

Digital Educational Games: Inclusive Design Principles for Children with ADHD

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ABSTRACT

This work presents the characteristics inherently present in games which can positively influence children's learning and are considered of special relevance in the learning process of those diagnosed with Attention Deficit Hyperactivity Disorder (ADHD).

The development of digital educational game requires the game designer's awareness of the influence of learning outcomes of all game elements. Starting with the first creative ideas until the last testing sessions.

Despite being the most common neurobehavioral disorder related to human infancy and a cause of severe hindrance to the personal and academic life of children, studies discussing how digital games can be developed or better adjusted to effectively support these children's learning process seems to be lacking. The main objective of this article is to provide guidelines with which game designers can create better educational games by improving their accessibility and inclusiveness, while having this target audience in mind. To do so, 11 guidelines are presented based on essential components of Interaction Design, User Interface and User Experience, as well as foundations of Cognitive Psychology and clinical characteristics common to children with ADHD. These guidelines are Simple interactivity; Recurring rewards through positive feedbacks; Removal of distracting elements; Emphasis on relevant elements; Level flexibility; Reduced level duration; Multiplayer option; Unlimited game session duration; Validation of important game actions; High visual standards; Motivation and fun as main components.

The isolated use of each guideline is already a contribution to the process of creating educational digital games for children with ADHD. However, this work intends to promote a complete and directed guidance to the game designer, who will be able to develop games that effectively improve the learning conditions of children with ADHD by combining the different proposed guidelines.

Introduction

Several pedagogical, neurological and prescriptive studies support the general idea that teaching methods should be adequate to the pedagogical profiles of students. This didactic procedure, oriented according to pedagogical profiles, requires that the educator knows the limitations, skills and potential of his students, in order to define strategies and resources more adequate to the learning aid. For the creation and development of successful educational games it is crucial that the game designer understands that its audience will have several types of profiles with different potentials and cognitive constraints. It is up to the game developers to create inclusive and accessible games that can cover all types of audiences, so that it can be an effective aid during each player's learning process. Player-centered approaches are increasingly assumed by large communities of developers and issues related to inclusive design are also gaining terrain in the learning and entertainment industry. Several studies, regarding digital games in education, focus on this particular disorder as it is already the most common neurobehavioral disorder found in young children and has a particularly negative effect on their performance in school.

ADHD

Understanding kids with ADHD it is often difficult as most of them will present very unstable behaviours. Their limitations, skills and potential should be considered as one to understand the origins or neural bases, the division in subtypes and what is its prevalence. Also relevant in the context of education, it is important to understand what the general neuropsychological profile of a child with ADHD is focusing on which cognitive processes are more often affected and what losses can be expected. Before presenting the guidelines for the development of accessible and inclusive educational games for ADHD, we will briefly address the most common teaching strategies used with these children.

Definition and subtypes

Coming from genetic, biological or neuropsychological causes, ADHD is a neurodevelopmental disorder that offers harmful levels of inattention, disorganization and/or hyperactivity-impulsivity and which occurs in childhood and persists into adulthood. There are three subtypes of ADHD: *Predominant Inattentive*

; Predominant Hyperactive-Impulsive; and Combined. The *Inattentive* subtype is manifested in infantile behavior through rambling in tasks; lack of persistence; difficulty in maintaining the focus of attention and disorganization. Inattention does not correspond to a lack of understanding, however, it can be an obstacle for it to happen. The *Hyperactive-Impulsive* subtype is manifested in behavior through excess motor activity and impulsivity, which leads the individual with the disorder to perform precipitate and unplanned actions. Finally, the Combined subtype is manifested through the combination of symptoms present in the *Inattentive* and *Hyperactive-Impulsive* subtypes.

Prevalence

According to Hora et. al. (2015), it is the most common disorder in childhood, with a worldwide prevalence rate among individuals aged 3 to 17 years from 2.7% to 31.1%. This disorder is more frequent in females, with a ratio of 2: 1. In adults, this ratio is lower, falling to 1.6: 1. Females are also more likely to be inattentive than males. During the child's development process other mental disorders associated with ADHD may manifest, such as Conduct Disorder with 40% of the cases; Depression with 21%; Anxiety Disorder 18%; 12% Bipolar Disorder and 10% Learning Disorder.

Neural Bases

The origin of the disorder is not fully defined. Szobot, et. al. (2001), emphasize two groups of researchers in this area. The first group argues that the characteristics of the disorder are the result of changes in some brain regions, enumerating the prefrontal, parietal, nuclei of the base and cerebellum, and their integrated circuits. A second group of researchers has related ADHD with failures in the transmission and reception of neurotransmitters, mainly dopamine and noradrenaline. Dopamine is responsible for fine motor behavior, cognition / perception, hormonal control and motivational behaviors of desire. Noradrenaline is related to mood control, motivation, cognition / perception, fine motor behavior and blood pressure maintenance. These failures result in malfunctioning of the posterior cortex attention system to external stimuli.

Executive Functions and Attention

In addition to the possible changes in the neural basis, individuals with ADHD show signs of bad behavior in a set of cognitive processes responsible for the performance of voluntary, independent, self-organized and goal-oriented actions, often called executive functions. These function problems affect inhibition, flexibility, emotional control, volition, operational memory, planning, self-monitoring and organization of space and materials. Another problem in the cognitive process of an individual with ADHD is related to attention, a neuropsychological function responsible for the selection and maintenance of focus on the input of information needed at a given moment. Changes in these cognitive domains can have a great impact on children's daily lives, with important consequences for their school performance.

Neuropsychological Profile

The disorders mentioned above are presented in different ways in each subtype of the disorder. Individuals with the predominantly inattentive subtype have changes related to selective attention (which is responsible for directing attention to a stimulus when there are many other distracting stimuli around them), attention maintenance, and information processing speed. On the other hand, those with the predominantly hyperactive-impulsive subtype present difficulties in inhibitory control and in the maintenance of attention over time and therefore these individuals are more vulnerable to distraction. Despite that, the academic performance of the *Inattentive* individual is usually considered inferior when compared to the *Hyperactive-Impulsive* individual. On the other hand, the implications in social relationships are less evident for *Inattentive* than for *Hyperactive-Impulsive*.

Learning difficulties

In addition to low school performance, children with ADHD tend to have a higher than normal rate of disapproval. In addition to having more suspensions, when compared to their classmates, they are considered lazy and irresponsible mostly because they take too long to complete tasks, or, in some cases, can't complete them. This stigma is a misunderstanding and can bring great suffering to these children. They also have a greater tendency to get injured, which results in absence from school. All of this can contribute to several negative effects, such

as suffering social rejection or even being victims of bullying, due to the unusual or exaggerated characteristics shown for their age. Furthermore, this affects not only the academic life of the individual with the disorder, but also their social and familiar relationships and later on, their professional life. During adolescence, they are more likely to develop conduct disorder and, in adulthood, an antisocial personality disorder, which increases the risk of substance use. Therefore, when they do not have adequate follow-up, individuals with ADHD may not reach a more advanced level of education and, professionally, may present low levels of performance, low success rate, as well as attendance failures that, in isolation or combined, can lead to unemployment. It is important to emphasize that, with adequate follow-up, individuals with this suffering from this condition can improve academic and social performance and have a good quality of life.

Teaching Strategies for Children with ADHD

To improve the academic performance of children with ADHD, it is possible to use several teaching strategies. According to Costa et al. (2013), based on a study with children with ADHD, six strategies were identified that can aid in the learning process. They are: the creation of a bond between teacher/student and student/student; cooperative work; mediation for conflict resolution; routine; pedagogical resources; and delimited environment. The ADHD Brazilian Association (“ABDA - Associação Brasileira do Déficit de Atenção”) showcases on its website (tdah.org.br) strategies aimed at assisting: attention and sustained memory; time and information processing; organization and study techniques; inhibition and self-control.

Both strategies proposed by Costa et. al. (2013) and ABDA advise the use of more than one pedagogical resource, so that the child can have the freedom to choose the resource that best suits his or her profile. This can contribute to increasing the interest and motivation for learning, besides strengthening sustained attention. Regarding aid of time and information processing, ABDA also suggests the use of technologies that may aid in learning. Digital games, often associated with devices and more accessible technologies, are increasingly present in the lives of children and young people. These games can be powerful means for the promotion of educational activities, making them appropriate for Digital Game-Based Learning strategies (DGBL).

Digital Game-Based Learning

Digital games assist in building a deeper understanding of scenarios, concepts, processes, and systems, through repetition and experimentation. Recognizing the usefulness of digital games not only for common practices, but also for children with ADHD is of great value as it is the first step to improve accessibility in digital games and DGBL strategies for all children. DGBL introduces or reinforces good practices for using technology and game dynamics in teaching. Most of the DBGL design principles are planned to support the development of new knowledge and promoting skills and attitudes, while taking advantage of digital games characteristics.

Digital Games and their Benefits in Education

In a dynamic and fun way, the digital game can transform the student. Traditionally the student mainly assumes the role of a spectator. However, digital games provide a much more active role in a dynamic and fun way for the student. When playing, students become full participants, with a relevant role in the construction of the knowledge that they acquire along with their peers and teachers. Several advantages are associated with the use of digital games in education. One of the most relevant advantages is the possibility of reducing the stress associated with failure, by being able to modify actions or levels of difficulty in failure cases. As such, players can take more risks and are encouraged to explore and experiment more. This can make digital games become a great learning environment, where learning can be reflexive and critical, benefiting the learning process through trial and error. Several authors in the field of education also support the use of digital games as they can be adaptive educational tools, especially if they enable customization of levels according to the level of knowledge and experience of each student. Some authors add up that digital games can provide increased creativity, planning capacity and strategic thinking.

Digital game development in educational contexts should, however, require some considerations so that it does not become a problem neither for the student nor for the teacher in the classroom environment. The playful component of the act of playing should not be compromised and thus make the game a problem. With this in mind, teacher interference during the game should be limited and the rules of play should be well explained. Most importantly, the student should not be

36 forced to play. Different games and devices should be carefully chosen according to learning objectives. Teachers and the educational institutions should take these aspects into account when using digital games to avoid the risk of making these resources an obstacle to learning.

Types of Digital Games

Most games types and subtypes available on the market have pedagogical characteristics and may be included in the classroom according to the educational context and teacher's objective. Action games can aid in the development of children's psychomotor development by developing reflexes, motor coordination and assisting in the process of rapid thinking. Adventure games, which focus on solving puzzles, collecting and managing items, stimulate students' exploratory abilities by proposing problem solving solutions through experimentation. Simulation games, on the other hand, enable students to experience real situations that would be impossible to perform in the classroom. Strategy games mainly stimulate thinking and the ability to predict and plan actions, providing new knowledge and also allowing the categorization of resources learned during the game. Thus, digital games as a teaching tool can be useful in concrete contexts to achieve specific pedagogical goals, and, in general, will contribute to the child's cognitive development.

Graphical User Interface and User Experience

The didactic features present in the game are not the only ones that can contribute to the player's learning. The Graphical User Interface (GUI) can have a specific role and positively influence the overall user experience (UX) contributing to the way the student learns and develops.

GUI

Summarizing the GUI is what stands between the human and the machine. In a digital game, the GUI is what allows communication between the player and the game. Its main function is to provide feedback and control to the player. The GUI can be a game control or a display device and all elements that the game uses to communicate. It can also be called virtual interface.

The feedback given by the game presents information to the player, such as obstacles, score, lives, duration and progression of the player, becoming the element responsible for the output of information. Based on this information, the player can define his strategies, as well as his short and long-term decisions within the game. The control communicates to the game the actions of the player, being he, the player, the element responsible for inserting the information. It's through feedback and control that the interface unites the player and the game. The GUI can provide a good balance of functionality, usability, accessibility, immersion and aesthetics. When the interface is poorly designed some issues will certainly arise. One of the most common problems is the need for excessive training time for their use, which potentially discourages their usage. When the interface is not clear or coherent it may cause confusion in the players and induce them to error generating dissatisfaction and decreased productivity. In these cases, the game does not reward the student for the expected return on investment in terms of effort and time.

UX

User Experience is the term defined by Donald Norman and Jacob Nielsen to gather all factors and elements that influence the union between the user and the product. The authors count as most important factors all those that will influence the perception and behavior of users. Usability is thus, part of what is evaluated in the scope of UX focusing on information architecture and interaction design. UX aims to study all aspects of the user experience with the system. For the creation and development of digital games, UX becomes a key element by optimizing the player experience. It provides the player with an interactive and meaningful experience by incorporating not only explicit interactivity but also choices and system response as the way to identify the depth and quality of the interaction. Thus, through it, it's possible to create not only a good experience for the game and its mechanics but also satisfaction and fun for the player.

Accessibility in Digital Games

An accessible digital game guarantees as much as possible the inclusion and autonomy of any player. Accessible games have a larger audience or a larger percentage of the gaming market than non-inclusive ones. Accessibility promotes the

establishment of a relationship between a person and an environment or object in a friendly and secure way, in the case of the digital game, it also includes the promotion of satisfaction and enjoyment.

By employing good practices when developing the GUI and UX, it is possible to implement accessibility methods within a game that avoid most or all possible problems. A central factor in the UX study in a game relates to managing the levels of player frustration. If the player is unable to understand or perform any objective in the game he may feel frustrated, which may result in him giving up. Frustration can happen to anyone, not just someone with a disability and/or cognitive impairment. For this reason, accessibility should always be a game designer's concern and not only developed for specific games.

Accessibility is such an important component for digital games, that a group of developers belonging to the *International Game Developers Association* (IGDA), together with the UK non-profit organization *Special Effect* have created a list of 10 features that promote accessibility within digital games. This list was created to reach the widest possible audience, from designers to programmers, applied to any type of game, to be used in any context and for players with any kind of disability. These general characteristics are here listed: allow the definition of alternative controls; enable the choice of alternative sounds; enable volume control independently of music, sound effects and dialogs; show high visibility in graphics; present a design version aimed at color blind; offer various levels of difficulty and/or speed adjustment within levels; have a free mode, training mode and tutorial; display menus in an accessible manner; and present a list of features and accessibility requirements within the game. These features described by this group of experts will work as main reference and are adapted here to a pedagogical context taking into account our specific audience. The reframing of this list will provide a set of guidelines that hopefully are more suitable to the intended audience and will allow creating games that will be more effective and efficient.

Guidelines for the Design and Development of Educational Digital Games

The guidelines for the design and development of educational games for children with ADHD follow the previously presented neuropsychological profile of children with this disability. The following guidelines will not make the game less enjoyable

by other kids or will be less accessible for kids with other disabilities. The same game developed for kids with ADHD can be played by the whole class.

The proposed set of guidelines follow the analysis and adaptation of the already mentioned usability heuristics of Nielsen (1995), the list of accessibility features promoted by IGDA and the organization Special Effect and the teaching strategies proposed by the ABDA.

Below are listed the 11 design guidelines for the creation of educational games for children with ADHD that are described along with the main benefits they convey.

Simple Interactivity

Children with ADHD lose interest and are easily distracted. Limit the type of interactivity through simple mechanics. The child should not be presented with more content than the one that will be transmitted through the game. A simple design option is to remove any controls' setting from the start of the game so that the child can start the game right away. That option should exist but cannot be an obstacle to play. In addition to simple mechanics, it's important for the player to get used to the game and to develop in-game skills through free modes, training and an engaging tutorial. These modes not only facilitate the understanding of the game but can also respect the learning time of each child.

Recurring rewards through positive feedbacks

Because children with ADHD need support and encouragement, it's important for them to be rewarded for each in-game achievement. These rewards appear in the game through positive feedback, either through words of encouragement; graphics that represent achievements, such as stars or a trophy; or by rewards within the game, for example, score, life, ammunition or game items. These elements will be fundamental for the child to understand his evolution in the game, which may increase the satisfaction of playing.

It's also important that the child understands the reason behind the reward, in order to develop a perception of his potential and consequently be able to have the security and motivation to overcome each challenge proposed. Feedback should also be given in case of error, but in a clear, constructive and respectful manner, without letting the error appear to be a performance failure.

Elimination of distracting elements

The elimination of distracting elements facilitates access to information and game action, thus decreasing the probability of distraction. It is therefore suggested to insert in the UI, as well as in the game itself, only elements that are fundamental for the game to flow. A minimalist design approach should be followed providing a clean environment for the elements that are relevant to the learning process. Children with the *Inattentive* subtype are easily distracted. For this reason, it is very important to eliminate or reduce the amount of unnecessary information, which allows the child to stay focused on the game for longer periods of time. Elements of distraction can range from options that are poorly accessed or irrelevant in the definition, to elements of the heads-up display, secondary characters or a songs and even sound effects.

Emphasis on Relevant Elements

Features such as intensity, contrast, size, color, repetition, movement or sound can be great features to emphasize important information and direct the player's gaze to the necessary information at a given time, thus facilitating the player's understanding.

Flexibility of Levels

One way to reach a larger audience is to offer various levels of difficulty. This flexibility allows for various levels of experience, where, gradually, speed and difficulty are adjusted.

The motivation to keep playing can be found at each level surpassed, where the student can perceive his progress within the game. Therefore, in case of error, not ending the game may be a good practice, since it may prevent the generation of feelings of failure, which may lead to withdrawal from the game and, consequently, from learning. For this reason, in cases such as the previous one, providing clues that contribute to the accomplishment of the task or decrease of the difficulty of the game itself, may motivate the child to continue playing the game. However, easy games can also be detrimental to maintaining the player's attention, so it's important that each level presents challenging goals that can be overcome without frustration.

Short-Term Levels

Games with longer levels and complex goals are not indicated for children with ADHD, as they may lose interest and give up playing in the middle of the game. This issue can occur mainly with children of the *Predominant Hyperactive* subtype, who need to perform some motor activity at short intervals of time, besides having difficulty to sustain attention over a long periods of time.

One way for the hyperactive child to be able to perform motor activities between levels is to create short levels with clear and simple goals. Thus, the probability of the child playing the whole level will increase, which consequently will increase the chances of the child seeing and retaining all the didactic content transmitted by the game. However, each level must present some newness to arouse the child's curiosity and keep him in the game. A new scenario, a different character, or a new item for the inventory collection are artifacts that can be used to generate novelty within the game.

Multiplayer option

The development of children with ADHD is better when they are in a group, since they find motivation in other people. Allowing a child to play with other children through a multiplayer version means motivating and retaining the child in the game.

Unlimited play time

Frustration can occur when there is a time limit in the game. Regardless of the ADHD subtype the child possesses, he will learn in his own time. Those of the *Predominant Inattentive* subtype suffer from changes in the speed of information processing, while those of the *Predominant Hyperactive-Impulsive* subtype have difficulty sustaining attention overtime, however, they are still able to complete tasks, but require more time. For this reason, giving the child the freedom to fulfill the goals of the game according to their learning time is important. The levels can even be timed, but, they can't finish after a certain time. The completion of the game or level can only happen after the goal has been achieved or the game is abandoned by the child. For the child not to give up the game, it must be possible to save the game, in order to continue at different time.

Confirmation of the game's actions

Whether through impulsivity or inattention it's common for non-wanted actions to be taken within the game by children with ADHD. To decrease children's probability of error in a game, it's important to use action confirmation messages mainly for actions that are considered definitive and that may affect the outcome of the game.

Coherence of Graphics Standards

The creation of graphic patterns within the game facilitates the identification and understanding of the information transmitted by the game. To accelerate the child's understanding and influence the way he perceives, recognizes, interprets and reacts to an image, it's necessary to organize and structure the visual information of the game, which will contribute to intuitive learning of the functionality of each graphical element. Thus, allowing him to just play and learn the didactic content of the game. This organization and graphical structuring can be done in two ways: through the discrimination of primitive figures and/or the visual grouping of information into significant units. Examples of primitive figures are the use of color, movement, size, and orientation. They have features that highlight a visual element in an image during a search and so are noticed very quickly, even unconsciously. Visual grouping organizes sensory information by groups or units of perception. Thus, it co-relates elements of an image and the relation of an element to the image as a whole.

Definition of an Exciting Graphical Story

Competitive activities are inhibited when voluntary attention occurs. This is related to the motivations, interests, and expectations of an individual, being responsible for selecting and controlling the focus of attention. If the game doesn't arouse interest in the child, it will not be able to get their attention and they will distract themselves with other activities, which may jeopardize their learning process.

The use of graphical compositions that appeal to the emotional involvement of the player is a good method to retain attention in the game. These compositions can engage, stimulate interest and motivate the player to stay in the game. It is also possible to use strategies for creating game graphics with emotional appeals. Three possible strategies are:

- Presenting a thematic narrative: the player can identify with the dramatic and emotional aspect of the game narrative by going through similar experiences in his own life or by an experience he would like to go through.
- Using visual metaphors: these trigger non-verbal emotions, stimulate imagination and captivate the interest of the player.
- Incorporating novelty and/or humor: innovate either with humor or with diverse graphical aspects. These provoke curiosity and hold the player's attention for a longer time.

Children with ADHD have very striking characteristics such as creativity, spontaneity, joy, good humor, and have a more artistic side. Exploring these features for game creation is also a factor that will help make the game more engaging and fun.

Conclusions

The role of the educational game designer is to create and develop games that aid the teaching-learning process for as many children as possible. For the development of this type of game, it's necessary to know the elements and the strategies that can favor positively the transmission of the pedagogical content, while also focusing on the general characteristics of its target audience.

In this work, eleven guidelines were defined in order to provide the most appropriate design options for a young audience that in a determined learning context can have more than 20% of children with ADHD. For the game designer, these guidelines contribute to a clearer and more concise understanding of the elements that provide better learning conditions. It's worth mentioning that those who will benefit most from the use of these guidelines will be all children in school stage. Although there is a direct benefit for children with a learning problem, all children will be favored indirectly. The creation of equal opportunities will ideally provide a means of not leaving any children behind and including everyone in enriching the educational and recreational experience as a whole.

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