduce the frustration during the gameplay.

As future developments of this research, there is the application of gameplay tests, with evaluative focus on the elements of challenge-based immersion, adults groups, with different age groups, considering a subsequent comparative analysis with the results obtained under the sampling discussed in this article.

There is also the intention to expand this cooperation between Game Design and Neuroscience in the contexts of imaginative and sensory immersions.

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