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DESIGNING VIDEO GAMES TO ENHANCE CREATIVITY

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Designing Video Games to Enhance Creativity

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For Kuri.

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“The most creative people are motivated by the grandest of problems that are presented before them.” (Neil deGrasse Tyson).

ABSTRACT

Creative idea generation ability is considered as one of the most vital skills and abilities in 21st century's work force, businesses, and societies. To boost and control this ability, researchers proposed different solutions. Some advanced research suggests that video games have the potential to boost creativity in individuals but still there is scientific gap regarding the main digital features in video games that could boost creativity. In this regard, present research work aimed to investigate, identify and determine the most important digital factors in video games that have positive impact on Creative Fluency Level (capacity to generate many creative ideas) of individuals. Design science research methodology has been utilized to achieve the research goals and answer the research questions. "*Presence of Cool Colours*", "*Presence of Physical Display of Clues*", "*Presence of Background Noise*", and "*Presence of an Abstract Experience*" were the features being assessed. They were implemented in different levels of a video game, developed by authors. A video game has been developed in Unity Engine, using the C# programming language, and using a pixel art base style. To evaluate the creative fluency level of the participances, the research participants have been asked to provide as many creative words as possible with a set of letters in each level. To analyse the data, the mean and variance were calculated in each level, and the results were compared with a control level that had no features influencing it. The result suggest that all evaluated digital features have a favourable impact on the results, but "*Presence of Background Noise*" and "*Presence of Cool Colours*", have the biggest impact on creative fluency level of participant, by a significant increase in the mean value and low dispersion in the value.

Keywords: Video Game, Creativity, Design Science Research Methodology, Pixel Art, Unity, C#.

RESUMO

A capacidade de construir ideias criativas é considerada como uma das principais ferramentas, não só no meio empresarial, como em negócios e até na sociedade atual. Para incentivar esta capacidade, investigadores identificaram numeras soluções. Certas pesquisas sugerem que os vídeo jogos têm potencial de aumentar a criatividade nos indivíduos, porém, é uma área com muita falta de trabalho de pesquisa, principalmente quando se trata de definir funcionalidades ou variáveis dentro desses jogos que possam incitar a criatividade. Dito isto, este trabalho de pesquisa pretende identificar, explorar e comprovar que fatores podem ser aplicados nos vídeo jogos que possam contribuir para um melhor desempenho da fluência (capacidade de gerar ideias criativas). Foi usado um processo metodológico chamado Design Science Research Methodology para organizar e estruturar o método de reunir e tratar a informação e os resultados. Os fatores que foram definidos para serem explorados foram "Presença de cores frias", "Presença de uma demonstração de uma pista", "Presença de barulho de fundo" e "Presença de experiência abstrata". Estes fatores foram implementados em níveis diferenciados dentro do vídeo jogo. O jogo foi feito utilizando o motor de jogo Unity, que utiliza a linguagem de C#, e o estilo de arte "Pixel art". Para avaliar a fluência dos participantes, em cada um dos níveis são apresentadas um conjunto de letras ao jogador, e este tem de construir o máximo número de palavras possíveis num curto espaço de tempo. Para analisar os dados foram utilizados processos matemáticos como a média e a variância em cada nível e os resultados foram comparados com um nível "controlo", onde não havia fatores a influenciar. Os resultados mostrar que todos os fatores têm influência positiva, reforçando a "Presença de barulho de fundo" e a "Presença de cores frias" como fatores muito positivos para a fluência dos jogadores, mostrando altos valores na média e uma baixa dispersão na variância.

Palavras chave: Criatividade, Videojogos, Design Science Research Methodology, Pixel Art, Unity, C#.

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INTRODUCTION

1.1 Introduction

In the modern era, creativity in the workplace is one of the pillars of evolution and market growth. Many companies are opting for more creative solutions. However, the tools to incite this creative behaviour are limited and don't fulfil the objectives. This document presents the research problem, research state-of-the art, research novelty, research goal and objectives. Explains the technical and specialized terms and definitions, also the research methodology. Then explores the development process, the techniques and tools used as well as the evaluations methods. For last makes a review about the data resulting from the evaluation.

1.2 Research Motivation and Problem

By increasing complexity of modern problems, traditional solutions are not any more considered as efficient and appropriate which motivate modern individuals, firms, and societies to give more attention to the novel and innovative solutions [1], resulting in a 500 million US\$ increase of the Worldwide R&D expenditures since 1996, according to the Global Innovation Index of 2019[2]. Due to this, currently, creativity and creative idea generation ability are considered as one of the key skills in the modern individuals' professional, social, and private life [3]. According to the World Economic Forum, creativity is considered one of the most valuable skills in 2020, seeing a growth since 2015, as it was classified in 10th place [4]. In this regard, developing methods and tools that could boost creativity is increasingly crucial and, considering the technological development in the last century, an achievable target. The internet statistics of 2020 showed that, in December 2020, were registered around five thousand million internet users, making a total of 64.7% of the world population[5]. Developing computational creativity is one of the most famous efforts in this path[6]. Also, by developing digital technologies, and their influence in various aspects of human life, the hidden opportunities such as utilizing entertainment tools and methods to develop different skills are rapidly raising [7]. Video games as an entertainment digital tool is one of these opportunities [8]. According to the Entertainment Software Association (ESA), 80% of video game players think games

provide mental stimulation, 63% say video games helps solving problems, 79% say it provides the player relaxation and stress relief and 57% say games bring joy while playing [9]. While a lot of researchers have talked about the positive impact of implementing video game to enhance individual and group creativity, there are also researches that found negative or neutral impact of video games on creativity [10]. This matter highlights a gap in the creativity and video games literature that is: what type of games with which features could boost creativity. In this regard, present research aims to discover, determine, and implement digital features to video games to that can boost creative idea generation of users.

Having done research trying to find a relation between video games and creativity, there are numerous works exploring the impact that video games have on people's mental abilities, one of those creativity. However, by researching more specifically towards finding actual features which will boost creative idea generation, the number of studies decreases significantly, to the point where there are no objective evaluations of the impact of visible, audible, and even subconscious aspects in video games. Filling this gap of research can prove to be very useful and important when developing video games and even in other areas of technology, because it will positively improve the technological tool into incite a more creative answer by the user.

1.3 Importance of Research

Creativity is present in every area of studies, especially organizations [11]. With every innovation, the creation process must be present and start with creative idea generation, and the result must create something new to the organization. In the area of technology, studies demonstrated that creativity is a phenomenon that can be fostered through various technological applications and tools, some examples include blogs, cartoons, digital brainstorming sessions, digital storytelling [23], creativity support systems [13] and, the most important to this research, video games [14]. Studies show that video games have a significant impact and relation with creativity as it is present in the design of the game, in the development, and then in the impact that the game can have on the players. This impact, however, cannot always be positive. As some studies verify, video games can have a malevolent impact on someone's creativity [10] and sometimes incite violence or violent behaviours [15]. So, to make a separation between what elements in a game can have a positive impact or a negative impact on the player who is playing them, this research explores features that will be applied to a game and test their impact on someone's creativity. Once this research is complete and the elements proved, many new games, projects or applications can be created to foster people's creativity.

1.4 Novelty

The main novelty of this research lies in identifying digital features or drivers in video games that can boost end-user creative idea generation fluency. To test these features, a video game was designed based on the features extracted from the literature review to determine if they improve the creative idea generation fluency of players. Technology and video games have a significant presence in modern society, making them a fantastic tool for inciting creativity and testing which elements can increase creative behaviour. Since video games are primarily used for leisure, using them to test creativity is a unique and experimental approach that opens up new possibilities for exploring how video games can be utilized in various areas.

Various researchers have explored creativity, with some even studying creativity in the context of video games. However, few have investigated which game features provide creative feedback to the player. This study aims to select a group of features and validate their impact on creativity. Given the limited research in this area, this approach will provide numerous applications in the game design industry, allowing developers to determine if certain features have a creative result. This study draws on findings from various fields, including psychology, neuroscience, social sciences, computer engineering, information, and communication technology (ICT) engineering and management, and game design and development, to identify the features needed to test their creative potential through the redesign of a video game. Areas such as psychology, neuroscience, and social sciences provide a better understanding of how humans develop creative idea generation and how environmental and personal factors can influence their ability to generate creative ideas. More technical areas such as computer and ICT engineering and management, digital game design and development, help to understand how to apply external aspects to a digital program and the potential consequences of using digital tools on the user. With these features identified, the development process involves understanding how to digitally incorporate them and determining whether it is possible to program them in a digital way and relate them to the game. After planning, the practical process of designing the game follows, followed by the testing phase.

1.5 Goals and Objectives

Idealistic Goal

The idealistic goal of this study is conducting research that can be used to improve the creativity level of individuals in their professional, public, and private life.

The Main Goal

The main goal of the current study is to determine and implement video games digital features to stimulate the creativity fluency level (capacity to generate many creative ideas) of the users.

The Objectives

The objectives of this research are:

1. Identifying research related to creativity and skill boosting through video games.
2. Determining the video games digital features which stimulate player's creativity.
3. Defining the importance of the video games digital features which stimulate individual's creativity.
4. Implementing the video games digital features which stimulate individual's creativity, in a video game.
5. Evaluating and validating the developed video game and its impact on the creativity fluency level of users.

1.6 Research Questions

The questions in this research are:

"Can video games increase of players playing?"

"What features in the video games can have a positive impact on the creativity?"

"How can such features be implemented in the video game?"

1.7 Research Hypotheses

In this research, since some features are going to be evaluated, a group of hypotheses is created to structure and to prove in chapter 5 if the hypothesis was verified. With the different elements a list is constructed:

- H1.** There is a significant relation between the "Presence of Cool Colours" in the video game environment and video game player's fluency in creating novel and meaningful words (fluency in creative idea generation).
- H2.** There is a significant relation between the "Presence of Physical Display of Clues" in the video game environment and video game player's the fluency in creating novel and meaningful words (fluency in creative idea generation).

- H3.** There is a significant relation between the "Presence of Background Noise" (45 to 70 dB) in the video game environment and video game player's the fluency in creating novel and meaningful words (fluency in creative idea generation).
- H4.** There is a significant relation between the "Presence of an Abstract Experience" in the video game environment and video game player's the fluency in creating novel and meaningful words (fluency in creative idea generation).
- H5.** There is a significant relation between existence of a combination of creative idea generation's digital features in the video game environment and video game player's the fluency in creating novel and meaningful words (fluency in creative Idea generation).

1.8 Chapter's Summary

The process of developing this research work is reported in the six chapters. The first chapter introduces research context and the motivation of the work in addition to presenting research problem, expected goals and hypotheses, innovation of the work and the roadmap to achieve the goals. The second chapter investigates research concepts and related terms via the literature review and study state-of-the-art. The third chapter illustrates the methodology used (Design Science Research Methodology) and the method of data collection, data analysis, game design and development, as well as validation methods. The fourth chapter reports how the video game is conceptualized and executed and how the elements are presented throughout the course of the video game. The fifth chapter interprets the results collected and finds relations between the impact analysed in chapter 2 and the actual impact retrieved while playing the game. In the end, the sixth chapter concludes the research work and reports on what more could be done in this theme and in future themes related to this. A representation of the progress of this work is present below in the Figure 1.

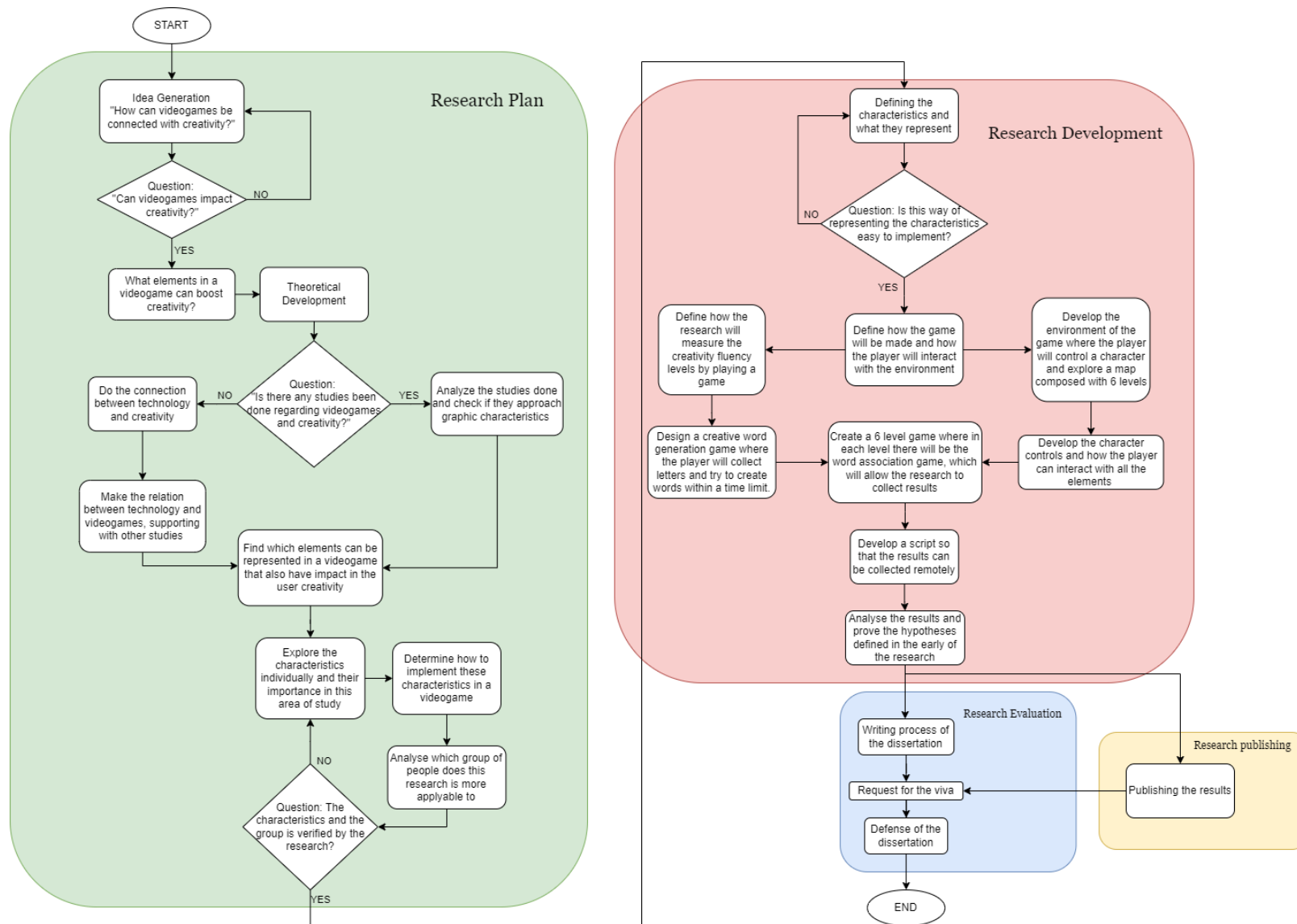


Figure 1.1: Representation of the progress made in this research.

STATE-OF-THE-ART AND CONCEPTS

2.1 Introduction

Creating innovative solutions in the modern world is crucial to thrive inside any area. New ideas in the market are created every day, therefore, to come up with an idea that is considered the best idea regarding a problem requires creativity. This concept of what's creative is relative and many studies have been made in this matter, studies that are now used to support research. Some main concepts are common when talking about creative ideas, the premise that something creative is something new that shows originality [16], that solves a certain problem in a different and more efficient way [17]. This behaviour can be motivated and fostered by actions or tools. Studies have shown that kids exposed to complex problems and puzzling experiences can increase their idea generation and, as a result, creative ideas [18].

Technology has evolved in the modern world and has spread to every area. Using technology can really help to apply creative factors in objects, applications, tools and more. Another application inside the technology that can not only show creative development processes but also motivate the creativity of their user are video games. Video games are already used to leisure and to educational uses. The goal of this chapter is to find a relation between creativity and video games and how by playing video games the players can increase their creativity.

This chapter will explore certain concepts important to this research and specify them, first related to the creativity area and then more focused on the video game subject. Then it will be made a literature review of the works already made in this area.

2.2 Research Theoretical Background

Creativity

Creativity is a wide concept. Researchers and philosophers have talked and made theories about it, which made the concept without a solid and converged definition. As of a conceptual

view of the subject, involves the capacity to generate novel, unexpected, and valuable concepts, either to solve a problem, fix an issue or get advantage from an opportunity [16].

The 1950's, was a decade that psychologists have started to investigate and explore this concept and tried to provide a concrete definition for it, as well as introducing various applications in different areas. Between many examples, some words start getting systematic, words like "Novel", "New", "Innovative", "Unique", keep appearing in studies and start to create a more closed definition on what is creativity [19]. Chambers (1973) defined creativity as "a multidimensional process of interaction between the organism and its environment that results in the emergence of new and unique products". Drevdahl (1956) [20] related creativity to the capacity of a person to create and produce ideas or compositions, those who could be considered new and novel. According to Wilson, Guilford, and Christensen (1974) [21], they concluded that the creative process is any method through which something novel is generated, as an original idea or arrangement of old elements to produce something new and, of course, efficient to solve a certain problem.

Margaret Boden, a very well-known computer scientist who did significant and impactful studies on creativity, in 1995 [17] suggested that creativity could have over sixty definitions in psychological literature. To simplify this, she defined two definitions of creativity, Improbabilist Creativity, which regards new and more unlikely (on improbable) ideas, and Impossibilist Creativity, which is more related to novel ideas that, when applicable to old versions of the problem would not be possible. She later completed the research and defined that creativity can be divided in three ways, the first being an unfamiliar combination of familiar ideas, adding as an example an analogy or even textile art. The other two ways are very close to each other, being one an exploratory approach, where it's created by exploring the environment and the last the transformational approach, where the creative outcome comes from transforming one or more elements of the ambient, giving a new branch of options that weren't available previously. The more changes made in the dimension, the more surprising the ideas may be [22].

The researcher Teresa Amabile (1996) [23] defined creativity as the creation of unique and appropriate ideas by individuals or sets of individuals. She also affirmed that elements in a work environment can have a certain impact on creativity in organizations, which can mean that creativity is not only influenced by the person herself but also by the people who work in that same environment, and by the environment itself, that can have factors that can influence creativity.

Some researchers highlighted the importance of creativity in different sectors and its impact on the future of that sector. For example:

Mumford, Hester, and Robledo (2012) [11], in their article entitled "Creativity in organization: Importance and Approach" highlighted the significance of creativity and

innovation in fostering the advancement and effectiveness of organizations. In this research work, they introduced three approaches to capitalize on creativity and innovation organizations:

Firstly, it's essential to acknowledge that creativity and innovation are intricate concepts that exhibit complexity regardless of the specific level of examination. Secondly, various factors come into play at the individual, group, and organizational levels. Lastly, it's important to note that the mechanisms operating at one level may not necessarily align or harmonize with those at other levels.

Sarri, Bakouros, and Petridou (2010) [24], in their research entitled "Entrepreneur training for creativity and innovation" delved into the significance of entrepreneurial training in the context of fostering creativity and innovation. The findings of their research indicated that the optimal training approach is still in its early stages of development, and additional research is warranted to identify the precise training intervention that suits the diverse needs within the entrepreneurial landscape.

Hollanders and van Cruysen (2009) [25], in their research entitled "Design, Creativity and Innovation: A Scoreboard Approach", discussed the quantification of a country's performance in creativity and design. They used proxy indicators to create composite indicators for this purpose. Their research findings revealed robust connections between creativity, design, and innovation. They observed that countries fostering a conducive environment for creativity tend to exhibit higher levels of Research and Development (R&D) activities, engage in design-related activities, and achieve strong overall innovation performance.

In a paper entitled "Promoting Creativity and Innovation in Engineering Education", Cropley (2015) [26] the author raised a fundamental question: "Why is creativity important to engineering and engineering education?" In the course of this paper, the researcher illuminated the challenges that have perpetuated the gap between creativity and engineering education. Furthermore, the paper proposed principles and strategies to address this pressing issue, including the redefinition of problems, the questioning and analysis of assumptions, and the promotion of idea generation, among other approaches.

In the matter of creativity within technology and video games, more specifically, is the ability to come up with the modern and appropriate solution to an issue, using the technological tools provided to solve that issue.

Innovation

Innovation is a term considered essential when discussing subjects as wide-ranging as organizations, companies, projects, and development groups. An innovative idea is coveted by the audience, whether it is a new product, a new use for a product, or even an adaptation of an

existing product. Scholars Henderson and Lentz [27] have declared that innovation comes when new ideas are implemented, and scholars Gulati and Nohria [28] have gone more in depth, affirming that innovative achievement is directly related to an issue, a process, a policy, a product, or even a market that the manager of the innovation area considers new. The success of innovation depends on various factors, such as the creativity and skills of the team involved in the innovation process, the resources available to them, and the external factors affecting the innovation, such as the market demand [29].

Innovation manifests in various forms, with incremental innovation consisting of making small-scale improvements to existing products or processes, and radical innovation, characterized by introducing entirely new products or processes that disrupt the market [30]. Organizations require both types of innovation to remain competitive. Incremental innovation improves efficiency and reduces costs, while radical innovation creates novel markets and business opportunities [31].

In the realm of video games, innovation can manifest in a multitude of ways, from the incorporation of fresh gameplay mechanics to the introduction of cutting-edge technologies and even the creation of entirely new genres. The impact of innovation in the video game industry cannot be overstated, as it enables companies to not only attract and retain players, but also generate new sources of revenue and drive technological progress [32].

In this study, innovation is essential in identifying the digital features or drivers in video games that can boost creative idea generation fluency. By redesigning a video game based on these features, this study aims to test their impact on creativity and contribute to innovation in the game design industry.

Fluency in Creative Idea Generation

According to psychologist JP Guilford [33], there are four levels of creative idea generation: fluency, flexibility, originality, and elaboration.

- Fluency refers to the number of ideas generated. This is often measured by the total number of ideas produced in each period of time.
- Flexibility refers to the variety of ideas generated. This is often measured by the number of categories or types of ideas generated.
- Originality refers to the uniqueness of the ideas generated. This is often measured by the novelty or rarity of the ideas produced.
- Elaboration refers to the level of detail and complexity of the ideas generated. This is often measured by the amount of information or level of complexity of the ideas produced.

Fluency is widely regarded as a fundamental element of creative thinking, serving as a cornerstone from which more intricate and novel ideas can sprout. This attribute is pivotal in the realm of creativity because it grants individuals the capacity to traverse a broad spectrum of potential solutions when faced with a problem [34]. Research has demonstrated that fluency can be enhanced through diverse methodologies, including techniques like brainstorming, mind mapping, and free association [35].

Thomas B. Ward's article implies that there exists a favourable correlation between fluency and creativity. In simpler terms, individuals who can produce a substantial quantity of ideas are more inclined to come up with fresh and inventive solutions when confronted with problems[34].

Fluency is often considered to be a necessary but not sufficient condition for creativity [36]. While fluency can provide a foundation for more creative thinking, it is not enough on its own to produce truly novel and innovative ideas. Rather, creativity involves a combination of fluency, flexibility, originality, and elaboration, as well as other factors such as expertise and motivation [35], [37].

Types of Creativity

Between the many areas where creativity is present, there are some studies that divide this term into subtypes. A common division is between individual, group, organization creativity. Where individual explores more task-solving problems, domain-relevant skills [38], group involves more team related activities like brainstorming [39], and organizational, where environmental factors are considered and the creative idea satisfies an organization goal, not just an objective goal [40].

In their article titled "A Cross-Level Perspective on Employee Creativity," Hirst, Knippenberg, and Zhou (2009) [41] delved into the realm of individual creativity. They developed and assessed a cross-level model of individual creativity, which incorporated aspects of goal orientation theory and team learning research. This model enabled them to draw the conclusion that engaging in team learning behaviours had a positive impact on individuals' creative abilities, essentially helping individuals bring forth their highest creative potential.

In a different study, Taggar (2002) [38] discussed the topic of "Individual Creativity and Group Ability to Utilize Individual Creative Resources: A Multilevel Model." This research highlighted key components of individual creativity, including task motivation, domain-specific skills, and creativity-related processes. Taggar also explored group creativity, introducing the concept of "team creativity-relevant processes." These included inspirational motivation, which involves motivating group members to elevate their goals; organization and coordination, which entails providing feedback and coordinating contributions; and

individualized consideration, which involves eliciting and appreciating diverse ideas, needs, and viewpoints within the group.

In their 2015 research titled "Effects of Cultural Power Distance on Group Creativity and Individual Group Member Creativity," [39] Yuan and Zhou examined how power distance influences group creativity. Their study introduced a model that addressed the significance of power distance in high-power-distance cultures by:

- Developing specific group-level mechanisms to explain why cultural power distance matters when studying group creativity across different cultural settings.
- Pinpointing leadership behaviours and work strategies that prove especially effective in nurturing group creativity within cultures characterized by high power distance.
- Introducing cross-level mechanisms that elucidate how a hierarchical group's social environment shapes the creativity of individual group members in similar cultural contexts.
- Uncovering variations in how individuals respond to the influence of cultural power distance while collaborating in group settings.

This research contributed valuable insights into the impact of cultural factors, specifically power distance, on both group and individual creativity in various cultural settings.

Amabile et al. (1996) [23] conducted a study called "Assessing the Work Environment for Creativity." They used a tool called KEYS to measure how people perceive various aspects of the work environment that are important for creativity in organizations. From their research, they identified five key factors in the work environment that can influence creative behaviour in organizations: challenge, support from the organization, support from colleagues, encouragement from supervisors, and obstacles within the organization.

In a study by Arne Dietrich (2019) [42], he introduced three different ways to look at creativity: deliberate, spontaneous, and flow modes. The deliberate mode is used as an examination process, where the result is inferred by the observation and guessing, as iterations of trial and error. The spontaneous mode, as the mode says it, revolves around the spontaneous, where the creative result just appears suddenly in the mind, not having any factor influencing them. The flow mode is where the mind starts getting creative ideas by being in an extreme state of concentration at certain task and ignoring consciousness at every aspect.

Personal and Environmental Factors which Influence Creativity

When talking about a person's creativity towards a problem, many factors can influence the person's judgement when trying to find a solution or come up with a creative idea. These factors can be intrinsic to the individual, being personal factors like "motivation", "attitude", or

can be influenced by the environment around the person, being more general factors like "time and space", "atmosphere", "society", etc.

A study was made on Hong Kong, Chan et al. (2015) [43], regarding "Personal and environmental factors affecting teachers' creativity-fostering practices". This study proved that personally, having a more creative and available teacher, giving their students a grand range of opportunities, showing a positive relationship between the teacher's personality and the teaching techniques are all proven to captivate the creative minds of the students. In terms of the effect of the environment in the students, one aspect that mattered a lot was the school policy, as the teachers felt restricted by resources, administrative procedures, and time control.

Researchers S. M. Parmerter & J. D. Garber [44] did a study on over one hundred scientists, so that they could identify which environmental factors had more influence on creativity. From a list the majority selected that "Recognition and Appreciation", "Freedom to Work on Areas of Greatest Interest", "Broad Contacts with Stimulating Colleagues" and "Encouragement to Take Risks" were the factors that had more impact on a person's creativity.

Amabile's study in 1988, "A Model of Creativity and Innovation in Organizations" [45], concluded that both personal and environmental factors can have impact on a person's creativity. In the personal level, elements like "self-motivation", "personality traits" and "area expertise" can be positive to promote creativity. Regarding the environment, the elements that matter the most are "freedom", "good project management" and "sufficient resources". With this information, she concluded that to incite creativity in an individual, three aspects have to be present, she even designed a graphic to explain this, present in the Figure 2. This representation shows the main factors that could influence a person on having a creative idea. Having resources available, knowing the techniques, and finding the right motivation are the aspects that, according to the group of innovators present in this research.

After all these studies made around the factors that could foster, be harmful or just influence creativity, it's time to talk about tools that could help apply these factors. Numerous exercises, physical tools and projects are already existent when comes to creativity development. One tool also very actual and present in studies about creativity is technology. Technology is such an important subject in the last century that every area is constantly connected with it and exploring how technology can be applied to projects, products, applications, and such.

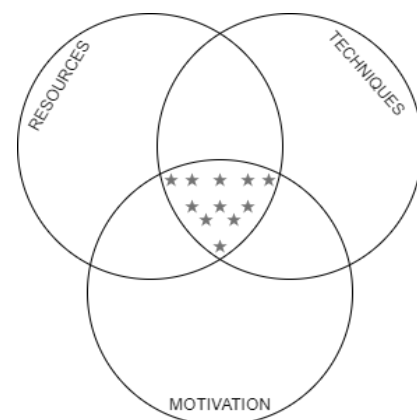


Figure 2.1: Three main factors to provide a creative solution.

Technology Impact on Creativity

Within the area of technology, there have been some studies made, regarding psychological effects and emotions and how can technology impacts all of that. Creativity is not an exception, as multiple studies have been made on creativity in technology. Here are some examples:

In their 2010 article titled "The Influence of Technology on Creative Design: A Boost or a Hindrance?" [46] Bonnardel and Zenasni examined whether the adoption of new Computer-Aided Design (CAD) technologies significantly aids designers in their work and enhances their creative capabilities. The findings indicated that recent technologies, particularly new CAD systems, can empower designers to effortlessly articulate their creative ideas and evaluate their concepts or solutions. Furthermore, the research illustrated that employing a critique system aided experienced designers in appraising their own solutions. Consequently, these technologies hold the promise of contributing to both the divergent and convergent processes that are essential to creativity.

In his 2014 work titled "The Technology Paradox: Efficiency Versus Creativity," [47] Edwards emphasizes the influence of technology on people's capacity for creativity in society. The author argues that the following steps must be taken to allow creativity and technology to be related:

- Society should acknowledge the importance of creativity in the growth of individuals.
- The substantial progress made through technology, such as improved access to information, open-mindedness to ideas, and enhanced interaction with others, should not be diminished due to inadequate progress in the relation between human and computer.
- Programs should be made to consider the factors known that enhance creativity.

Subbotsky (2010) conducted an experiment named "The Impossible as Stimulator of Creativity in Children" [48], where he tested if the presence of fictional characters such as talking animals, humans that can fly, magic, etc. in tv-series and movies guided the children to manifest more creative thinking. This study was made to a group of 4–6-year-olds, using the Torrance's "Thinking Creatively in Action and Movement", or TCAM, test to measure children's capacity to show creativity, and the results showed that the kids were very responsive to creativity in realistic thinking and, even though they were exposed to a fantastical world, it didn't affect their magical beliefs.

Mishra (2012) in research entitled "Rethinking Technology & Creativity in the 21st Century: Crayons are the Future" [49] explores the uses of technology to help in education, specifically helping students comprehend mathematics. In this research, the example utilized was the Kinect, created for the Xbox 360 video game console or Windows computers it is an input

device to capture movement. By employing this technology, fifth-grade students in a classroom were able to grasp concepts like the rate of change (ROC) without receiving any prior instruction on the topic.

In their article titled "Impact of Computers on Children's Creativity," Stoši et al. (2014) [50] conducted a study to examine the influence of computers and factors like gender on children's creativity. The findings revealed that when computers are used appropriately, with programs tailored to the children's age, they can enhance children's exploration of new experiences, promote intellectual growth, and consequently foster the development of their creativity.

The experiment of Ganguin and Hoblitz (2012) named "Mobile Media – Mobile Creativity?" [51] explore what function is most used by mobile users to test the creative applications of it. The results showed that communication is the main online function used. With the help of communication applications, such as *Facebook* or *Whatsapp*, it's easier to connect with people and this message exchange grants a link to creative language use. Another mobile function capable of showing creative results is the capture of pictures and videos. This function is also commonly used because mobile cameras are a great alternative to digital cameras, it's already connected to the phone, quality isn't an issue if the goal is a simple capture, and the growth of applications that incite users to share pictures makes people have a use to their captures. The ability to capture a moment can be a very creative demonstration of the real world, and this mobile device allows that manifestation.

Yet another function in mobile devices very important and very famous is the mobile games. According to Omori and Felinto (2012), in their article "Analysis of motivational elements of social games: A puzzle match 3-games study case" [52] indicate that mobile games, when compared to other digital games, are easier to play, don't consume much time, incite social interaction and have the focus on the entertainment.

The research of Fung (2017) entitled "The Impact of the Rise of Mobile Games on the Creativity and Structure of the Games Industry in China" [53] explores the fact these games are played in a small mobile device. The game developers, when have the goal of boost or foster creativity, often come up with easy game operation and give the user more freedom in character development, story background and reward system.

To add to these technologies, a very modern tool used all over the world are video games, not just as a leisure propose but also as a tool to give support to many areas, like architecture, education, and health. Video games and creativity can be easily associated with each other, as creativity is directly related to the invention of something new, efficient and that solves a problem, which are the points of creation of a video game.

Video Games

Video Games Definition

Video games are entertainment tools that serve to give the user a good digital experience [54]. Although, they are not as simple and as uniform as one might think, as their unique features result in different impacts and different experiences to a player when he's playing.

The evolution of video games from their initial form to their present state is quite remarkable. At the very outset of video games, one name stands out: William A. Higinbotham, a physicist who had been involved in developing electronic components for the first atomic bomb. Higinbotham recognized that the groundbreaking innovations his facility was developing, though world-changing in potential, might not be engaging or captivating to visitors. To capture the attention of the audience, he ingeniously created a simple tennis simulator called "Tennis for Two." This pioneering game utilized analogue computer technology initially designed for tracking missiles and was displayed on an oscilloscope. This marked the inception of the first documented video game in history [55].

After that, video games grew into a market. Arcades appeared with an adaptation of the digital game *Spacewar!: Galaxy Game*, in 1971 [56]. Arcades became very popular around that time and a specific game named *Pong* made that happen as it became a huge success in a local watering hole in California [56]. Arcades gained a competitor in sales when the consoles started to appear. Consoles like *Magnavox Odyssey* and *Atari Video Computer System* featured sports and shooting games and even some simulations such as roulette [57].

In this period, the industry of video games was starting to crash, as not many people were interested in the games, until the new company *Nintendo* launched ground-breaking games, *Super Mario Brothers game* being one of them [57]. These games and adaptations of arcade games made home consoles and computers very popular not only for video game players but also for developers, as they started to create more software and hardware focused on the home video games [58].

To address the diverse characteristics of video games, valuable research efforts have been undertaken to establish a concept of genres. This serves to provide a basic framework for the varied field [59]. First-person shooter, strategy, action, role-playing, adventure, and sandbox are among the most common labels used to categorize video games, helping players understand the style of gameplay they can expect when choosing a game [60].

Although video games may address the same purpose as in interacting with a virtual machine to exchange data information, there is a difference inside this communication. Games are divided into categories, depending on what the subject of the game is. It can be a game representing something real, like a sport (FIFA games, a video game representation of football), can be a fictional environment (Counter-Strike, which is a shooting game in a simulated

environment), even a video game representation of an existing game (Chess or Solitaire). Some of the genres or categories of video games are presented below.

Video Games Genres

RPG (Role-Playing Games)

Role-playing games follow a relatively straightforward concept: the player assumes the role of a character and progresses to make that character stronger, smarter, or better. This gaming genre has strong connections to the literary fantasy genre, with a classic example being the role-playing game Dungeons and Dragons played using paper and pencil. In this type of game, usually, there is a world with freedom in the character development. This tool allows the user to personalize the character in a unique way, exploring their imagination and their creativity. This genre has grown into numerous sub-genres so there's no specific game that can represent the genre by itself [61].

A game that can represent a sub-genre called MMORPG (massively multiplayer online role-playing game) is the game known as World of Warcraft. This is a game genre where an extensive number of players engage with each other within a virtual gaming environment [62]. World of Warcraft is currently the game with the largest database of players with more than 10 million subscribers. In this game, players create a character and enhance it by selecting professions and embarking on quests. Their character explores an expansive kingdom, engaging in battles with creatures in a cooperative and sociable atmosphere. Players have the freedom to choose their preferred style of play. Having this versatility, the players can demonstrate signs of creativity when developing the character and in the gameplay.

Sandbox

The idea of Sandbox game consists in an open world type of game, where the user can explore and interact with the environment. In this genre, goals are more optional and, usually, there are tasks to complete, guiding the player throughout the game. This causes a more immersive experience in the player, has the game can leave many options open and many pathways to follow. Some games use procedural generation of terrains and vegetation to simulate an "infinite" world[61]. One of the original ideas in developing these types of software was to explore the imagination of the players and play with their own narrative [63].

An example of a much-known sandbox game, between many, is Minecraft, an open world type of game that resembles digital Lego. In Minecraft the user begins the game in an earth similar world, with a feature that everything is made of cubes. Their character can interact with the world by breaking cubes, placing them and using them to craft some items. The

world generates a lot of interactive objects in the shape of animals, trading villagers, hostile enemies and even fluids such as water or lava. The level of freedom and interaction with the environment reflects on the people playing Minecraft, studies have shown that a group of kids increased their creative thought after playing. Even in education, Minecraft has proven to be a very complete and useful tool to stimulate creative solutions [64]. Alberto Blanco-Herrera et al [65] even admit video games are suitable to promote flow, and even to train creative thinking. They specifically recommend Minecraft as an ideal sandbox game to achieve this end. They called Minecraft "A tool that allows for a great variety of creative expression" and even said that "Minecraft might attract high-creativity individuals".

Strategy

Strategy games take as influence multiple board games, and the concept lies in a set of commands to play the game, having consequences to the strategy chosen in every situation [66]. This genre of games emphasizes planning behaviour, aspect management, and, in some examples, deal with challenges as collecting resources, building entities, manage the base, and more.

Inside strategy games, as in many other genres, the genre is subdivided. There are 2 types of video game strategy genres, the RTS (real-time strategy) games and the TBS (turn-based strategy). Both subgenres have similar aesthetics, having a global view of the actions occurring in the moment and the multiple commands that the player needs to play the game [67]. RTS games are more active, and they don't wait for the other players to finish their turn or complete their play, inciting the player to think of a fast solution in some scenarios, ex: Age of Empires. TBS games consist in a more sequential progress, mainly done by turns, one for each player. They resemble many board games like Chess or Monopoly but have much more complexity added based on the game being supported in a machine[68]. Steven Poole describes games within the strategy video game genre as "interactive simulations of dynamic processes", often presented in the form of narrative that illustrates conflict as fulcrum point in the story [69], ex: Civilization.

Let's take the example of a game called Civilization. These series of games were first released in 1991. Since then, the series has spawned numerous sequels, spin-offs, and expansions, with the latest main entry being "Civilization VI," which was released in 2016. The Civilization series is often cited as one of the most influential and popular games in the genre. The games have been praised for their depth, replay ability, and accessibility, as well as their ability to appeal to a wide range of players, from casual fans to hardcore strategy gamers [70]. In terms of gameplay, Civilization games are known for their complex mechanics and strategic depth. Players are required to oversee resource management, conduct technological research,

and navigate diplomacy and warfare with other civilizations to ensure their growth and prosperity. The games also feature a unique sense of scale, with players starting off with a small tribe and gradually building up to become a major world power. The Civilization games can influence creativity by requiring strategic and critical thinking, allowing players to exercise their imagination and creativity, and inspiring curiosity and learning about history and culture. These elements can foster a sense of exploration, experimentation, and innovation that can carry over into other aspects of life.

Puzzle

Video puzzle games find relation in puzzle games such as jigsaw puzzles, block puzzles or even tangram puzzles. Puzzle games can be defined as games that require players to use their spatial thinking skills to solve a problem or complete a task. These games typically involve rearranging or manipulating objects within a given space, solving riddles or brainteasers, and may require players to visualize and mentally manipulate objects in their minds. Puzzle games can also find relation to some areas like physics where the player may explore basic physics concepts such as gravity and friction, and more complex principles such as momentum, torque, and energy conservation. By requiring players to use their knowledge of physics to solve problems and complete tasks, puzzle games can help develop cognitive skills such as critical thinking, problem-solving, and creativity [71]. Puzzle games can even motivate the player to different levels of coordination. By requiring players to use both their mental and physical abilities to complete tasks, puzzle games can help develop a range of cognitive and physical skills, including critical thinking, spatial reasoning, hand-eye coordination, and reaction time [72].

A puzzle game recently released in 2019 is a game called "Baba is you". This puzzle game was created by Arvi Teikari [73], and it's a game where the player controls a character named Baba and manipulates the rules of the game to solve puzzles. The game is set in a world of words, where words are the building blocks of the game's mechanics. The game has a simple set of rules: the player can move Baba around the game world, and by pushing words around, they can change the rules of the game. For example, if the words "Baba is You" are pushed together, the player can control Baba. If the words "Rock is Push" are pushed together, the player can push rocks around. As the player progresses through the game, they will encounter increasingly complex puzzles, requiring them to manipulate the rules of the game in creative ways. For example, the player may need to change the rules so that "Flag is Win", allowing them to win the level by touching a flag. The game offers a unique and innovative puzzle experience that challenges players to think creatively and outside the box. The game's mechanics are easy to understand, but the puzzles require careful consideration and experimentation

to solve. The game's clever level design and simple but powerful mechanics provide a challenging and rewarding experience for puzzle fans [74].

According to the article by Rahimi and Shute "The effects of video games on creativity: A systematic review" [75], there is evidence to suggest that playing puzzle video games can enhance creative thinking skills. In particular, it may enhance specific facets of creativity, such as divergent thinking. This entails the ability to generate a broad spectrum of ideas and some solutions. The article suggests that these games may be particularly beneficial for enhancing creativity in younger individuals. Puzzle video games can also provide a sense of achievement and satisfaction when players successfully solve a puzzle, which can help to boost self-efficacy and motivation to engage in creative tasks.

These examples of genres of video games show how someone can express their creativity just by playing the game. With this information, the goal in this paper is to determine what features when developing a game are considered crucial to boost the creative process.

Tools that can Help when Developing a Video Game

Unity

Unity is a game engine and an IDE, also known as "integrated development environment", for creating interactive media, specially, video games. Unity can be accessed by downloading the Unity Editor, which is available for free on the Unity website. The Unity Editor is compatible with multiple operating systems such as Windows, macOS, and Linux. Unity game engine is known for its cross-platform compatibility, for having a visual editor to create and modify game assets, a powerful C# scripting language, a physics engine for realistic game physics, and a component-based architecture for building games using reusable components. The Unity development environment is a visual editor that allows developers to create and modify game assets, such as 3D models, animations, and sound effects, and to build scenes by placing assets in a 3D environment. The editor also provides tools for creating and editing scripts, managing project assets, and testing and debugging games. Some famous games that were designed with Unity include "Hearthstone", "Temple Run", "Superhot" and "Kerbal Space Program" among others. Unity also includes cross-platform compatibility, a robust visual editor, a wide range of community resources, and a large asset store with pre-built assets and plugins. Some potential disadvantages include a relatively steep learning curve for beginners, occasional bugs and glitches, and potential performance issues with large or complex games. However, many of these limitations can be mitigated with experience and knowledge of the platform [76].

Pixel Art

Pixel art can be defined as a form of digital art that uses a limited colour palette and small, discrete squares of colour, called pixels, to create images with a blocky, pixelated look. Pixel art is often associated with 8-bit video games and also used in animations, and other media, and is known for its nostalgic and retro aesthetic. While it has some limitations due to its reliance on a limited number of pixels, it also offers unique advantages in terms of efficiency, readability, and visual impact. Pixel art can be accessed through various online platforms and communities, such as PixelJoint, and Pixelation and created with programs like Aseprite, Photoshop and many others [77]. Pixel art programs generally have a user interface that is designed to be simple and easy to use, with a focus on providing the tools and features needed to create pixel art. These programs typically have a canvas that is divided into a grid of pixels, which can be individually coloured using various drawing tools. Some of the most classic video games used this type of digital art, games like Mario Bros., The Legend of Zelda, and Sonic the Hedgehog. More recent games, such as Celeste and Undertale, have also utilized pixel art to great effect.

Pixel art was the technique chosen in this project to create the map and player elements in the scene. The programs used were 2, Tiled and Piskel. Tiled was used along with a tile map to create the environment, the levels, and the elements in the scene. Piskel was used to create the player, the other interactable objects and the animations. The dialog boxes and the panels in the scene didn't used pixel art and are just normal digital art.

Importance and Impact of Video Games

The growth of the video game community has been unimaginable and with a growth this big, some questions started showing, if the video games have a positive impact on the person playing the game, if games would only be used to leisure, or also as an educational or applicational tool. These questions explore the impact that video games can have on society and on the individuals. The study made by M. Quwaider (2019), about "The impact of video games on the players behaviours" [78] concluded that video games and player's behaviour show a relation, either on a positive side or a negative one. The study divided the benefits that came from playing different types of video games. In games like shooting/action, the player shown more attention, more spatial resolution, and collaborative behaviour. In puzzle games, the player has shown benefits on a more emotional level, like "elevated inspiration", "relaxation", "increased commitment and achievement". Also, in these categories, were collected some negative emotions related to playing the games. In shooting games, the "aggressiveness", the "anger, in Fantasy games (RPG), the "social anxiety", "depression" and more. Overall, it can be concluded that the impact is real, and although there is a strong negative side to it, the main

impact that video games have on the player are in the players emotions, reflexes, behaviours, motivations, needs and thinking way.

Video Games and Creativity

Regarding creativity and video games, there are numerous studies made on the matter, although very few explore the features that a game has in order to make a real impact on the players creativity.

Hutton and Sundar (2010), in their article named “Can Video Games Enhance Creativity? Effects of Emotion Generated by *Dance Dance Revolution*” [79] explore how video games can prove that emotion significantly affects creativity through the interaction of arousal and valence. The study found that the level of mental energy was correlated with the level of arousal, up to a threshold point. It appears that physiological activation was transferred from the stimulus of the video game “*Dance Dance Revolution*” to a subsequent creative task or expressive behaviour proving that game-induced arousal may have increased participants’ capacity for cognitive tasks.

Strielkowski et al. (2020), in their work entitled “Does Playing Video Games Increase Emotional Creativity?” [80] emphasize the effect of video games and the use of digital technologies in general on public health. Their results suggest that extended time playing video games is associated with lower emotional creativity as a whole, and as novelty and preparedness and effectiveness components, in particular.

Yeh (2015), in his research called “Exploring the effects of video game play on creativity performance and emotional responses” [81] talked about the effects of two different types of online video games (an action video game and a non-action video game) on subsequent creativity performance measured using an idea generation task and emotional responses. The results demonstrated that after playing the action game participants performed higher on originality, elaboration, and flexibility than after playing the non-action game. The action games demonstrated various forms of visual stimuli and, in a controlled environment, a certain level of arousal which can benefit creative thinking, this suggests that changing forms and contexts to elicit changes of emotional experiences are preferable in the game design to benefit players’ creative thinking.

These are some studies regarding the impact of video games on creativity. More will be discussed in the literature review in the chapter.

Other Games that Stimulate Creativity

After conducting research on games that are considered creative or known to inspire creative behaviours, certain titles consistently appeared in every list, warranting a discussion about them. This analysis not only focuses on the games themselves but also explores how specific features within the games are perceived, aiming to assess their impact and explore potential correlations. Some features include visual elements such as light, background sound and colours, and other elements are more specific, such as the difficulty and objectives.

The Witness

The Witness is a first-person puzzle/exploration game set on an island filled with maze puzzles. It emphasizes puzzle-solving and exploration rather than combat or negative interactions. To finish the game, players must complete all levels while also being provided with a narrative to understand the meaning of the story. The game encourages players to perceive their surroundings, discover hidden puzzles and paths, and contemplate their thought processes, learning methods, and knowledge acquisition. The absence of explicit instructions may pose a slight challenge for new players and possibly lead to frustration for those lacking patience. However, it is in these moments that creativity can thrive, allowing truly creative players to flourish.

In terms of audio, The Witness does not feature music. Instead, it utilizes environmental sounds such as footsteps, trees rustling, and wind, creating a calm and relaxed atmosphere. Regarding lighting, the game predominantly takes place outdoors, resulting in a significant influence of natural sunlight. The sun serves as the main source of light and is even incorporated into certain puzzles. While there are also indoor puzzles, the game generally features ample lighting throughout [82].

Terraria

Terraria is a sandbox game set in a 2D environment, consisting entirely of squares, similar to Minecraft. However, unlike Minecraft, Terraria incorporates a sense of progression. The player must defeat enemies in a specific order, not because they are physically blocked, but because they are inaccessible until the previous challenges are completed. Despite this progression, the gameplay remains open-ended, without any imposed objectives. Upon starting the game, the player selects and customizes a character before being placed in a randomly generated 2D world with boundaries on both sides. The player has the ability to interact with every element in the game, including the floor, caves, trees, entities, and items. Some entities pose threats to

the player, while others offer quests, gifts, or missions. Similar to other sandbox games, Terraria features mechanics such as mining, crafting, and building.

The sound design in Terraria varies across different stages. The music primarily consists of synth and chiptune-like sounds, along with live instruments, creating a diverse range of auditory experiences and emotions. During boss fights, the music undergoes significant changes, incorporating a heavy combination of synths that evoke a sense of nervousness and anxiety, signalling challenging encounters. In terms of lighting, the game dynamically changes based on time progression. A "day" in the game lasts 24 minutes in real-time, with approximately 15 minutes of bright daylight illuminated by the sun, followed by 9 minutes of darkness, lit only by the moon. In the underground areas, players are required to create their own light sources [83].

Scribblenauts

Scribblenauts is a video game initially released for Nintendo DS, but later adapted for computer players. This unique puzzle game challenges players to solve puzzles using creative thinking. Players can input words representing objects, which will then appear in the game environment. With over 10,000 spawnable objects available, the possibilities are endless for players to explore.

The game features a combination of simple drawings in its environment, creating a visually appealing aesthetic. The music in the game is groovy, incorporating high-pitched instruments that evoke a sense of happiness. The lighting and colours in the game remain mostly consistent, only varying when there is an impact on the player's side [84].

Undertale

Undertale is an innovative indie role-playing game known for its emphasis on player choice and consequences. Players navigate an underground world filled with monsters, making decisions that shape the narrative and character interactions. The game subverts RPG conventions, challenging players' moral perspectives and offering a unique blend of storytelling and gameplay. Undertale's captivating story, memorable characters, and distinctive art style have earned it critical acclaim and a dedicated fan base.

The game's narrative and gameplay mechanics encourage players to think creatively and make choices that impact the story. The game presents a unique approach to combat, allowing players to resolve conflicts through non-violent means and emphasizing empathy and understanding. This unconventional approach to gameplay fosters creative problem-solving and encourages players to think outside the box. In addition, Undertale's distinctive art style and music contribute to its creative appeal. The game's pixel art graphics and evocative soundtrack

create a captivating and immersive atmosphere, enhancing the player's imaginative experience [85].

Video Games' Digital Features that could Boost Individual Creativity

On the process of creating something that was never made, there are numerous elements that need to be addressed. When developing a video game, features to have in consideration may be elements like light, sound, colour, speed, and others. The goal of this study is to check if such features can have a creative influence or not.

To adapt the game environment to test these features, many options were considered and not every element was evaluated, as it was very difficult to represent some of them in the development of this game.

The features chosen to be a part of the evaluation were colour, sound, perception (by a change in the environment), deduction (by a clue), which will be explained in-depth in the next chapter.

Colour

Colours are very important when talking about the mental and psychological, especially when talking about creativity. Colours can be divided in two categories according to their perceived colour temperature, warm and cool, and from this division results different behaviours. Janetta McCoy and Gary Evans [86] confirmed that cool colours have a negative impact on creativity when studying the impact the physical environment had on creative performance. Studies made in Shanghai Jiao Tong University in China [87], proved that bright warm lighting had a more positive effect when exploring creative solutions. On the other hand, a study made by Ravi Mehta and Rui (Juliet) Zhu (2009) [88], approached the impact of the colour Red or Blue in creative task performance. They concluded the red colour could be beneficial when the task at hand required detailed attention, however, the blue colour proved to be more influential when working on creative tasks, such as brainstorming. Thus, one of the digital features this research will evaluate its presence in video games' Impact on the Individuals creativity Is " Presence of Cool Colours ". These colours are mainly including Blue, Green, Gray.

Clue

This category comes with a simple premise. Realize if giving out a visual clue in the scene will have some trigger in the player's creativity. The player won't have a direct reference to it, or contact with, it's just present in the scene, and the evaluation will check if unconsciously the player can trigger any creative solution. A group of psychologists led by Mark Jung-Beeman

[89] made a similar study. The team, by handing out some keywords, for example (pine, crab, sauce), tried to check if the mind of the subject could form a familiar compound word by adding a common word to it (apple -> pineapple, crab apple, applesauce). The results showed that some individuals solved the problem in a non-creative way, by thinking about all the combinations that each word could create, but a group of people came to the solution by insight, insinuating that the word "apple" just came to their attention when looking at the three words. Thus, one of the digital features this research will evaluate Its presence in video games' Impact on the Individuals creativity Is "*Presence of Physical Display of Clues*".

Sound

The sound is present in almost every element around us. Many evaluations have been made on how sound can have effect towards feelings, emotions, and attitudes. It is a huge feature to have in consideration. Considering this, it is crucial to make an evaluation on how sound can have effect on the creativity, specifically on how background noise can affect the creativity of someone. A very good example of a background noise is the cafeteria noise, with the mumbling of the people, the plates clinking, the doors opening letting the sound of the street and the traffic come in for a brief second. Ravi Mehta, Rui (Juliet) Zhu and Amar Cheema [90] studied if the noise can be bad to creative cognition. Their results showed that a moderate ambient noise in the background with a volume not greater than 70 decibels enhanced the creativity and the ability to produce creative ideas. If the volume is much bigger than that it would harm creativity. Thus, one of the digital features this research will evaluate Its presence in video games' Impact on the Individuals creativity Is "*Presence of Background Noise*".

Abstract Experience

The idea behind this feature is more abstract. In order to confuse the unconscious of the individual being tested, the objective is to alter a certain factor in his reality and provoke an unusual event, that can have a repercussive effect on how well the creative task will be done. Studies made in this subject include research made by psychologist Simone Ritter (2012) [91]. She and her colleagues tested if an unusual event would trigger creativity on a positive level, reenforcing that abstract experiences break the mental block when we are thinking and allow the individual to consider more factors or options. They characterize the unusual event as something as natural as the death of a close parent, to a trip, to everything that is unexpected and creates a change in the individual. The results of their experiments showed that either more complex, unusual events and diversifying experiences increased the cognitive flexibility. Thus, one of the digital features this research will evaluate Its presence in video games' Impact on the Individuals creativity Is "*Presence of an Abstract Experience*".

2.3 Related Works

The world has changed the last century, problems are much complex now and require much elaborated solutions. From a technological aspect, information and digital technology evolution changed the human life. Concepts that companies such as *Google* or *Facebook* are presenting are not any more something exclusive, they are part of our reality and life. Developing the complex devices and programs have fuelled a burst in creativity and innovation, factors considered as key factors for modern professional, public, and private life. For example, in the business world, companies that desire to keep up and follow the dynamic work environment are already aware that their employers need to come up with novel, appropriate and efficient business ideas [92]. Which could not happen without boosting creative idea generation, abilities, and skills of employees. In this regard, researchers gave high attention to studying creativity in different fields.

Inside the field of technology, many instruments, applications, and programs were developed not just to provide amusement to the consumer but also to help the creation of content and the development of the products. One of these instruments that has a double propose is video games, that were mainly developed to motivate the costumer to play and to have fun with it, but nowadays are used also as a tool. Can be a tool to teach students programming and graphic design, but also an opportunity to create applications or programs that can influence players to have certain feelings or behaviours.

By trying to find a relation between video games and creativity, various researchers made experiments. Blanco-Herrera's work (2019), "Video Games can Increase Creativity, but with Caveats" [65] focused on finding a game where the creative factor could be observed and measured. In his work, numerous types of games were in consideration: role-playing games, due to the fact the player has to be creative in the character development, backstory, relations with other players and even in the decisions needed to complete the game; strategy games, in which the player needs to come with a creative solution to a puzzle, a hidden strategy or something; even the well-known first-person shooter (FPS) give the player a creative factor when making a decision out of the ordinary that gives them advantage in field. Although, the type of game selected in his research was the sandbox games, specifically *Minecraft*. The work of Ocio and Brugos (2009) named "multi-agent systems and sandbox games" [93] explored the idea of Sandbox game, consisting in an open world type of game, where the environment can be altered by the user. When there's a goal, the player has a high level of creative tools to achieve it. Hall et al. (2020) in their research "Expressivity of creativity and creative design considerations in digital games" [94] relate to various forms of creative expression and what features video games should have to foster these forms. The study's findings were categorized into three forms of creative expression:

1. **"Creativity as Problem-Solving"**: This aspect focuses on design considerations such as the "freedom of play", available tools, and the environment within the game. It allowed players to experiment with various approaches, try many combinations to devise new strategies, and leverage the game's terrain so they could perform better.
2. **"Creativity as Appropriation"**: In this form, design considerations also emphasized the "freedom of play" but encouraged emergent forms of play by providing a range of options and items. Players were encouraged and permitted to modify the game, fostering creativity through player-driven adaptations.
3. **"Creativity as Affective Change"**: This aspect highlights design considerations related to the narrative aspects of the game, its replay value, and avatar customization. It allows players to engage with the game by exploring decision-making paths, experiencing multiple endings, and personalizing the appearance of the main character.

On a psychologic view, Granic et al. (2011) in the paper named "The benefits of playing video games" [95] noticed that the overall opinion towards video games and the mental health was a negative impact, where the video games were only associated with violence, depression, and addiction. To get a second opinion they made research on how video games could bring benefits in the main domains like cognitive, motivational, emotional, or social. The results showed the social factor is strongly present, connecting players from different geographical places on earth, family members and friends. The connections the video games gave to people created many relationships, putting apart factors as culture, religion, age difference, gender and even language. Regarding the amount of time spent in a single game gives also positive feedback because it's providing various quality experiences.

The authors Jackson and Games (2015) made research called "Video Games and Creativity" [96] in which they observed the effects that video games could have in the players. This research showed different effects such as cognitive, social, motivational, and emotional. In cognitive effects, the researchers have observed that: recent video game players when are subjected to a *shooter* video game increase their spatial skills, confirming this analysis with a similar study made by Uttal et al. (2013) in their work "The Malleability of Spatial Skills: A Meta-Analysis of Training Studies" [97]; the need to allocate the attention of a *shooter* game player is lower, resulting in a more efficient and filtered attention; the lack of information given in a game, usually, gives the player a more challenging and immersive gameplay, hence, develops the problem-solving skill. In a social level, the video game community has evolved a lot in the last 50 years. As seen before by the ESA tests of 2020, 65% of the tested community prefers to play with others. This result suggests that gamers may be increasing their social skills because of the need to communicate to achieve the desired goal. Even the more violent video games have proven to increase prosocial behaviour. Playing violent video games in a group setting

can lead to reduced feelings of hostility as opposed to playing them individually. The emotional effect comes with a very simple idea, that people play video games to feel good with themselves. Some video games are more focused on the relaxation such as *puzzle* games and some to a more engaging feeling, a feeling that people in the area call *flow*. Flow is when someone is so deep immersed in that generates a heightened perception of control, resulting sometimes in a loss of self-consciousness. These experiences contribute to higher self-esteem, lower anxiety. At last, the persistency and the effortful engagement are motivational styles responsible for success and achievement.

The study of the impact of video games have showed that video games can have an impact on the *incremental* theory of intelligence, because of the immediate feedback on their effort.

2.4 Chapter's Summary

As seen above, many researchers studied the concepts of creativity, how creativity influenced many areas of study, what impact creativity had on those areas, specifically the areas of technology. There were also many studies regarding the areas of technology, the instruments and tools within technology that had impact on human behaviour. Amongst those tools, a new and effective one is video games, which some researchers have already explored and made works on their influence in creativity, but since the topic is so modern, many fields are yet to be discovered. This work as the propose to evaluate the influence of video games on creativity and to see what elements can help foster creativity into someone when playing a video game.

Terms	Definition	
	Conceptual	Practical
Creativity	Creativity is the capacity to generate novel, unexpected, and valuable ideas, or creations to address and resolve problems or challenges [16].	Creativity is the ability to come up with the modern and appropriate solution to a problem.
Creative idea generation fluency	The capability of generating multiple, valuable, creative ideas, in order to solve a problem [34].	The act of providing a number of novel and appropriate idea that and individual could produce to solve a defined problem.
Video games	Video games are entertainment tools that serve to give the user a good digital experience [54].	Video games are digital tools that involve interaction with a user interface of input device to generate visual and audition feedback for a player.

Table 2.1: Conceptual and operational definition of major terms in the research

The previous table 1 illustrates some of the concepts talked earlier, to help the readers understand the document and have a more organized option to review these concepts.

The following chapter will define the methodology used while developing this work. Will also define the population to be used and the calculations needed to process the results.

METHODOLOGY

3.1 Introduction

The goal of any research is to take a topic that there's no work or very few work about, explore that topic to find something new and test that hypothesis with practical results. The complete process when making research starts with defining the problem and the hypotheses required to prove the idea, then it's needed to define how the research will be made, how the data will be collected and, in the end, how it will be analysed.

The goal of the research is always reached as long as the work is well structured, and even if the results are not as positive as hoped, every research is valid and the work is important to future researchers, who will know that those hypothesis in that environment failed in that experiment. Khaki (2000) [98] stated that methodology was a group of connected ruled, principles and routines in a field of knowledge. This idea transmits that when selecting the method of execution, the research methodology will have to be best adapted to the work and subject. Inside the scientific research, the best methods to opt are those where the main concern is to prove the research goals defined in the early stages. This chapter makes an overview of the research methodology used throughout the development of the dissertation. To better specify the research, it will be addressed the main research problem, the influence in technology and specifically video games, the field tests, the research participants, the size of the sample, some data analysis techniques, and the research validity.

3.2 The Research Methodology

In terms of research's philosophic foundation, the present study has interpretive and post-Positivism paradigms. The main trend of the research process is based on design science research (DSR) (Figure 3). In terms of research orientation, goal, and approach, this research is applied development. The research data will be obtained from the participants inputs in the designed video game and in-deep literature review. In other words, research data will be obtained based on pluralism in the method implementation.

At the first phase of research, literature review will be used to understand research problem and possible solution, determine state of the art, and discover the digital features that could implement in video games enhance users' creativity. In this stage the digital note-taking method will be used. After structuring the research question, using the digital note-taking method from the documents, the theoretical foundations of the research will be obtained, and the conceptual model of digital features that could implement in video games to enhance creativity will be designed and presented. In the next step, a pre-designed video game will be developed and empowered by the determined feature and to validate the research results, the results of each level of game that is empowered by the defined digital feature will be compared with the control level which does not include any of these features.

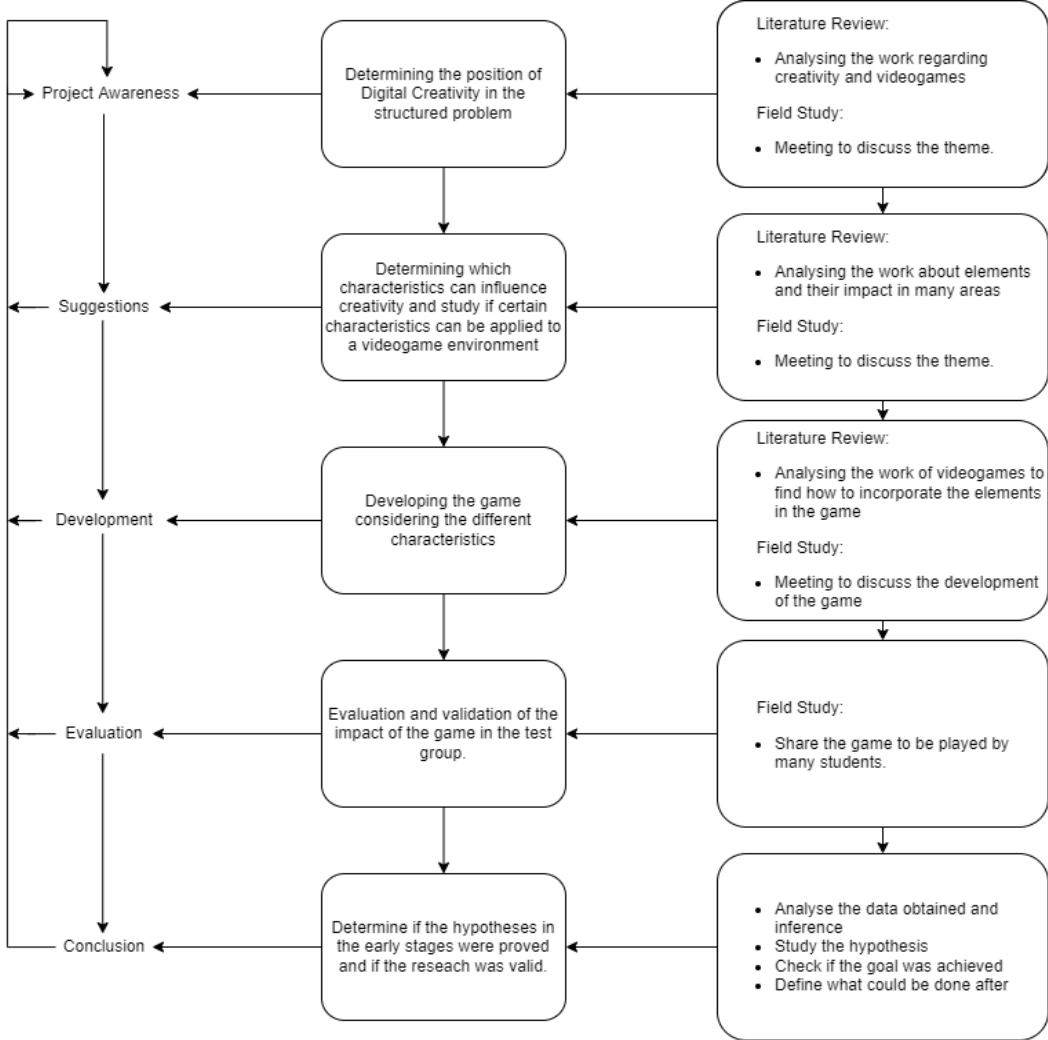


Figure 3.1: The research process based on design science research.

3.3 Methods and Tools for Collecting Data.

In every research, there's always the data collection and treatment part. Regarding the collection of data can be by reading, observing, testing, pondering questions or even a mixture of all of them. This study is based on a pluralistic approach consisting of descriptive methods and design science research and the required information in this research is obtained from the following two methods:

- A: Field Study: In this method, the approach for collecting field data is:
 - Game trials.
- B. Literature Study: These methods have also been used extensively due to the trans-disciplinary nature of the present research. In this research, the digital notetaking from previous studies method will be used in the process of defining the research problem, determining the state-of-the-art and the theoretical foundations of research, identifying the underpinnings of digital features that could be used in video games to enhance user's creativity, and validating the research results.

3.4 Design Science Research in Developing the Video Game.

The concept of the design science research is a process of identifying, defining, and solving problems that come from creating a goal and finding a path to achieve that goal. This method follows a progressive order, and the results influence if the order continues or if the early steps need to be repeated. The following figure 4 explains how this method's progression is made:

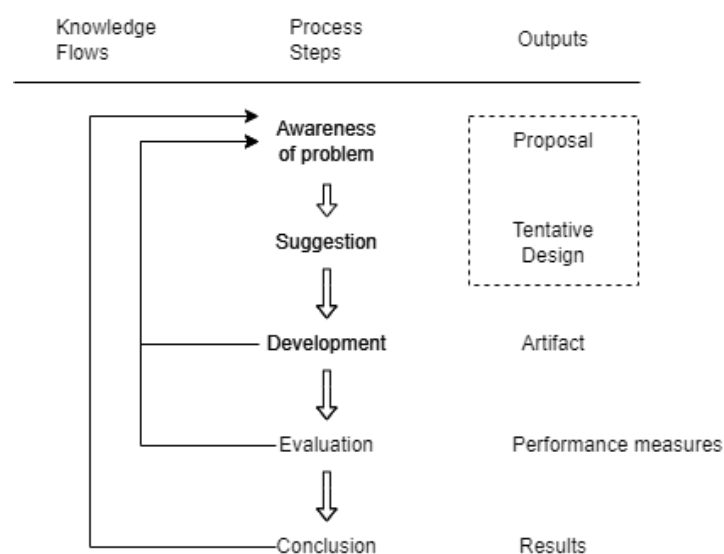


Figure 3.2: The method progression

Design science research, often referred to as "improvement research," underscores its problem-solving and performance-enhancing nature. In this approach, all design activities commence with understanding the problem and what it represents, defining its scope and nature. The subsequent step involves proposing an initial solution based on existing knowledge or theories related to the problem domain. After defining the design, the process moves into the actual development phase. This stage is characterized by creativity, refinement, and multiple iterations to produce a tangible artifact. It is during this phase that a constructivist methodology is often employed, emphasizing hands-on learning and iterative development [99]. Once the product is ready, it undergoes evaluation based on the implicit or explicit parameters laid out in the initial proposal. Empirical methods, such as theory testing, "action research", "controlled experiments", simulations, or scenario analysis, are commonly used in the evaluation process [100]. The goal is to assess how effectively the artifact functions and performs. Throughout these stages, there is a continuous process of repetition and criticism, referred to as "circumscription". In the end, the project is closed and concluded.

Inside the video game development, it was used the same developing method, starting with the suggestion on how to evaluate and selecting the word guessing game, next the development of the game and the environment around it. After the game was done and ready for testing, the initial suggestion was confirmed by the evaluation. In the end the results are gathered by the subjects playing the game and results are proven.

3.5 Literature Review and Digital Notetaking

In various phases of this research, the Literature Review have been carried out using Digital note-taking method. In this regard, to obtain the necessary data, the researcher crawled most valid databases related to the subject of research, books, scientific and research journals, dissertations, Ph.D. and M.Sc. reposts, reputable interviews, valuable conferences proceedings and valid electronic documents. Primary and secondary resources that could be useful to answer the research questions were extracted and digital note have been taken.

3.6 Field Test

To create the tests, the game was developed, and the features were implemented in each level, in order to have a control level without influence from the features and 5 levels influenced.

To gather information about the creative fluency level of the participants in this experiment, the results (the number of words guessed in each level), are stored in a spreadsheet. The

evaluation is made by comparing the performance of the player in the first level, which corresponds to the "vanilla level" (the level where none of the features are present and there's no influence towards the player) and the remainder of the levels, where the aspects to evaluate are present and their impact is tested. The levels are divided into 4 different features to evaluate, first "Presence of Cool Colours", second "Presence of Physical Display of Clues", third "Presence of Background Noise" and for last "Presence of an Abstract Experience". The specifications for each level are in the chapter 2.

In order to facilitate the data collection at a distance, and also due to the COVID-19 pandemic, a functionality was developed to send the results of the player to an email in order to store it. This functionality allowed participants to download the game in their personal space and play the game.

3.7 Research Participants

Research participants are individuals who take part in human subject research. Researchers gather information from these participants to aid in addressing the study's research question. Each research study establishes its own standards for determining who can be a part of the data. These standards are contingent on the specific research question at hand and may include certain restrictions or prerequisites.

The present study includes only a type of participants as the results are based on the experience of university students and their creativity when playing a video game. Selecting university students as the scope of the sample for this is justified for several reasons which include:

- **Developmental Relevance:** Adolescence and young adulthood are critical developmental stages where cognitive, emotional, and creative abilities undergo significant changes. Exploring the impact of video games on creativity during these formative years can provide insights into how such experiences influence life-long creative abilities.
- **Educational Context:** High school and university students are actively engaged in learning and problem-solving within an educational context. Their experiences with video games may directly relate to their academic performance and creative tasks, making them a pertinent population to study in the context of education.
- **Age Cohort:** High school and university students typically fall within a specific age range. This cohort can provide insights into the creative development of

young adults, and findings from this group may be more easily extrapolated to other young adult populations.

- **Longitudinal Studies:** High school students can serve as a starting point for longitudinal research that follows participants into their university years and beyond. This approach can help track the long-term effects of video game exposure on creativity.
- **Access and Feasibility:** University campuses provide a convenient and accessible environment for research. Researchers can easily access a diverse pool of university students, making data collection more manageable and cost-effective. Moreover, students are often willing to participate in research studies, which facilitates recruitment.

3.8 Sampling Design and Size

The process of sampling in an evaluation consists of selecting a portion of a population to evaluate and simulate the whole population. This is a must-have process when doing research as sometimes the size of the data is too large to analyse by one algorithm. Also, the sampling is sometimes made to test different points in discussion. The sampling plan should align logically with the research question. Regardless of the sampling strategy employed, the research proposal and report should explicitly address the sample size and the method by which it will be selected.

The data collected in this research made a full sample of 100 individuals, all of them having in common attending the university. This sample was chosen to analyse if could be a way to improve the creativity in a point of life of an individual as important as the university. This sample was also important because in this time in life, students are very connected to video games, and if certain features can boost their creativity while they're playing the game, it would be very interesting to apply them and give another meaning to the activity of "playing games"[9]. The method for choosing the individuals was "Simple random sampling" method. The database is composed by the performance in the first level where the factors were not applied to set the base score and the performance in the rest of the levels to compare with the base score and see if there was an improvement or a decay in the performance.

A sample size of 100 for a master thesis' research study conducted over a period of three months can be considered appropriate. Here are several reasons why a sample size of this research is appropriate and satisfiable:

1. *Statistical Significance:* A sample size of 100 is often sufficient to achieve statistical significance for many research questions. It provides a reasonable level of

confidence in the research findings, allowing you to detect meaningful patterns or relationships in the data.

2. *Feasibility*: Conducting research can be resource-intensive, including the time required for data collection, data processing, and analysis. Given the three-month timeframe, a sample size of 100 allows for efficient data collection and analysis without overwhelming research resources.
3. *Time Constraint*: The master thesis duration imposes limitations on data collection and analysis, which caused author to choose maximum 3-month duration for collecting data.
4. *Research Focus*: If the primary objective of the research is exploratory or preliminary in nature, a sample size of 100 can provide valuable insights without the need for an extensive sample.
5. *Ethical Considerations*: Researchers must consider the ethical implications of data collection, including the burden placed on participants. A sample size of 100 minimizes the burden on participants while still allowing for meaningful data collection.
6. *Practicality*: Depending on the research topic and methodology, obtaining a larger sample may not be feasible within the given time frame or resources available.

From the total samples received, not all of them were completely valid, and a filter had to be applied to leave in the database only the valid results. This filter set aside all the results that were incomplete, had null and empty values, and came compromised. The final database has been set in 81 valid results.

3.9 Data Analysis Techniques

To gather valuable information, numerous analyses were applied to the data bank in order to get some type of conclusion towards the hypothesis in question. In this analysis process, the data collected were mainly numbers representing the number of words each player guessed right in each level. Also, in the levels where the "Presence of Physical Display of Clues" were evaluated, there's another value that represented the number of clues found in each level. Giving that these values were mostly numbers, a mathematical approach is considered most valid and complete.

The whole process of research was based on the design science research methodology. In this regard, in the first stage, the problem is identified and structured, in the second and third stages, suggestions are made and developed for solving the problem. In the fourth and fifth stages, the designed model has been evaluated.

Mean, Variance, Standard Deviation, and Coefficient of Variation Measures.

The importance of calculations in research cannot be overstated. Mathematical tools such as the mean, variance, standard deviation, and coefficient of variation serve as the backbone of data analysis and play a pivotal role in research across numerous disciplines. Firstly, they provide researchers with a concise and quantifiable way to summarize complex datasets, allowing for a clear understanding of data central tendencies and variations. This, in turn, aids in the effective communication of research findings to both peers and the wider community.

Secondly, these calculations are indispensable for making rigorous and informed conclusions. Researchers rely on them to assess the reliability of their data, detect outliers or anomalies, and determine the statistical significance of observed effects. Whether in the natural sciences, social sciences, economics, or any other field, these calculations empower researchers to draw meaningful insights, identify trends, and make evidence-based decisions. In essence, they form the bedrock upon which sound research and data-driven discoveries are built, underlining their critical importance to the research process.

Mean

The mean, often referred to as the arithmetic average, is a fundamental mathematical calculation used to find the central value within a set of numbers. It is computed by adding up all the values in the dataset and dividing this sum by the total number of data points. Mathematically, the mean is represented as:

Sample Mean: 1:
$$\bar{x} = \frac{\sum x_i}{n} = \frac{x_1 + x_2 + x_3 + \dots + x_n}{n}$$

where Σ signifies the summation of all data points, n is the total number of data points, and x_i represents individual data points.

Population Mean

In the realm of mathematics, the population mean, often denoted as μ (the Greek letter mu), holds a special place. It signifies the average value of a variable across an entire population. The formula for calculating the population mean is the same as for the mean, where N represents the total number of data points in the population:

Population Mean: 2:
$$\mu = \frac{\sum x}{N} = \frac{x_1 + x_2 + x_3 + \dots + x_N}{N}$$

Variance

Population variance is a mathematical measure that quantifies the spread or dispersion of data points within an entire population. It represents the average of the squared differences between each data point and the population mean. Mathematically, population variance is expressed as:

Population Variance: 3:
$$\sigma^2 = \frac{\Sigma(x_i - \mu)^2}{N}$$

where Σ signifies the summation of squared differences for all data points, N is the total number of data points in the population, x_i represents individual data points and μ represents the population mean.

Standard Deviation

Population standard deviation is derived from population variance and provides a more interpretable way to understand data dispersion in an entire population. It is calculated as the square root of the population variance. Mathematically, population standard deviation is:

Population Standard Deviation: 4:
$$\sigma = \sqrt{\frac{\Sigma(x - \mu)^2}{N}}$$

Coefficient of Variation

The coefficient of variation (CV) is a dimensionless mathematical calculation that represents the standard deviation as a percentage of the mean. It is used to compare the relative variability of datasets, especially when dealing with data of different units or scales. The formula for CV is:

Coefficient of Variation: 5:
$$CV = \frac{\sigma}{\mu} (100)$$

These mathematical calculations are fundamental in statistics and data analysis and this research will utilize them to complement the results and take conclusions about the performance of the players while playing the game.

3.10 Research Validity

The results were collected from students that study in the university. This specific group represents a large portion of students that opt for continue their studies into universities around the world. Given that this study was very limited, and that the students had multiple factors in common such as the country, the language, the academic degree, etc., applying this research to a group of people outside of these factors could cause a different result.

To validate this work, the results of the game were collected, then analysed, based on the calculations previously determined. With the calculations, some conclusions could be taken by the values of mean, variance and coefficient of variation and compared with the hypothesis. Lastly, peer validation was made to strengthen the conclusions and proving if the hypothesis was rejected or not.

3.11 Chapter's Summary

This chapter represents the methodology used in the full process of this research and the evaluation methods used to collect data. The Design Science Research Methodology was used to structure the procedure, by first identifying the problem, defining it, and presenting a way to solve it. Second by creating a goal and finding a path to achieve that goal. Third to get results based on the process defined earlier and to test if those results justify the problem defined in the beginning. If the results don't take the conclusions needed, then it's necessary to repeat the testing phase till we have a batch of data coherent and relevant to the research. After having a valid group of results, the tests on those results are made and the conclusions are taken, confirming or denying the hypothesis set in the beginning of the research and checking the peer validation to see if the results have been proved.

The evaluation will be collected through game trials made by a group of engineering students. To the data will be applied mathematical processes to test if results such as the average, median or standard deviation show any different conclusions.

The next chapter will demonstrate how the game functions, how the features are going to be applied in the levels and how the map will be constructed. Then it will show pictures of the game levels, and the word game itself, with an explanation of how the game will work.

DEVELOPMENT OF THE GAME

4.1 Development Overview

When first designing the game, the main question was: “What will this game be about?” This question would define what kind of evaluation would be made while playing the game. The concept of the game had to be something easy to understand, fast to play, recognizable to every subject of study and, mainly, evaluable in terms of creative development.

In the brainstorming process, some ideas were considered to be plausible to the evaluation. The idea that stood out was having a word completion game, where the player gets 8 letters and with those letters has to construct the greatest number of words possible in 45 seconds. For example: The player gets 8 letters “A \ B \ T \ U \ O \ G \ E \ T “. With these letters the player can make the words “about, boat, toad, get, got, etc...”. This game checks every point considered in the concept phase. It’s easy to understand, as every person constantly creates words in their quotidian life. It’s fast to play, as the player only has 45 seconds to think of a way to make the most words possible. Recognizable to every subject, as the game is very close to an existing game named “Scrabble”. And, for last evaluable because the player in the end will present a result corresponding to how many words were made in the time-limit.

To develop this kind of game some questions had to be answered. How will the game be made? In which platform? How will the game look visually? Will the player have a character to move around? How will the player interact with the environment of the game? How will the player obtain the letters? How will the player interact with the game itself? What features will be considered in the game? How will the features be incorporated into the game? How many word completion games will be played to evaluate everything and give the player the sense of accomplishment?

Still in the process of designing the game some ground guidelines were defined. The game would be made in the Unity platform, a game-engine used for creating games. The visuals would integrate the pixel art form, a simplistic way to represent the environment. The player would interact with a character and move around a map, in a level-based game which would evaluate different aspects in each level. The game would have 6 levels, being the first the introductory level with no elements to evaluate and the last one the level where all the elements would be evaluated. The features to evaluate are *"Presence of Cool Colours"*,

"Presence of Physical Display of Clues", "Presence of Background Noise", "Presence of an Abstract Experience". All these features will be explained in-depth throughout the document.

The document with the explanation of the game that is included in the game is in the annex 7.2.

4.2 Development of the game

Features to Evaluate

Presence of Cool Colour

To evaluate the effect that the "Presence of Cool Colours" has in creativity the approach made was to analyse the colour groups warm and cool. In level 2 the elements in the scene are all in the cool pattern, to test if the player shows any difference in the result. In level 3 the colour pallet is around the warm pattern.

Presence of Physical Display of Clues

The player is tested on his attentiveness and the ability to pick up clues. In the level 3 it's given two visual clues that represent two words available to make with the letters given in that level. The elements showing the clue are a bonfire that represents the fire ("FOGO" in Portuguese) and an old camera that represents a photo ("FOTO" in Portuguese). The clues are accounted for in the results and analysed in the results chapter.

Presence of Background Noise

Sound is one of the main aspects of every game. Every element with sound gains a more real interpretation and, in a video game, some sounds can alter the environment of the scene. In this game, the only continuous sound effect is the walking effect. In order to test how creativity can be influenced by the sound, background noise was added to level 4. Level 4 is a representation of a restaurant, and the background sound is a mixture of people talking and plates and silverware clinking. Also, in the last level it's added not just the restaurant background sound but also the fireplace and waterfall sound effects. In this level the sound gets higher the closer the player is to the element.

Presence of an Abstract Experience

To represent a reality change, the player is not directly present with the letters like in the other levels. To get the letters the player has to see his reflection in the mirror and by the mirror understand where the letters are situated and then click to get them. After the letters are gathered the player goes to the controller and after going through a mirror, a pair of circular arrows spins in the screen and the movement controls get switched. The "up" key sets the player to walk down, the "left" key to walk right, and so on.

Map Development

The map is separated into 6 areas, with a common room in the middle, each room representing a level. To unlock the next area, the player has to complete the actual level. The level overview is in figure 5.

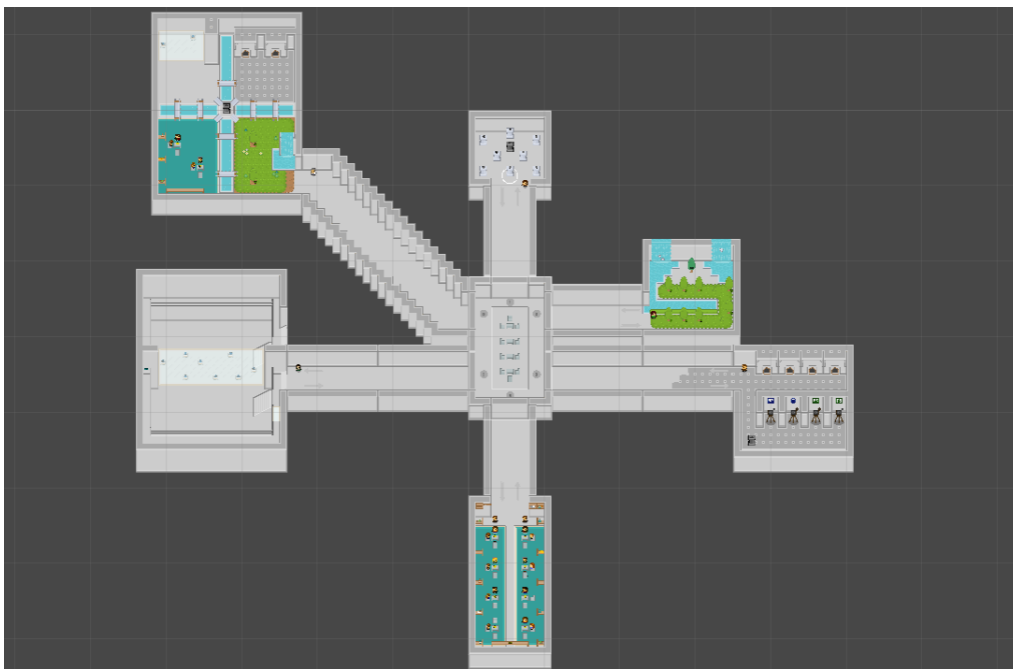


Figure 4.1: Overall view of the game

The player starts in the main area, a rectangular area with 6 doors and a trader in the centre of the room. There's a quick tutorial to teach the player the basic controls and after that the first door opens. In the levels the principle is simple, get the letters and find the game controller to play the game. After finishing the game, go to the next level. The map in each level is different considering the feature being evaluated in the level.

The game, in the beginning, has a tutorial panel, explaining how the game works and the controls used. After that panel, the player can interact with the tutorial experimenting with

the controls to have a better understanding of the tools available throughout the game. The main controls are the movement keys (W/A/S/D to play with the left hand or UP/DOWN/LEFT/RIGHT to play with the right), the click button to pick up the letters, to talk to other elements in the scene (left-click of the mouse or SPACEBAR in the keyboard), and finally the pause button to access the inventory or to review the controls of the game (ESCAPE key in the keyboard).

Level 1

The first level it's the introductory level, where the player is introduced to how the game is played and has to complete the highest number of words in 45 seconds, with no element in the scene to evaluate.



Figure 4.2: Level 1

Level 2

The second level is to evaluate if "Presence of Cool Colours" have impact on creativity. To do so, every element in the scene level is coloured with cool colours such as green and blue.



Figure 4.3: Level 2

Level 3

In the third level the feature to evaluate is the hint, that means, if the player is alert to the clues given in the scene, he will get the words right. The words fire and photo are the ones the player needs to discover, and to get the letters, the player has to interact with bonfires and photo cameras, hence the clues.

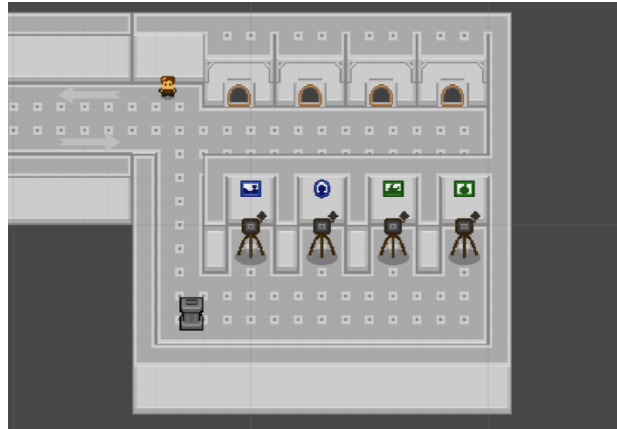


Figure 4.4: Level 3

Level 4

The level 4 is testing the "Presence of Background Noise" and how it affects creativity. To test this, the level is in a restaurant environment, where there are more people eating and the noise of people talking, and plates clinking makes the background noise.

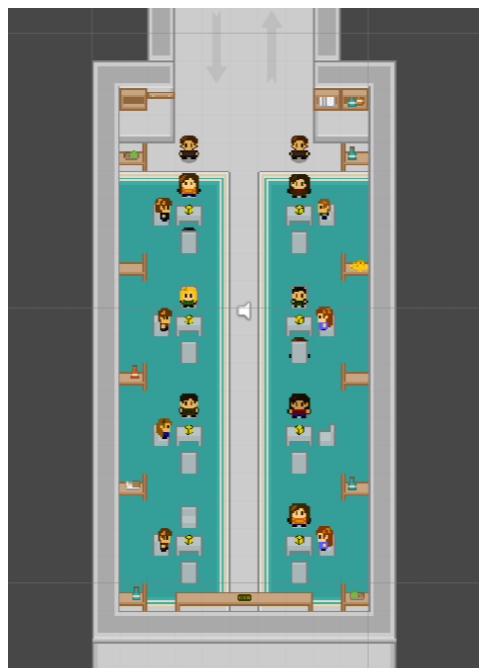


Figure 4.5: Level 4

Level 5

This level is different from the rest, it combines elements to confuse the head of the player. To get the letters, the player doesn't have just to click in the boxes when near them, the player must see his reflection in the mirror and see in the reflection where the boxes are located to collect them. When the player manages to collect every letter, must go to the controller and play the game, however, in the path to the controller, the player enters a glass that inverts his controls, and has to get to the controller knowing that by pressing the up button, the character will move down, by pressing the right button, the character will move left...

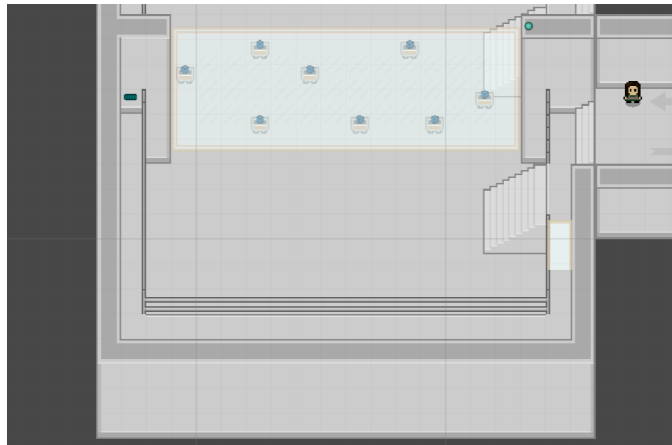


Figure 4.6: Level 5

Level 6

The final level combines a little of everything. There are four areas, each one representing a level, one with cool colours, one with the bonfire clue, one with the restaurant and one with a mirror. In the centre there's the controller to play the game.



Figure 4.7: Level 6

The Word Game

Although the game is composed of a map and places to explore, the real game starts when the player clicks in the level controller. How is shown in picture X, the letters collected are displayed in the bottom slots, when the player clicks a letter slot, it gets transferred to the upper slots. The number of correct words is shown in the mid-left panel and the words discriminated are in the mid-right panel. The controller starts only when the mid-bottom "PLAY" button is pressed, activating the upper-left clock and displaying the letters in the bottom slots.

When the player sets the clock, the timer starts descending from the 45 second timer and the player must create three, four or five letter words before the time runs out. If the player makes a mistake, it's possible to click in each slot to transfer the letter from the top slots to the bottom ones. After placing the first letter in the top slots, a "CLEAR" button appears so that the player can clear all the slots at once.

Once the time runs out, a new panel appears to show the performance of the player in the level. Then, the panel closes, and the level gets disabled. In the last level after the completion, the game returns to the main menu.

The display of the game is in figure 12 ahead.



Figure 4.8: Display of the game

Rewarding

An important element in every game is rewarding the player for the game played, so that the player feels a purpose while playing the game, motivating him to perform better. To achieve this, was added a currency into the game and a shop where the player can personalize his character with visual elements. The coin system is very straightforward, for each word guessed correctly, the player is rewarded with one coin. In the main room of the game there is another character that works as a trader and can trade coins for accessories such as hats, glasses, gloves and more. This element can have a positive impact on the performance as the player has a motivational goal.

4.3 Chapter's Summary

This chapter represented the development of the game. First it was discussed the theme of the game, fitting the genre inside of the puzzle games. Second the proper game was defined as a word guessing game similar to "Scrabble". Then, the art style pixel art and the game engine Unity were chosen. This game was set to implement the features discussed in the previous chapter.

The following section of the chapter discussed how the features would be included in the game, being distributed in the various levels, and what impact would they have on level. Then, the map development explained, with the help of images from the game, how the map would be displayed, how the controls work, and then what differentiated each level from the other, again explaining the influence of the features in the level design.

In the third section the word game panel is presented to help visualize what the game would look like and what are the game rules.

For last, a chapter refers the importance of rewarding in a video game, which is represented in this video game by the possibility of purchasing visual effects of the main character. These effects are only visual but in order for the player to get them, he has to score points and get coins.

The next chapter will address the results of the game. It will make an explanation of the game, the research participants, their different ages and genders and the game itself. The results will be presented in decimal form and some considerations will be made, to later be used to prove the hypothesis.

5.1 Introduction

This research consists in an experiment that gathered data through practical tests in form of a video game. The video game intends to prove if a set of features, when applied in the video game, have any impact in the creative idea generation of the person playing it. To achieve this comparison between an "influence-free" result and a "influenced" result, multiple levels were developed in the game, with the main premise of the game unaltered: Every level will present the player 8 letters, 45 second time limit and the objective is to form as many words as possible under those restrictions. The first level returns the "influence-free" result and remainder the "influenced" results.

To gather the results in a way that a person could play the game on their own computer, the game was downloadable from a drive link and when the person finished, their results were sent by email and stored in a database. This method has some advantages like the simplicity of getting results without having to dislocate to the university or having to carry the computer to make the people play the game, but also some disadvantages, as some results were incomplete and invalid, and for that reason, were not valid to use as a subject. That data was removed from the file and ignored, as only a complete example is valid to make the calculations.

The total data collected, including the invalid results, rounded the 100 entries. Although, the population used to create the database was narrowed down to 81 valid entries.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	PlayerName	Age	Sex	Level1	L1WordsFou	Level2	L2WordsFou	Level3	L3WordsFound	Level3n	Level4	L4WordsFoun	Level5	L5WordsF	Level6	L6WordsFound	Level6HintsDiscovered	
32	Bernardo	21	True	4	BDA, ECO, C,	7	AND, NADO, S	5	MATO, FOGO, MAGI	1	5	CARIL, MAR, MAR	6	ROTA, MATI	7	FOTO, GOTÁ, ATO, GATO, GALO, OLHO, FOLHA		2
33	Diogo	21	True	3	COBRA, BAR	3	IDA, NADO, NC	6	EGO, FATO, GATO,	1	7	AMA, LAMA, RIM,	6	POMAR, TEI	6	FOLGA, GALO, GATO, ATO, FOGO, FATO		1
34	João	22	True	5	PAP, PARI, I	6	SOL, SOLDA, I	4	FOTO, FOGO, ATO,	2	8	CAMA, ALMA, LAI	6	POR, MOR,	7	GALO, GATO, FOTO, GOLO, GOTÁ, GALHO, FALHO		2
35	Joana	23	False	3	CACO, CECO	3	LHA, NADO, O	6	METO, FOME, ATO, I	1	7	MAR, ARMA, LAC,	6	ROTA, MOR	6	TALHA, ALHO, OLHA, OLHO, GATO, FOTO		1
36	Beatriz	22	False	5	ARCO, BOA,	5	LINHA, ANDO,	6	FOME, FOTO, MATE	1	8	CARA, ARCA, SAI	11	POR, PORT	9	FOLHA, GALHO, ALHO, TALHO, OLHO, FOGO, FOTO,		2
37	Carolina	22	False	6	COBRE, ARC	7	SAL, SALDO, L	3	META, TEM, FATO	0	5	CRIA, MAS, MASC	9	TEM, TEMO,	7	ALTO, FALTO, GATO, GALO, FOLHA, ALHO, OLHA		0
38	Rafael	21	True	4	ECO, BROCA	6	SONDA, ANDC	5	FOGO, FETO, MOTE	1	4	RIMA, CARA, MAL	6	PATO, RATI	6	FOGO, ALTO, TALHO, GATO, FOTO, LOGO		2
39	Ruben	20	True	3	COA, ROCA,	4	SOL, SONDA, I	5	EGO, MATO, METO,	1	7	LIRA, CAL, RIMA,	6	TER, ROMPI	9	GOTA, FOTO, ALGO, FALHO, LOTO, LAGO, FOLHA, LI		1
40	Leonor	23	False	7	BOA, COA, A	4	SOCA, DADO,	8	MATO, METO, GEM	1	5	ARCA, LIAS, LASC	11	METO, MOTI	11	GALHO, TOGA, FALHO, TAL, FOGO, FOTO, TALHO, AI		2
41	Helder	21	True	4	CEPO, POR, I	6	OLHA, ILHA, AI	5	AFOGO, TEM, TEMC	2	4	CARIL, CASA, CAI	6	POR, PORT	6	TOGA, GOLÁ, GOLO, OLHO, FOLHO, FOGO		1
42	Margarida	20	False	6	CABO, BAR, I	7	AND, NADO,	2	GATO, FOTO, FOGC	1	5	MIA, MAS, MAR, M	7	PER, PERIC	8	GALO, FOTO, GOLO, TOLO, ALTO, FATO, ALGO, OLH		1
43	João	20	True	4	COBRA, COE	6	DONA, SAL, S	5	GOTA, MOTA, TEM,	0	4	CASA, RASCA, LF	6	TOA, TEM, I	6	OLHA, TOA, OLA, FOTO, GOTÁ, FOGO		2
44	João	20	True	4	COBA, BOBA	6	ALHO, ANDA,	3	MAGO, FOTO, AND	1	5	MIRA, ARMA, ALA	6	POTE, MOTI	6	GOLA, FOLGA, LOTO, GOLO, FOGO, OLHO		1
45	Maria	20	False	5	RABO, CARC	5	AND, DONA, A	4	META, FOGO, METC	1	8	CRIA, MAR, MARC	11	POR, PORT	9	TAL, TALHO, FALHA, TOLA, FOTO, GOTÁ, OLA, LAGO		1
46	Francisco	21	True	7	CARO, ROCA	8	NOS, NAS, LIA	6	GATO, FATO, MATC	1	5	LIA, CRIA, ARMA,	11	MOTE, METI	11	GOLO, TOLO, FATO, FOTO, GATO, FOGO, GOTÁ, FOL		2
47	Ines	21	False	5	ARCO, CABE	6	ONDA, OLHA, I	4	FOTO, GATO, ATO,	1	6	AMA, ALMA, LAM,	8	POR, PORT	7	FATO, ALTO, FOGO, FOTO, LAGO, GATO, GOLÁ		2
48	André	21	True	4	ORA, BOCA,	6	LONA, SONDA	5	FOGO, GATO, MATC	2	4	MACA, SARA, LIR	6	RATO, MOR	6	FOLHA, OLHA, FOTO, FATO, GATO, FOGO		2
49	Antonio	20	True	5	ECO, CARO, I	4	DONA, OLA, LI	4	FATO, FOGO, MOTF	1	4	CAL, CALMA, RAR	7	MATO, TEM	7	FOLGA, ALGO, LOGO, ALTO, GOLÁ, ALHO, FOGO		1
50	Manuel	24	True	6	BROCA, ECO	7	DOS, LADO, L	3	OBRA, AME, FOGO	1	5	ARMA, MAR, MAL	9	RETO, TORF	9	ALHO, GOLÁ, ALHO, LAGO, GOLO, FOGO, FATO, GO		2
51	Francisca	22	False	3	BOCA, COEF	3	IDA, LIRHA, AN	4	FOGO, ATO, MATE,	1	7	ALA, ALAS, LAM	6	TER, POMAI	5	ALGO, FOLGA, GOLÁ, OLHO, ALTO		0
52	Madalena	23	False	5	BOCA, BOA,	6	INDO, LADO, S	4	META, METO, FOTO	1	6	ALMA, MAL, LIRA	8	POR, PORT	7	ALTO, GATO, FALTO, FOGO, FOLHA, FOTO, LOTO		2
53	Maria	20	False	6	PER, PERCO	7	LADO, DONA, I	3	ATO, FATO, MOTE	1	5	CRIA, MIA, MIA, L	9	TOME, RATI	9	FOGO, ALGO, ALTO, FATO, LAGO, GALO, TAL, TALH		1
54	Luis	24	True	7	OBRA, CRA,	8	NAS, NADO, L	4	GATO, FOTO, MATC	1	5	LIRA, MAR, MARC	11	MOR, MAR	11	GALO, FOTO, FALHO, OLHA, FOLHA, ALHO, FOGO, LI		2
55	Tiago	22	True	4	BOA, COA, R	6	SAL, LONA, LF	5	ATO, FATO, MATO, I	1	5	CASA, MAL, ALM	6	PATO, ARTI	6	GOLA, GATO, GOLO, FOGO, OLHO, LOTO		1
56	Donatelo	20	True	3	COBRA, ARC	4	INDO, LINDO, L	6	TEM, MOTO, FOGO	1	7	MAR, MARCA, AR	6	TEM, TOMA	6	OLA, OLHA, FOTO, OLHO, ATO, OLHA		1

Figure 5.1: Database

The students that played the game were asked their age and gender. Although today gender is a very sensitive topic to define, the game's decision was based on the biological meaning of gender, allowing the player, in the beginning of the game, to choose if they were a man figure or a woman one. The following tables show the results to these choices:

Age	Amount	Percentage
20	18	22,22
21	30	37,04
22	20	24,69
23	9	11,11
24	4	4,94
TOTAL	81	100

Table 5.2: Students that played the game divided by age

Gender	Amount
Man	46
Woman	35

Table 5.1: Students that played the game divided by gender

The data was retrieved from the game in a numerical form, each level returning the number of words the player had guessed. A database was formed containing the words guessed each level and the clues found in the levels 3 and 6. Then, with the data collected, the calculations of the mean, standard deviation, variance and coefficient of variation were calculated with the intent of testing the hypothesis formulated in the earlier chapters.

Mean:
$$\mu = \frac{\sum x_i}{n} = \frac{x_1 + x_2 + x_3 + \dots + x_n}{n}$$

Variance:
$$\sigma^2 = \frac{\sum (x_i - \mu)^2}{n}$$

Standard deviation:
$$\sigma = \sqrt{\sigma^2}$$

Coefficient of variation:
$$CV = \frac{\sigma}{\mu} (100)$$

where x_i means every individual result, n the number of results, μ the mean and σ the standard deviation.

5.2 Results

Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
4,84	5,67	4,70	5,54	7,56	7,22

Table 5.3: The results of the mean calculations

This result shows clear evidence of the influence of the features in the levels, and the impact they appear to have on the player. Considering that the Level 1 is the "influence-free", we can see a noticeable increase in creative idea generation in certain levels, for example the level 5 and even levels 2 and 4. The level 6 is a combination of all the features, and we can also see the positive impact of the features, even when applied together. From the mean it is also possible to verify that the experience can affect the results, the player gets progressively better results, in general, whilst completing the levels.

A level that needs a further discussion is level 3, which corresponds to the "Presence of Physical Display of Clues" level. The results show that the mean of the values in this level was below the mean of the "influence-free" level. Although if we do a mean based on the clues being guessed or not, the results turn out to be a little different:

Level 3 With 0 Clue	Level 3 With 1 Clue	Level 3 With 2 Clue
4,11	4,51	5,53

Table 5.4: The results of the mean calculations in the level 3 with the different clues

To the player who only discovered 0 or 1 clue, the mean remains below the level 1 mean, but to the ones who discovered the 2 clues present in the level the mean of the words guessed increases and surpasses the value of the "influence-free" level, which indicates a positive influence of displaying clues to the player's creative idea generation.

The level 6 was also influenced by "Presence of Physical Display of Clues", similar to the level 3, although it was only a part of the influence. The results show the following:

Level 6 With 0 Clue	Level 6 With 1 Clue	Level 6 With 2 Clue
6,38	6,95	7,74

Table 5.5: The results of the mean calculations in the level 6 with the different clues

These results were similar to the ones in level 3, resulting in an increase in the number of words guessed for each clue guessed. The players who found 0 or 1 clue are still below the average player in level 6 but it is possible the results have also been influenced by the other features as this level is a combination of the remaining levels.

Other calculations based on the results that allow further interpretation are the variance and the standard deviation, both applied in a population. The results are the following:

Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
2,18	2,93	1,71	1,93	3,7	3

Table 5.6: The results of the variance calculations

Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
1,48	1,71	1,31	1,39	1,92	1,73

Table 5.7: The results of the standard deviation calculations

These results show how much the values change within the mean value. We can see a higher deviation in levels 2, 5 and 6, which indicates a wider range of values and represents a more disperse result. Results like this indicate that even though the results were more positive in the final levels 5 and 6, there were some results that had to be lower than expected and some higher, hence the increasing values in the deviation. The level 4 shows an interesting result, as it already demonstrated a positive result in the mean calculation, with an increase compared to the level 1 and a very low value in the variance/deviation result, making it a very good example of positive influence.

At last, the final calculation is the CV (coefficient of variation), that allows to comprehend if there's a great dispersion around the mean. The results are the following:

Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
30,54	30,18	27,81	25,04	25,46	23,98

Table 5.8: The results of the coefficient of variation calculations

The lower the coefficient is, the less disperse the results around the mean are. We can see a decrease throughout the levels, especially in the levels 4, 5 and 6. Adding to the other results it's clear that these levels were the ones where the features acted most positively to the creative idea generation or fluency.

The results were divided between woman and man, and the calculations were made based on these values:

	Level1	Level2	Level3	Level4	Level5	Level6
Man	4,74	5,65	4,80	5,46	7,48	7,26
Woman	4,97	5,69	4,57	5,66	7,66	7,17

Table 5.9: The results of the mean calculations for both man and woman sides

The results show some differences between the man and woman. The overall results were similar, with a woman side showing higher results in the levels 1, 2, 4 and 5. In both sides we can see the same evidence we saw earlier, seeing that the results improve in the levels 2, 4, 5 and 6.

The basic level was higher to the woman side which set a higher base of comparison. This is reflected in the level 3, where the man side saw an increase relative to the basic level and the woman side, there was a decrease of the number of words guessed. To complement these results, we can see the impact of the "Presence of Physical Display of Clues" with the mean:

	Level3With0Clue	Level3With1Clue	Level3With2Clue
Man	4,5	4,70	5,15
Woman	3,33	4,31	6,33

Table 5.10: The results of the mean calculations for both man and woman sides in the level 3 with the different clues

We can see a more despair result in the woman side. In the results where there were no clues or only 1 clue found, the values were lower comparing to the base, but in the ones where 2 clues were found there was a significant increase comparing to the base. In the man side the results demonstrate the same but have lower amplitude, being closer to the base value. These results show a positive impact of the "Presence of Physical Display of Clues" feature in both sides because the presence and acknowledge of the "Presence of Physical Display of Clues" resulted in an increase of the words guessed and a higher fluency.

Although the results in the level 6 were not that different, the clue was still present, and the results showed that:

	Level6With0Clue	Level6With1Clue	Level6With2Clue
Man	6,67	6,92	7,83
Woman	6,2	7	7,63

Table 5.11: The results of the mean calculations for both man and woman sides in the level 6 with the different clues

We can see an increase as the clues were found, which again shows a positive impact towards the player's fluency.

In the variance and standard deviation calculations the results for the woman and man side were the following:

	Level1	Level2	Level3	Level4	Level5	Level6
Man	1,98	2,53	1,51	1,86	3,64	2,98
Woman	2,43	3,36	1,90	1,94	3,65	2,94

Table 5.12: The results of the standard deviation calculations for both masculine and feminine

	Level1	Level2	Level3	Level4	Level5	Level6
Man	1,41	1,59	1,23	1,36	1,91	1,72
Woman	1,56	1,83	1,38	1,39	1,91	1,71

Table 5.13: The results of the variance calculations for both masculine and feminine

The results here show a little difference in some levels. The overall results show more disperse results in the woman side. The results vary the most in the levels 1, 2 and 3, but the values still show in both sides a bigger dispersion in the levels 2, 5 and 6.

Apart from the level 4, which was already set as a positive impact, the level 3 in the man side shows a positive impact, having a mean above the level 1, as seen earlier, and a significantly low value of variance/deviation.

The last calculation shows the difference between the CV (coefficients of variation):

	Level1	Level2	Level3	Level4	Level5	Level6
Man	29,66	28,15	25,54	24,97	25,52	23,76
Woman	31,34	32,23	30,17	24,62	24,96	23,92

Table 5.14: The results of the coefficient of variation calculations for both masculine and feminine sides

The results show a bigger dispersion of results in the woman side, especially in the levels 1, 2 and 3. These results are very close and the levels 4, 5 and 6 still show the lower values, like the results together. One result proving what said earlier, is the CV in the level 3 for the man side, that is very low, showing a positive impact of the "Presence of Physical Display of Clues" comparing to the woman side.

5.3 Validation and Discussion

The whole propose of the results are to prove if the hypothesis were not rejected, which can be checked by the following graphs:

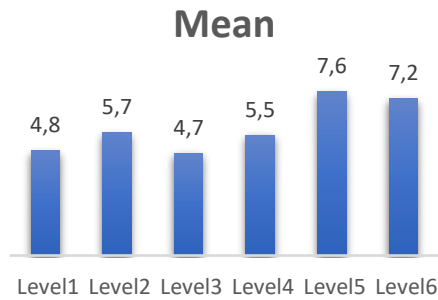


Figure 5.2: *The results of the mean for all the results*

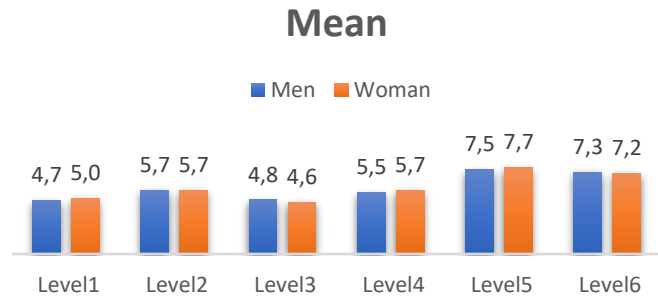


Figure 5.3: *The results of the mean for both Man and women sides*

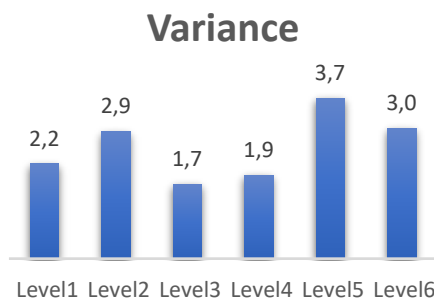


Figure 5.4: *The results of the variance for all the results*

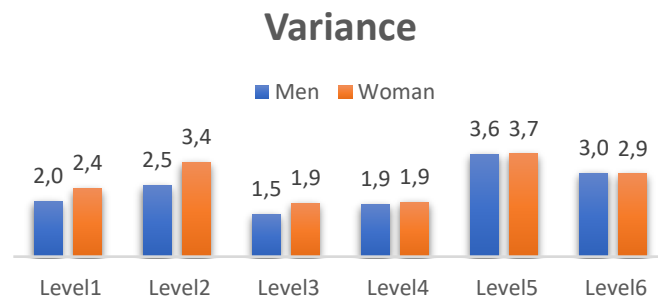


Figure 5.5: *The results of the variance for both masculine and feminine sides*

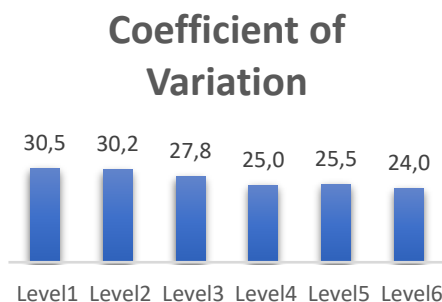


Figure 5.6: *The results of the coefficient of variation for all the results*

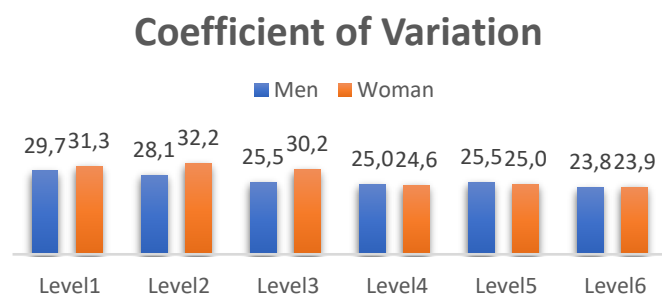


Figure 5.7: *The results of the coefficient of variation for both masculine and feminine sides*

The Hypothesis

H1. There is a significant relation between the "Presence of Cool Colours" in the video game environment and video game player's the fluency in creating novel and meaningful words (fluency in creative idea generation).

This hypothesis was not rejected based on the mean and the coefficient of variation from graphs 1 and 5. There was a significant increase in the mean comparing to the control level.

H2. There is a significant relation between the "Presence of Physical Display of Clues" in the video game environment and video game player's the fluency in creating novel and meaningful words (fluency in creative idea generation).

Although the level 3 didn't show the best results in an overall analysis of the data, it had another variable to have in account, which was if the clues were discovered or not. The following graphics show these results for the level 3:

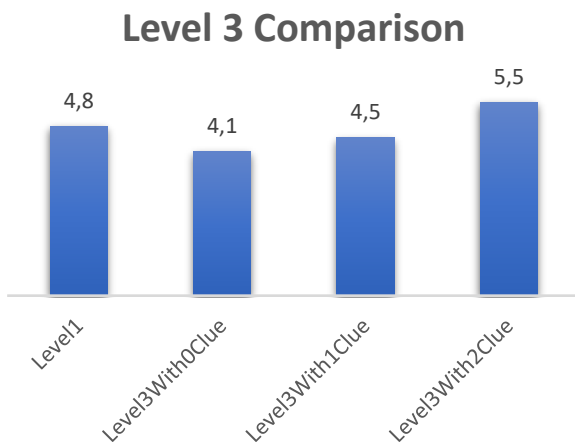


Figure 5.8: *The results of the mean in the level 3 with all the clues found for all the results*

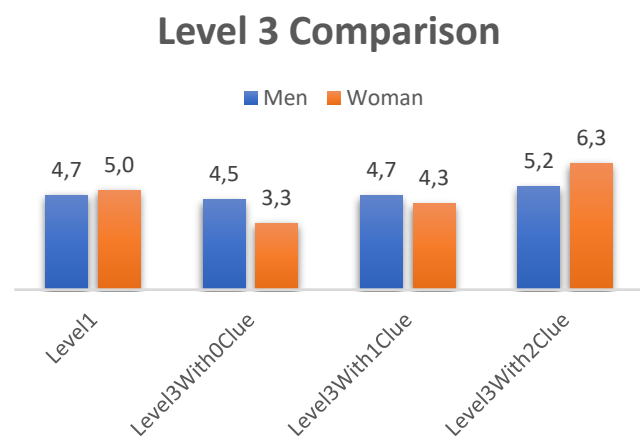


Figure 5.9: *The results of the mean in the level 3 with all the clues found for both masculine and feminine sides*

These results show an increase in the fluency of the player for the number of clues guessed, which comes to conclude that hypothesis 2 was also not rejected.

H3. There is a significant relation between the "Presence of Background Noise" (45 to 70 dB) in the video game environment and video game player's the fluency in creating novel and meaningful words (fluency in creative idea generation).

This hypothesis was not rejected based on the mean, variance, and the coefficient of variation from graphs 1, 3 and 5. This level showed the better equilibrium between the higher value in the mean and lower value in the variance.

H4. There is a significant relation between the "Presence of an Abstract Experience" in the video game environment and video game player's the fluency in creating novel and meaningful words (fluency in creative idea generation).

This hypothesis was not rejected based on the mean and the coefficient of variation from graphs 1 and 5. This level showed the higher improvement from the control level, although showed a larger variance.

H5. There is a significant relation between existence of a combination of creative idea generation's digital features in the video game environment and video game player's the fluency in creating novel and meaningful words (fluency in creative Idea generation).

This hypothesis was not rejected based on the mean, variance, and the coefficient of variation from graphs 1, 3 and 5. This level combined the features from all the levels and showed a very high difference in mean from the control level, and a low variance, resulting in a very positive result.

The results regarding the woman and man side also prove the hypothesises as they were not that different. The biggest changes, as seen in the graphs 4 and 6, were a bigger variation of values in some levels and a different range of results in the mean in level 3 graph 8, concluding that the "Presence of Physical Display of Clues" had a bigger impact on the woman side as the mean increased more with the players who found 2 clues.

Peer Validation

The hypothesis 1 refer to how the "Presence of Cool Colours" would interact with a person's creative idea generation. Our research concluded that they had a positive impact on the player, although, researchers Janetta Mitchell McCoy & Gary W. Evan in their paper " The Potential Role of the Physical Environment in Fostering Creativity" evaluated the "Presence of Cool Colours" and experienced a negative correlation between them and creativity [86]. This could indicate that the result could have been influenced by the experience of the player as it was the second level to be played. The researchers Ravi Mehta and Rui Zhu, in their study " Blue or

Red? Exploring the Effect of Colour on Cognitive Task Performances" [88], concluded that red colour (warm) had a positive impact when the task required detailed attention and blue colour (cool) when working with creative task, such as brainstorming, and this example supports the results as the task in hand was similar to a brainstorming as it consisted in word guessing, which validates de the result.

The second hypothesis involved the "Presence of Physical Display of Clues" and the results shown that the presence of them in the scene had a positive impact to the player. This is supported by researchers Mark Jung-Beeman et all that developed a similar study called "Neural Activity When People Solve Verbal Problems with Insight" [89]. They presented keywords (pine, sauce, crab) that could be formed into new words with a combination with "apple" (pineapple, applesauce, crab apple). They verified that a large group of people reached the "apple" word by watching the keywords, resulting in a positive effect of the "Presence of Physical Display of Clues".

The third hypothesis was the "Presence of Background Noise" in the scene. The results were very positive in this research and the paper "Is noise always bad? exploring the effects of ambient noise on creative cognition" by researchers Ravi Mehta, Rui Zhu and Amar Cheema [90] discussed the impact of noise to the creative cognition. They concluded that the noise can be disturbing when it's higher than 70 decibels, lower than that can enhance creativity and the ability to produce creative ideas. This is the case in the research, as the sound was background noise, not supposed to surpass the 50 dB range, which corresponds to a normal conversation.

The fourth hypothesis was related to the "Presence of an Abstract Experience", in this research was the alteration of the axis and the perception of the mirror, where the player would need to use the mirror to figure out where the letters were and then, when heading to the controller to play the game, had their controls switched. This had a positive, yet disperse, result in the players. Although no other studies were found with this exact experiment, psychologist Simone Ritter and her team developed an experiment called "Diversifying experiences enhance cognitive flexibility" [91] where they tested if unusual events would trigger creativity and the results shown that their abstract experiences broke the mental block and increased the cognitive flexibility, which supports the results received in the level 5.

The last hypothesis was if the combination of the various features would still have a positive impact. The level 6 results were very positive, having the least coefficient of variation which implied that were the results with the best mean and the least dispersion. Although, something to consider is that it was the last level, and the player had been "training" in the rest of the game, which could mean the result could be influenced by that also. The other works mentioned above proved that all these features could influence for the better the creativity, but the experience is something to consider.

5.4 Chapter's Summary

This chapter focused on the results and findings. The first section explained how the game was played, how did the results have been gathered and how the database was constructed, with the influence of invalid data and the multiple calculations that needed to be made. This section showed some graphics about the different ages and genders of the player that validly played the game.

Then the results were presented, and some considerations were taken. The first step was looking for the database as a whole, and display the values of mean, variance and coefficient of variation, and make some considerations about the results. Then, the database was divided in gender and the same calculations and considerations were done. The results would be later compared with the hypotheses.

The next chapter will make an overview of the work done in this research and give further details and considerations towards the results gathered in this chapter.

CONCLUSION

6.1 Summary

Promoting creativity among students is very important for a multitude of compelling reasons. To begin with, creativity stands as a foundational aptitude that equips individuals with the capacity to adapt and excel in a world marked by continual transformation. Whether applied in the realms of the arts, sciences, business, or daily life, creative thinking emerges as a valuable skill that not only unlocks new prospects and advancements but also reinforces the ability to navigate an ever-changing environment.

Video games, as a powerful technological tool, should not be set aside and used to integrate elements that foster creativity within their development. Recognizing the general influence of video games in modern society, it becomes imperative to see this as an opportunity not only for entertainment but also as a conduit for nurturing creativity. By infusing games with features that may encourage players to think critically, solve complex problems, and engage in imaginative exploration, we can use their potential to stimulate and enhance creative thinking. This intentional incorporation of creativity-promoting aspects in game design not only enriches the gaming experience but also aligns with the broader educational and cognitive benefits that gaming can offer, contributing to the cultivation of a more creative and adaptable generation.

This work set to find main features that when applied to a video game, would influence the players to think more creatively, and to improve their fluency (creative idea generation).

This chapter will explore the results, the hypothesis defined earlier in the paper and the relationship between the two. This chapter will also relate the results to the works already done in the topic. These followed by future works that could be done in the area, research challenges and difficulties, address future works within these limitations and even consider other targeted groups.

6.2 Objectives

The objectives defined in the first chapter of this research started as a ground level definition of what this work would achieve.

The first objective was to find research related to the theme initially defined. This was an easy task in papers regarding creativity, creativity amongst students and kids, creativity and technology, technology, and video games and even some papers that discussed some impact of the video games in the creativity. Although, the specific topic of finding features/aspects in a video game that had some connection with a person's creative thinking, was very hard to find as none of the papers found explicitly related both. Even so, the research helped defining the early keywords of the work, helped fitting this paper's topic in the studies already done, helped defining and searching for some possible features to study their impact, and defining not only genres of video games that had relation to the creativity but also existing video games that proved to have a positive impact on the players creativity.

The second step was defining the features, based on the previous research. The hypotheses were defined to later relate the results to the initial problem. Were defined 5 hypotheses, 4 of them for each feature, which in the game represented each level, and 1 final hypothesis for the combination of all of them. The features defined were the "Presence of Cool Colours" (level 2), "Presence of Physical Display of Clues" (level 3), "Presence of Background Noise"(level 4) and "Presence of an Abstract Experience" (level 5).

The third step was to define the importance of these features based on work previously done, analysing the results other papers had and comparing them with the hypothesis to establish a relation. This step required to define the impact of this features in fields such as technology, creativity and innovation.

The fourth step was developing the video game itself. The game started with a panel that asked the player a name, an age and a gender (M/F). The game then was divided in 6 levels, the first being the "influence-free" level where there were no features influencing, the levels 2, 3, 4 and 5 included each one a feature, as specified earlier, and the level 6 was a combination of all of them. The game also had an open area in the middle of the map with an interactable character, serving as a shop, that allowed the player to customize his character based on their performance. Each level was composed of 8 objects that contained a letter, and a game controller that opened the "Word guessing game". After the player finished the level, the number of words he guessed would be converted to coins to use in the shop. At the end of the game, the player's results were sent to an email.

The last step was to process the results received, with the valid ones make a database to work on and do the calculations defined in the methodology chapter. The calculations were not only made for the whole set of data but also for the set divided by gender, to check if there

were any differences. The database was made with 81 valid results, with 46 man and 35 woman. The calculations made to analyse these results were the mean, the variance and standard deviation and the coefficient of variation. There was another variable retrieved from the game, as mentioned in the previous chapters, that was in the level 3, the mean values for the players who found 0, 1 or 2 clues. The results have given a lot of information about the features, since the comparison between the level 1 and the rest gave clear evidence on if a feature had a positive or a negative impact on the person's creative idea generation and, therefore, their creativity. These results could also be influenced by the experience, as the player, throughout the game, could get more used to the type of game and discover more words.

6.3 Applications in the Real World

This research had the goal to connect creativity, which is so important in the modern era, with video games, that are more popular than ever. The ability to foster creativity with a program or software is something that every modern company is looking for, and to be able to do it with video games opens a lot of doors.

A very possible application with video games and creativity could be in education, in a stage where every person needs to be able to be creative and apply that creativity in the future. An example comes from Punya Mishra and a research group where they used a program used by Xbox 360 video game console to understand a math problem [49]. Introducing processes that can impact the students into having more ideas, more diverse ideas, being able to come up with solutions, and to think critically, can help them throughout their journey, in future academic works, in their jobs and even in their own life. An using video games, which is something that they are familiar with, could even be easier to apply.

Another area where this work could be impactful could be psychology, where there are so many applications where video games could be beneficial. Researchers Mark D. Griffiths et al talk in their work "Video games as therapy: A review of the medical and psychological literature" [101] of many applications for video games, from experiencing something new and out of their ordinary which could lead them to being able to open up and express themselves, to use the video games as a tool to keep them focused for a long period of time without making them unaware of the surroundings, to even use the games as a motivational tool and keep them happy and doing something that brings them joy. This applied with the features discussed in this research could have a great impact on some people.

6.4 Limitations

Research as complex as this can have multiple factors that can serve as a limitation. Some can classify limitations as problems gathering data and processing the data, others can look at limitations as those factor features no one can control that place restrictions in the methodology or conclusion.

Some limitations may present themselves as:

1. **Sample Size and Generalizability:** The population in this research work was very limited and specific, which may limit the generalizability of this research findings to a broader population.
2. **Participant Characteristics:** Most of participants of this research were university students, young, with experience of gaming, that may not be representative of the general population, it could limit the applicability of our findings to other groups.
3. **Duration of the Study:** The research was conducted over a short period; it may not capture the long-term effects of playing creativity-enhancing video games.
4. **Measurement Tools:** The accuracy and reliability of the tools that this research work used to measure creativity may have limitations.
5. **Subjective Nature of Creativity:** Creativity is a complex and subjective concept. Author acknowledges that assessing creativity is inherently challenging and may involve some level of subjectivity.

Other challenge that influenced this work were the way the data was gathered. With the COVID-19 pandemic, the ability to go to the university and talk to students to make them play the game to gather results became difficult and an alternative needed to be made. That's where the idea of sending the game to a drive for the people to download it can from, and although it was a very positive approach, had his own limitations and gave a big number of invalid results.

6.5 Future Works

This work was done with the intent of selecting a group of features that was large enough to build a game and try to take conclusions but there's other options of research that could differentiate the results from this work. For example:

1. **Conducting longitudinal studies** to investigate the long-term effects of playing creativity-enhancing video games. This would help in understanding how the benefits of gaming evolve over time and whether they have a lasting impact on creativity.

2. Expanding the participant pool to include a more diverse range of individuals, including different age groups, cultural backgrounds, and levels of gaming experience. This would provide a more comprehensive understanding of how video games affect creativity across demographics.
3. Conducting comparative studies that analyse the impact of different types of video games on creativity. Compare, for example, puzzle-solving games, open-world exploration games, and simulation games to assess their relative effectiveness in enhancing creativity.
4. Exploring the integration of video games into educational settings to assess their potential as tools for fostering creativity in students. Investigating how games can complement traditional teaching methods.
5. Focusing on specific game design elements that contribute to enhancing creativity. Investigating which game mechanics, challenges, or narrative structures are most effective in promoting creative thinking.
6. Exploring how collaborative and multiplayer gaming in digital environment experiences can impact creativity. Investigating whether digital teamwork and social interaction within video games contribute to creative thinking.
7. Conducting neuroscientific studies to gain insights into the neural mechanisms involved in creativity enhancement through video games.
8. Developing guidelines for game designers to create effective creativity-enhancing games, considering the limitations and insights from previous research.
9. Exploring the practical application of the creativity skills acquired in video games to real-world scenarios, such as problem-solving, innovation, and creative thinking in professional contexts.

6.6 Chapter's Summary

This research was based on the question "*Can Video Games Increase Creativity?*". The goal was to find any features that could be inserted into a video game that would have a positive impact on the creativity of the player that was playing the game.

The research began with a phase of finding research that would support the idea and motivate it, hoping to find an area where no investigation had been made. The area that seemed to lack information was based on specific features, such as colour, sound, etc., and their impact on creativity when incorporated into a video game. So, with the area of research found, hypotheses were formulated and the methodology was defined, as Design Science Research Methodology, giving a place to start the development. Which resulted in a video game that consisted of guessing words, while getting access to a limited number of letters, which

could help measure an important value in the creativity area called fluency (capacity to generate many creative ideas). This game would be then altered to incorporate in different levels features such as: "*Presence of Cool Colours*", "*Presence of Physical Display of Clues*", "*Presence of Background Noise*", and "*Presence of an Abstract Experience*". The game was then sent to research participants so they could try and provide the research some results. The results were collected, filtered, used to do some calculations, and stored in a database to be analysed.

With the database ready, some tables of results and graphics were made. Then the hypotheses early defined were brought to be compared with the results and the conclusions proved all the hypotheses were not rejected, showing the most positive results in the levels where the "*Presence of Cool Colours*" and the "*Presence of an Abstract Experience*" were presented. This was a very positive result regarding this population.

This final chapter focused on resuming the work, making the final considerations, and making some analyses on what applications this work could have on the real world. Also, on what limitations had presented to this work and on what future works could be done to complement these findings. This brings an end to this project and to this research.

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7 ANNEX

7.1 Link to the game

The game is deployed in a website and it's ready for anyone to play.

The link is the following:

<https://girusso.itch.io/kuri-and-the-vaspt-kingdom>

7.2 Manual of the game

Below we have the manual of the game.

KURI

The Word Game

This game was developed for research purposes. This was included in an experiment that helped getting results for the author's master thesis "Developing videogames to increase creativity."

Gameplay

The objective of the game is to find as many words as possible with 8 letters in 45 seconds. The game has a total of 6 levels, and the player must unlock them 1 level at a time.

In every level, the player must collect the letters located inside little cubes like this:



For every word the player guesses correctly, gets 1 coin.

In the centre of all the levels the player can interact with an NPC (non-playable character) and exchange coins for cosmetics for the character.

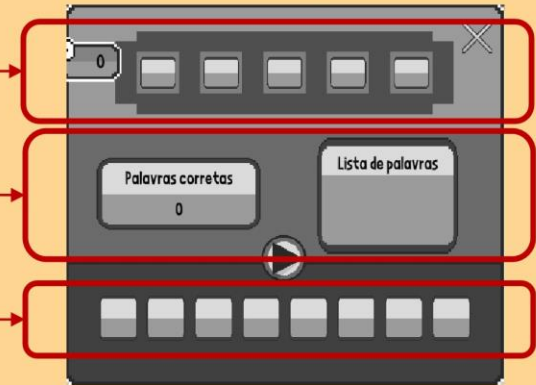


Word Game

Slots for letters

Words found

Letters acquired



Controls



Movement
W – Up
A – Left
S – Down
D – Right



Mouse
Left click – Interact



2022

GUILHERME RODRIGUES RUSSO

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