

FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Neuropal - Mobile game for preventing spinal cord injuries

Luísa Freire



Mestrado Integrado em Engenharia Informática e Computação

Supervisor: António Coelho

Co-Supervisor: Joana Barros

Co-Supervisor: Pedro Cardoso

July 22, 2021

Neuropal - Mobile game for preventing spinal cord injuries

Luísa Freire

Mestrado Integrado em Engenharia Informática e Computação

Approved in oral examination by the committee:

Chair: Prof. Bruno Sérgio Gonçalves Giesteira

External Examiner: Prof. Nelson Troca Zagalo

Supervisor: Prof. António Fernando Vasconcelos Cunha Castro Coelho

July 22, 2021

Abstract

Annually, around 250 000 to 500 000 people suffer spinal cord injuries, mostly due to preventable situations. Nonetheless, the widespread availability of information, is not sufficient to promote behavioural change, and as such, it is necessary to provide motivation, competences and autonomy.

Serious games and gamified applications are increasingly being used to achieve an engaging environment as game elements and game design techniques can work as drivers towards behaviour changes. Digital games have natural, engaging mechanics along with immersive surroundings and work as an emotional stimulus when used with a purpose other than entertainment. When outlined with the player's needs as the focal point, it can achieve a reliably alluring experience that can be steered towards behavioural change.

This project aims to increase literacy and promote a behavioural change amongst children between the ages of eight and twelve regarding the prevention of risky situations. For this purpose, it has been devised a full game organised into six levels, each with five main interactions. These interactions are accompanied by small challenges to add a layer of increased difficulty without discouraging the intended behaviours. Additionally, the game includes an online mode, allowing users to register their score and compare it within a community leaderboard.

The developed game will be playable on mobile for both Android and iOS devices. To assess the game design, the testing phase has two primary moments: a preliminary and a post-game questionnaire. The former validates the audience's knowledge of the given matter, while the latter ascertains the game's overall enjoyment. Collectively, they allow a greater understanding of how this application performs as a whole and if it is able to promote a positive behavioural stimulus for the intended matter. The results' analysis validates this premise, as the overall response was very positive, and the data perceives that the game mechanics fulfil their theoretical goal.

Keywords: serious game, behavioural change, games for health, game design, mobile game

Resumo

Anualmente, cerca de 250 000 a 500 000 de pessoas sofrem lesões na medula espinal, maioritariamente devido a acidentes passíveis de serem evitados. Considerando a difusão de informação do mundo atual, o seu acesso assume-se como um dado adquirido. Contudo, esta massificação não é suficiente para promover mudanças comportamentais; daí tornar-se essencial fornecer competências e autonomia.

Os jogos sérios e as aplicações ludificadas são cada vez mais usados para proporcionar um ambiente deveras cativante onde as partes do jogo e as técnicas de design contribuem para potenciar mudanças comportamentais. Os jogos digitais têm mecânicas naturalmente desafiantes que quando aliadas a um ambiente imersivo e usadas com um propósito para além do entretenimento, enaltecem as emoções. O alinhamento com as ideias do jogador pode ser usada em prol das mudanças comportamentais, ao alcançar uma experiência consistentemente envolvente.

Este projeto pretende aumentar a literacia e promover mudanças comportamentais tendentes à prevenção de situações de risco em crianças com idades compreendidas entre os oito e os doze anos. Para este propósito, foi idealizado um jogo completo com seis níveis, cada um com cinco interações principais. Estas interações serão acompanhadas de pequenos desafios, de modo a aumentar o nível de dificuldade, sem comprometer o alcance dos comportamentos desejados. O jogo também inclui um modo online que permite o registo da pontuação dos utilizadores e a respetiva comparação com outros jogadores.

O jogo desenvolvido estará disponível para dispositivos móveis, tanto Android como iOS. De modo a validar as mecânicas do jogo, a fase de testes tem dois momentos principais: um questionário preliminar e um pós-jogo. O primeiro permite perceber o grau de conhecimentos dos jogadores relativamente às matérias abordadas, enquanto o segundo averigua a experiência global no jogo. A junção destes questionários permitirá compreender se o jogo desencadeia mudanças positivas nos seus utilizadores. A análise de resultados confirma esta premissa, tendo em conta a reação positiva por parte do público alvo. A informação proveniente dos testes também valida a ideia por detrás das mecânicas de jogo.

Keywords: jogos sérios, mudanças comportamentais, jogos para a saúde, desenvolvimento de jogos, jogo móvel

Acknowledgements

I express my sincerest gratitude to everyone who helped and accompanied me on this journey, as the writing of this dissertation was an important academic and personal milestone.

I would first like to thank my supervisor, António Coelho, and my co-supervisors, Joana Barros and Pedro Cardoso, for their help, guidance and availability throughout this dissertation, and to professor Eduardo Magalhães for all of his advice and assistance.

To Valter Abreu from the sound team and the FAVO studio as the design team, for their efforts in complying with my timelines.

To my mom, my dad, my sister and my aunt for their immeasurable support and care during my years of study and during the development of this thesis.

To my friends, who never hesitated to aid and support me no matter the reason.

And finally, to everyone who playtested the game, for their feedback and availability.

Luísa Freire

*“They serve as entertainment, a powerful form of art,
a peaceful escape from the chaos of modern life,
and a way to have experiences that are impossible otherwise.
Through these means, games have a powerful and growing influence on culture.”*

Eric Barone [1]

Contents

1	Introduction	1
1.1	Context	1
1.2	Motivation	2
1.3	Objectives	2
1.4	Research Questions	2
1.5	Contributions	2
1.6	Document Structure	3
2	Games for Behaviour Change	5
2.1	The drivers of behaviour change	5
2.1.1	Behaviour change theories	5
2.1.2	Extrinsic and intrinsic motivation	7
2.1.3	Motivation in related works	8
2.1.4	Conclusions	8
2.2	Gamification and serious games	9
2.2.1	Distinction between gamification and serious game	9
2.2.2	Serious games in related works	10
2.2.3	Conclusions	15
2.3	Summary	15
3	A serious game for behavioural change	17
3.1	Background	17
3.1.1	Prototype	17
3.1.2	Game elements relevant to the final idea	19
3.1.3	Pedagogical objectives	20
3.2	Project Description	20
3.3	Game Overview	20
3.3.1	Concept	20
3.3.2	Genre	20
3.3.3	Target audience	20
3.4	Gameplay	21
3.4.1	Core mechanics	21
3.4.2	Player controls	23
3.4.3	Inventory	23
3.4.4	Challenges	23
3.4.5	Points	25
3.4.6	Leaderboard	26
3.4.7	Quiz	26

3.5	Levels	27
3.5.1	Level 1: The Pool Party	28
3.5.2	Level 2: The Escape	28
3.5.3	Level 3: The Bridge	31
3.5.4	Level 4: The Port	32
3.5.5	Level 5: The Voyage	33
3.5.6	Level 6: The Reunion	34
3.6	Story and progression	34
3.6.1	Storyline	34
3.6.2	Game setting	35
3.6.3	Characters	35
3.7	Tools and resources	37
3.7.1	2D Assets	37
3.7.2	Sound	38
3.8	Visual and audio style	38
3.8.1	Main menu	39
3.8.2	Prompts	40
3.9	Game engine	41
3.10	Summary	41
4	Game logic	43
4.1	Player	43
4.2	Game controller	44
4.2.1	Quiz controller	45
4.2.2	Sound	46
4.2.3	Prompt manager	47
4.3	Items and inventory	47
4.4	Challenges	48
4.4.1	Puzzle challenge	48
4.4.2	Sequence challenge	48
4.5	Camera movement	49
4.6	Scenes manager	49
4.7	Localisation	49
4.8	Save system	49
4.9	Backend	50
4.10	Game Analytics	51
4.11	Tweening library	51
4.12	Summary	52
5	Testing	53
5.1	Preliminary questionnaire	53
5.2	Game phase	55
5.3	Post-game questionnaire	57
5.3.1	Preparation	57
5.3.2	Results analysis	58
5.4	Conclusions	63

6	Conclusions and Future Work	65
6.1	Conclusions	65
6.2	Limitations	68
6.3	Future work	69
	References	71
A	Level's Schemes	75
B	Kahoot questionnaire	83
C	Used adaptation of the Game Experience Questionnaire	87
A	FBM License	93
B	Original Game Experience Questionnaire	97

List of Figures

2.1	Fogg Behaviour Model [2]	6
2.2	Gamification context as defined by S. Deterding et al. [3]	10
2.3	<i>iLift</i> gameplay moment [4]	12
2.4	<i>Grab2BeHealthy</i> gameplay moment [5]	13
2.5	<i>Play It Safe</i> gameplay moment [6]	13
2.6	<i>Festarola</i> gameplay moment [7]	14
2.7	<i>It's a Deal!</i> gameplay moment [8]	14
3.1	Early prototype first interaction	18
3.2	Early prototype quiz	18
3.3	Early prototype second level	19
3.4	Initial prototype screens	19
3.5	Highlight of a main interaction object. The highlight of the helmet has a subtle colour shift and an animated size change.	21
3.6	Types of interactions	22
3.7	Change of room mechanic	22
3.8	Accident sequence when crossing the banana peel without picking it up	23
3.9	Puzzle pieces location on a mockup from level 3	24
3.10	Colour puzzle found at level 2	24
3.11	Visual clue when gaining or losing points	25
3.12	Quiz screens	26
3.13	Introductory cinematic - Level 2 cutscene	27
3.14	Top floor interactions	29
3.15	Middle floor interactions	29
3.16	Bottom floor interactions	30
3.17	Level 2 screenshot with a bar full of interactions	30
3.18	Mockups of the interactions from level 3	31
3.19	Mockup of the second crosswalk interaction	32
3.20	Mockups of the interactions from level 4	33
3.21	Mockup of the environment from level 5	33
3.22	Game environments	35
3.23	Neuropal sprites	36
3.24	Mockup of Neuro	37
3.25	Mockups of NPC from level 3	37
3.26	In-game HUD	38
3.27	Main menu	39
3.28	Sub-menus	40
3.29	Different type of prompts	40

4.1	Game flow diagram	44
4.2	GameController logic	45
4.3	QuizController logic	46
4.4	PromptManager logic	47
4.5	Backend UML	50
5.1	Kahoot overall performance	54
5.2	Number of occurrences per accidents	56
5.3	Answers to the question "Were you able to complete the game's tasks?"	59
5.4	Answers to the question "Did you like the game environment?"	59
5.5	Answers to the question "Did you find the game challenging?"	60
5.6	Answers to the question "Relative to the number of activities, did you think that the game had"	60
5.7	Answers to the question "What did you think of the game experience?"	61
5.8	Answers to the question "Were you able to complete the game's tasks?" organised by ages	62
5.9	Answers to the question "Did you find the game challenging" organised by ages	62
A.1	Level one scheme	76
A.2	Level two scheme	77
A.3	Level three scheme	78
A.4	Level four scheme	79
A.5	Level five scheme	80
A.6	Level six scheme	81

List of Tables

2.1	Behaviour change theories key points	7
2.2	Motivation types explored in related works	8
2.3	Serious games and some of their main elements in related works	11
3.1	Number of points per game action	25
5.1	Kahoot demographic information	54
5.2	Mapping GEQ modules to a single idea	57
5.3	Post-game questionnaire demographic information	58

Abbreviations

FBM	Fogg Behaviour Model
FEUP	Faculdade de Engenharia da Universidade do Porto (Faculty of Engineering of the University of Porto)
GDD	Game Design Document
GEQ	Game Experience Questionnaire
HUD	Heads-Up Display
HTTP	Hypertext Transfer Protocol
LGP	Laboratório de Gestão de Projetos (Project Management Laboratory)
SDT	Self-determination Theory

Chapter 1

Introduction

Spinal cord injuries hold extensive consequences, all with the potential for jeopardising one's life [9]. Some symptoms include loss of sensory, motor and other body functions. Spinal cord injuries are likewise linked with the chance of developing secondary conditions which can have economic and social consequences. To avoid such infirmities, it would be relevant to understand the most common causes of these injuries and learn how to avoid them.

For the purpose of this dissertation, a serious game will address this gap of knowledge by creating an engaging environment to provide literacy that may promote behaviour change.

1.1 Context

The motivation for this dissertation originated from a project lead by the Institute of Molecular Medicine named "Targeting induced-senescent cells: a novel approach to promote spinal cord regeneration in mammals" ¹. This institute, alongside Associação Viver a Ciência ², are the main project promoters. This game, as the investigation project, is being sponsored by the Fundação "la Caixa" ³.

The game's stakeholders include the project's supervisor, professor António Coelho and co-supervisors professor Pedro Cardoso from the University of Aveiro and Joana Barros from the Associação Viver a Ciência. It counted with the collaboration of professor Eduardo Magalhães and Valter Abreu for audio and sound, and FAVO Studio ⁴ for the production of the game's visuals and animations.

¹<https://imm.medicina.ulisboa.pt/pt-pt/investigation/laboratories/leonor-saude-lab-2/#intro> [Access date: May 06, 2021]

²<https://www.viveraciencia.org/pt/> [Access date: May 06, 2021]

³<https://fundacaolacaixa.pt/pt/> [Access date: May 06, 2021]

⁴<https://favostudio.com> [Access date: Jun 17, 2021]

1.2 Motivation

Every year, many people suffer spinal cord injuries which hold several setbacks. As most of them happen due to preventable accidents, it becomes a matter of correcting the behaviour that led to the accident, hence the value in understanding behaviour change theories as they arise as guidance on effecting change. A category of games has risen, linked to the spreading of purposeful information: serious games [10]. They can unfold as the means to materialise these theories and have indeed proven to be a powerful tool to promote change along these lines.

The problem then lies in the absence of an interactive way to present actions endangering the spinal cord. For this reason, the stated game could address these matters and provide an environment favourable for the increase of literacy in this regard.

1.3 Objectives

This dissertation aims to work upon an existing prototype and devise a full serious game to increase literacy among children between the ages of eight and twelve in the aforementioned topic. This game's architecture will encompass six levels, with an increasing number of challenges to immerse the player in an exploratory environment. Each level will have five behaviours that the player should safely accomplish to carry on. Thus, the game's difficulty level lies not in the safe behaviours but in exploring the world to enact those behaviours. The game will also be tested with real-life players to validate the proposed solution.

1.4 Research Questions

To create a serious game for behaviour change, it is important to understand the context of this game, regarding the field of research and its fundamentals. As such, some research questions were raised, to aid the initial study and the validation of the game:

- What triggers behaviour change for avoiding risky behaviours?
- How can we design a serious game capable of increasing literacy of behaviours that may lead to spinal cord injuries?
- How to design a game adequate for children between the ages of eight and twelve-years-old?

1.5 Contributions

As explained, this project intends to devise a game capable of creating an environment suitable for increasing literacy regarding preventing injuries in the spinal cord. Thus, its main contributions to the area of study are:

- Enumeration of the triggers for behavioural changes tied to a gaming environment;

- Implementation of a serious game to promote literacy regarding dangerous behaviours for the spinal cord;
- Analysis of the impact of a serious game in the increase of literacy.

1.6 Document Structure

The present document holds five more chapters beyond the present chapter, which includes introductory topics alongside the project's context, motivation, and objectives. Chapter 2 explores the state of the art, focused on behaviour change theories, gamification and serious games in related works. Afterwards, Chapter 3 explains the developed application. Chapter 4 presents the game logic from a programmatic view. The testing phase is reported and analysed in Chapter 5. To enclose this document, Chapter 6 provides the conclusions and future work.

A demo of the current game version can be found at:

<https://drive.google.com/drive/folders/1yuwzS-IaaFwImm7NFx85L5o-AJzXZuLr?usp=sharing>

Chapter 2

Games for Behaviour Change

The causes of spinal cord injuries often lack acknowledgement, requiring increasing literacy in a more beneficial form. Being the knowledge of a particular subject, literacy can be spread through books, articles, illustrations and other informative fashions. While reliable options, they lack the interaction that often stimulates users, a common factor in the gaming world.

Games are naturally engaging environments and render meaningful learning opportunities in an immersive and interactive fashion [11]. The design elements provide immediate feedback which emphasises the passing of information by doing, rather than by reading [6]. Further research states the complexity that games can provide when dealing with the processing of information and hence the potential to support skill acquisition and behaviour changes [12]. For these reasons, the design of a game requires both understanding of the mechanical tasks inferred as well as the theories on which to sustain the gameplay.

2.1 The drivers of behaviour change

The domain of game and game-related activities are commonly recognised to bring out a motivational flow of rewards and challenges, with a sometimes manipulative design. An increasing number of games and gamified apps have been exploring why and how persuasion works to foster a change of certain behaviours [13]. The main idea is to achieve an environment that shapes human behaviour supported by known theories, without discouraging the user or the context on which the user will be included [14].

This section explores two theories that further analyse how people are pursued to attempt different actions and incite the suitable type of motivation.

2.1.1 Behaviour change theories

Understanding what drives human actions is an important aspect of designing persuasive environments. The Fogg Behaviour Model (FBM) [15] defines three factors required for a behaviour to

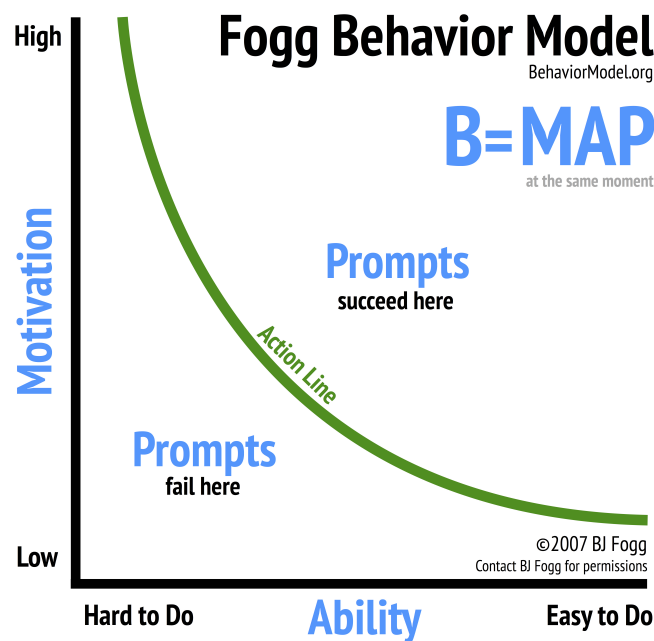


Figure 2.1: Fogg Behaviour Model [2]

occur: motivation, ability and a trigger. This model presents a conceptual view of these factors and underlines the relationships between them as shown in Figure 2.1. The balance between motivation and ability can be translated into game design fundamentals. An arduous activity met with a high motivational factor will be attempted by the individual, and the opposite principle likewise applies. Even if someone is not keen on doing something, low levels of difficulty may compel them to do it. However, these conditions alone do not effect change as the behaviour needs to be prompted. The stated trigger is also a matter of timing: When the motivation levels and the ability ceiling are appropriate for enabling a behaviour, the trigger should occur. This idea can be easily translated into a serious game: As we provide a structured environment, where the skill level and the game objectives are increasingly challenging, the trigger becomes distinct game moments that will only enact change with the right balance of the aforementioned components.

Self-determination theory (SDT) is a theory focused on the motivation behind human actions. It defends that humans have inherent growth-oriented behaviours and highlights the importance of autonomous motivation [16]. This theory also states that people search for a sense of competence, connection to their peers, and autonomy to satisfy their psychological needs. Social support plays a fundamental role in sustaining this growth as our relationships and the social environment can influence our well-being. Notwithstanding, it is valuable to understand that self-determination can be influenced differently depending on the motivation sources. External compensation for an already self-desired action will diminish its value to the individual, thus feeling less in control of

stated behaviour. Still, unexpected positive reinforcement tied to the action's performance will increase one's confidence and motivation.

Table 2.1 underlines the main ideas from the theories mentioned above.

Table 2.1: Behaviour change theories key points

Theories	Key Points
FBM	A behaviour will only occur by the convergence of motivation, ability and a prompt
	Motivation and ability experience a trade-off relationship
SDT	Behaviour is guided by one's autonomy and personal goals
	Internal sources of motivation are directly tied to personal growth

2.1.2 Extrinsic and intrinsic motivation

Following Section 2.1.1, it can be recognised that both FBM and SDT understand the value of boosting one's motivation. The basic idea of motivation is often used to support self-initiation, persistence and mediate certain behaviours across various contexts [17], a principle particularly relevant when dealing with serious games.

Motivation can be classified as being extrinsic or intrinsic. The former is present when one is eager to accomplish a task for the sake of a reward [18]. A clear consequence is that this type of motivation will only last as long as the user is appropriately compensated. However, as previously explained, SDT states that spontaneous extrinsic motivators aligned with one's performance can have positive behavioural effects.

Intrinsic motivation refers to when an activity is done due to its own meaning and enjoyment [19]. It is a long-lasting behaviour, the type of motivation fomented by the SDT and aligned with one's sense of autonomy and personal goals hence proving its effectiveness: A personal goal is far more powerful than a goal established by others. This type of motivation is of high value for game design, as people may get invested in the learning process itself without being reliant on compensation [17].

In 2001, Deci et al. [20] reviewed the relationship of extrinsic rewards and intrinsic motivation in an educational context. Their study followed a recent meta-analysis on the effects of extrinsic rewards for educational policy by the same authors [21]. Their article states that tangible rewards, both material and symbolic, lower intrinsic motivation levels, especially in school-aged children. In contrast, verbal rewards in an informational format, have a positive effect on the younger students. Further analysis indicates that, instead of focusing on rewards to increase motivation, it is more beneficial to develop interesting learning activities, where the students have a sense of

autonomy, and the tasks are appropriately challenging. These results are aligned with the aforementioned ideas: extrinsic rewards independent of the activity can be harmful to one's learning process, whereas intrinsic factors that do not control the user are valuable for one's motivation.

2.1.3 Motivation in related works

Festarola by Rodrigues et al. [7] used a serious game to strengthen problem-solving strategies and promote self and shared regulation learning. The game's design of a party that requires teamwork and individual activities allowed the students to reflect on the relevance of topics presented in class. By creating a game with a relatable topic, the students felt more motivated to perform the required tasks and thus get involved in new problem-solving strategies.

In a similar approach, the project *iLift* aims to train health professionals in lifting and transfer techniques. Kuipers et al. [4] developed a game to work as an autogenous trigger for a behavioural change system. The game was designed so that it does not clearly guide the player towards the required behaviours. Instead, the player explores the game at its own will and sets in-game goals as it best suits their playstyle. The compliance with the behaviours comes into play as the player must complete them to progress. As such, the player is intrinsically motivated to carry on. Furthermore, the game showcases a dashboard at the end of each session, enabling peer comparison, which may resemble an extrinsic motivational factor. However, as explored previously, when an external source of motivation, such as the dashboard, is aligned with the player's personal goals, it carries intrinsic value to the individual.

The game *Grab2BeHealthy* by Ihsan et al. [5] was designed to increase awareness of diabetes. The game's aim is to grab the healthy food as it shows on screen. The player is rewarded or penalised depending on the type of food grabbed, emphasising the score element.

Table 2.2 showcases the kind of motivation primarily supported by each of the previously mentioned games. ¹

Table 2.2: Motivation types explored in related works

Related work	Motivation type explored
<i>iLift</i> [4]	Intrinsic
<i>Grab2BeHealthy</i> [5]	Extrinsic
<i>Festarola</i> [7]	Intrinsic

It should be noted that it is not a linear task to separate intrinsic and extrinsic motivation inside a game context. As different people have different goals, game elements' perception and value will vary, preventing the feature's effects from being strictly defined.

2.1.4 Conclusions

Game design relays on an immersive environment to provide meaningful gameplay to its players. As such, players need to feel compelled to fulfil the game's objectives. FBM highlights a balance

¹Further information regarding the aforementioned games can be found in Section 2.2.2.

of motivation and ability in the foundations of the prompt to captivate the user. By doing something small and manageable, one performs it successfully without being highly motivated. In like matter, one can feel propelled to engage in an arduous activity, if their desire is met with equal strength. SDT, by stating that people are driven by their necessities, explains the value of intrinsic motivation, without altogether disregarding extrinsic motives to incite a behaviour. The key-factor is maintaining a sense of competence in an autonomous environment, where one feels in control.

On the whole, understanding the psychological aspects that may impact behaviour change, provides game design with some guidelines to better suit the intended audience.

2.2 Gamification and serious games

As it has been explored thus far, behaviour changing theory can be contextualised in game design. First and foremost, a game should be distinguished from play. A game is a structured, interactive activity with an explicit set of rules, where a player must overcome challenges to achieve a pre-established goal [3]. Play has a somewhat looser interpretation as it denotes an improvisational environment, without the same structure of a game, and that does not have an exact outcome. Moreover, as game techniques further develop alliances to a variety of areas beyond game design, gamification arises as a solid concept [19]. In this respect, it grows in importance to understand the differences between gamification and serious games.

2.2.1 Distinction between gamification and serious game

Gamification can be formally defined as the use of game elements in non-game contexts [3], but its conceptualisation can be challenging to identify given its subjectivity. Figure 2.2 provides a possible contextualisation of this topic by S. Deterding et al [3]. It is crucial to understand gamification as parts of the gaming scene that maintain the same structure from game design, never fully crossing to a playful design. This latter can be naturally connected to more improvisational and free activities. Gamification is inherently connected to games which, even though included in the broader category of playing, have a more goal-oriented approach. The use of game design techniques implies understanding the user as a player, as someone whose efforts will alter the final result, therefore requiring the creation of an experience that keeps them engaged.

Some of the most used game patterns include points, badges, and leaderboards [22]. Points provide immediate feedback whilst giving a sense of progress in the game; badges consist of the fulfilment of optional goals outside the extent of the main activities [23], and leaderboards work as comparative metrics. Although these patterns contribute to an enjoyable environment, overuse of rewards can lower intrinsic motivation levels. The user becomes dependent on external rewards to keep on playing, and an arbitrary threshold on how much one can progress is created [24].

Given the scope of gamification, it is also relevant to analyse two prevailing branches of this field, as defined by Nicholson [25]: a reward-based approach and a user-based approach. The former can be understood as the simpler variant to implement where the use of points and points thresholds is commonly shown as the application's gamification element. It provides immediate

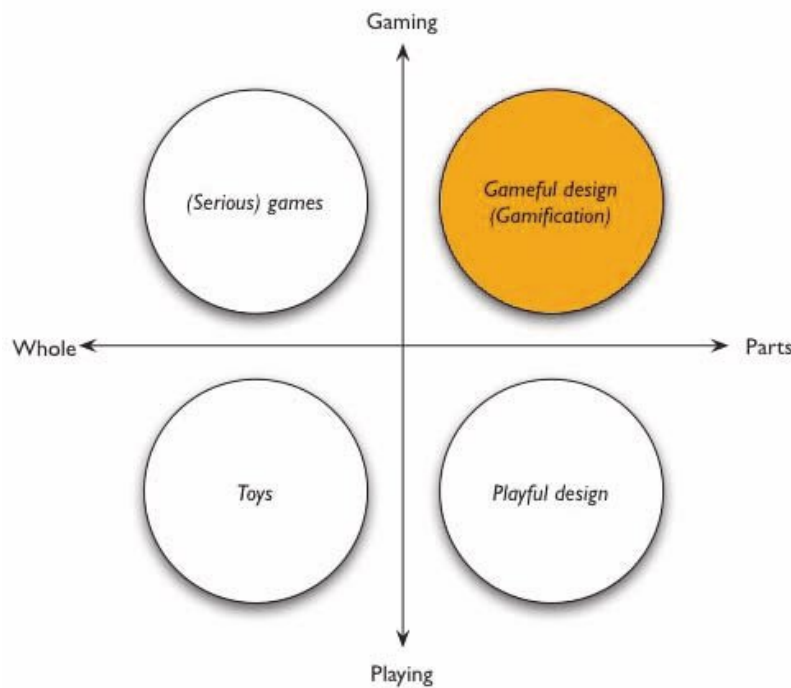


Figure 2.2: Gamification context as defined by S. Deterding et al. [3]

effects on the user and is ideal for short-term activities, as this gamification type is inherently connected to extrinsic motivation. However, the second approach, user-based gamification, can utilise the game elements in a less time-sensitive matter. Nicholson explains that through the addition of meaning to other applications components, the gamification features improve internal motivators, therefore empowering the user instead of controlling them. This latter approach of gamification then carries value when considering the implementation of game elements, as they connect to the player in a meaningful way, with long term benefits.

Serious games are perceived as games with a purpose other than entertainment, not as games for learning and training [10]. Being a digital game, it possesses one's characteristics: a set of rules, a length of challenges and a victory condition. A game is expected to be fun, thus devising an inherent expectation to provide a sense of enjoyment. Once again, we enter the spectrum of intrinsic motivation, the long-lasting type of motivation, and the kind that shows excellent engagement levels [26].

2.2.2 Serious games in related works

The use of game elements, either as a whole or as isolated parts, has been a growing trend in the learning industry [11] [27]. It is known that digital games long for active participation from the player, and so, the standard paradigm of learning can capitalise this platform [28].

Based on an analysis of related works, several serious games were highlighted alongside a few of their game elements to ascertain their usefulness, as shown in Table 2.3. Points tend to be

a rather popular game element, supported by the good effects its immediate feedback provides. Further analysis of the points gained and why they were gained, can provide insight into how the intended behaviours were achieved. Feedback, solely as a response to one's performance, is another conventional game element useful for its informative side and versatility. It can guide the player in their endeavours and provide some knowledge on the intended behaviour [4]. A less directional use of feedback yields the effects of the accomplished action but lacks showcasing the correct path, letting the player find out for themselves.

Table 2.3: Serious games and some of their main elements in related works

Related work	Highlighted game elements	Effects on target audience
<i>It's a Deal!</i> [8]	Points and feedback (small preview of the consequences of each decision)	Players considered the game to be balanced and easy to play which correlates with the high scores
<i>iLift</i> [4]	Points and feedback (dashboard that analyses in-game behaviour)	Higher game scores comply with the desired behaviour. Multiple game sessions led to consistent similarity between game and dashboard scores
<i>Play It Safe</i> [6]	Points, narrative and feedback (showcase of the consequences of each action)	Playing the game increased the children's literacy in the area of cyber security
<i>Grab2BeHealthy</i> [5]	Points, achievements and feedback (tips)	High levels of acceptance towards an alternative platform to raise awareness for diabetes and game mechanics
<i>Festarola</i> [7]	Points, narrative and feedback (guidance and reflection of each activity)	Positive changes in mathematical reasoning and increase in awareness of problem-solving phases

These components alone do not create the full immersive experience but are a meaningful part of the whole of game design. *iLift* is a health behaviour change support system built upon persuasive design techniques by Kuipers et al. [4]. Focused on the correct execution of transfer and lifting techniques, this paper's game component applied a metaphorical re-contextualisation of these techniques. The game used a space colony context composed of a central area and two small domes, representing sub-levels of the game. In each sub-level, the player can fulfil tasks to win in-game currency used to improve the central area. The game is built with a series of tasks that encompassed the intended behaviours whose movements were always accompanied by visual clues. Afterwards, the game registered the performed motions and returned the corresponding feedback. Figure 2.3 exhibits the game interface when the player is asked to grab space sheep, the main activity of the first sub-level. On the top left corner lays a visual clue of the motion to guide the player when bending down to grab a sheep.



Figure 2.3: *iLift* gameplay moment [4]

The game resembles an open-world concept, as the player is free to choose which sub-level to visit. It allows the player to set personal goals, enabling a user-oriented context that increases intrinsic motivation levels as the player's actions are tied to their rewards. The dashboard element allows peer comparison, which the authors suggest can influence the player and the player's context. The desire to teach about transfer and lifting techniques is not displayed as a clear goal for the player. Instead, the progress in-game is controlled by compliance with the intended behaviours, and the dashboard presents an overview of the in-game results. Had the game exposed this intention to the player, it would become a training instrument, not a persuasive game. After multiples sessions, it could be observed that the results from both the game and the dashboard's score increased, thus implying that repetition was beneficial for assimilation of said behaviour.

A more straightforward approach of behaviour change was employed by Ihsan et al. [5]. They created a game entitled *Grab2BeHealthy*, which aimed to increase awareness of diabetes. The user is informed of the healthy and unhealthy foods beforehand, and during gameplay must grab the healthy foods as they drop down. An example of the game world can be seen in Figure 2.4. A sequence of tips is shown in between levels, to increase user literacy in the given matter. This approach was aligned with the previous project, as it likewise stated that repetitive actions reinforce the retention of the information.

Play It Safe is a game-based learning approach created by Zahed et al. [6], which can be understood as learning by using games in an educational environment. To test this game, experiments were led where the participants would learn about cybersecurity via three distinct environments: the game, reading and e-learning. Figure 2.5 showcases the latter environment. The game element revolves around solving security problems and mini-games to unlock clues to solve those problems. Results showcased that the game-based learning approach yielded the best results.



Figure 2.4: *Grab2BeHealthy* gameplay moment [5]

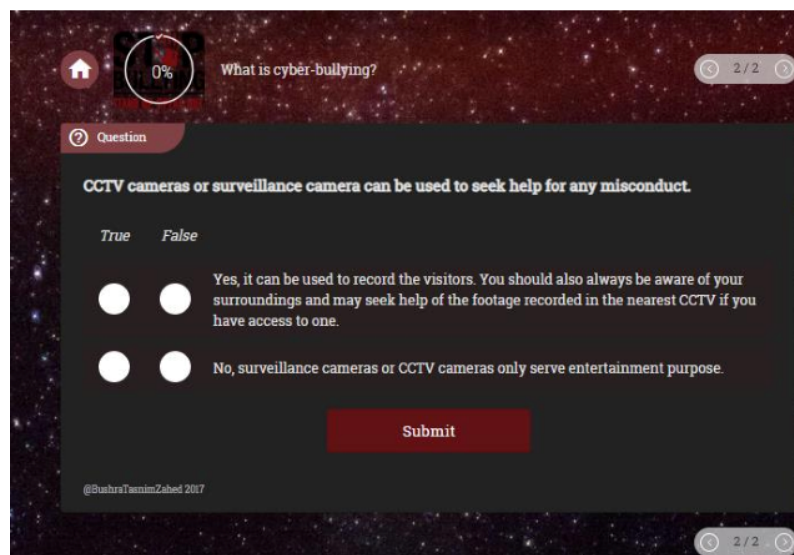


Figure 2.5: *Play It Safe* gameplay moment [6]

Rodrigues et al. [7] designed *Festarola*, a serious game to strengthen problem-solving strategies. The main gameplay is to organise a party. The action is divided into five activities, each symbolising a problem-solving phase. The party planning moment is illustrated in Figure 2.6. The test users were divided into groups. Throughout these phases, the users experienced shared and self-regulation learning by either discussing as a team the actions to follow or executing them themselves. The final results showcased an increase in collaboration skills and ability to complete problem-solving tasks.

In 2011, Guillén-Nieto and Aleson-Carbonell [8] discussed the learning effectiveness of *It's a Deal!*, a serious game used to teach intercultural communication to Spanish and British students in a business environment. The game is divided into six episodes, each with different business communication situations, such as placing an order and making a payment. Figure 2.7 exemplifies a business task. To complete each task, the player has to select the best response from a series



Figure 2.6: *Festarola* gameplay moment [7]

of options, followed by a small preview of its consequences. The player should then recognise the most beneficial and appropriate way to fulfil each task, thus achieving the intended didactic goals. The study concluded that this game serves as a useful learning tool for the desired intercultural communication. Moreover, the game's design and immersive environment contributed to the enhancement of the student's competence.

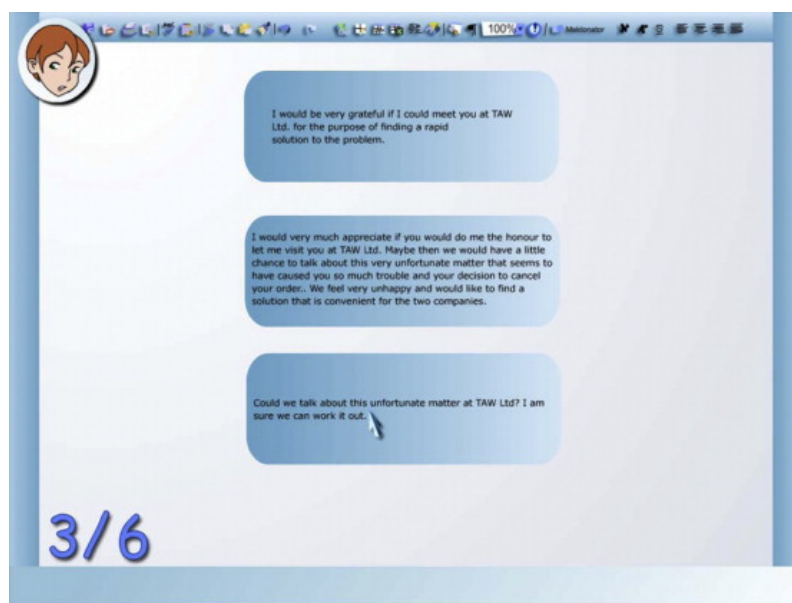


Figure 2.7: *It's a Deal!* gameplay moment [8]

Overall, game elements can be assessed as worth-having when attempting to enforce behaviour changes bearing in mind the undeniable side effects they can produce. When used without overflowing the player, they may raise awareness and aid the learning for the given topic. Furthermore, the game elements should exist with meaning to the player, not just as an extra feature. The player needs to feel connected to the game activities for the internal motivation factors to overlap the external rewards dependency [25].

2.2.3 Conclusions

Even with different formal definitions, serious games and gamification are hard to distinguish effectively given the share of game design elements [29]. Gamification adds game-like components to otherwise gameless applications while serious games function as digital entertainment with educational value. Nonetheless, these concepts share the common goal of intrinsically motivating the player to carry on a given activity.

Feedback and other game techniques create a behavioural flow where expected actions are reinforced through rewards, and less desirable ones are conditioned through consequences. While other works vary on behaviour contextualisation, most seem to suggest that action repetition is beneficial for effecting stated behaviour. Thus the gaming world is linked to the learning field in an enjoyable design.

2.3 Summary

This study on related works and topics showcased the value of game elements to affect behaviour change. Theories such as FBM and SDT simplify the complex understanding of human actions and lay down ideas with direct game design usability such as motivation, ability and autonomy. The first idea can be further expanded into extrinsic and intrinsic motivation. While the former relates to external rewards and the latter to personal urge, it should be noted that both carry value in games. External rewards can take the form of points, badges and leaderboards, all elements present in gamified applications, and when used with care and aligned with personal ambitions have a positive effect on the player, similar to intrinsic motivation [30]. Likewise, intrinsic motivators are strongest when linked to personal desire and external factors do not interfere with one's autonomy [24].

Serious games and gamification areas encompass all of these concepts in a structured, enjoyable environment where the player needs to feel encouraged to explore and solve the various challenges. Reinforcement techniques and application of consequences should be used with moderation to neither tire nor alienate the player and thus affirm the behaviour or concept to internalise.

This work's main objective is to utilise the aforementioned ideas and incorporate them into a serious game capable of raising awareness for risky behaviours that may cause spinal cord injuries. In the following chapter, the project's framework will be outlined and explained.

Chapter 3

A serious game for behavioural change

The Game Design Document (GDD) is a blueprint for how a game is built and is often used within the videogame industry to organise a multidisciplinary team. Given its descriptive nature, such layout contains a series of guidelines valuable to explaining the project's direction and entity. In the present chapter, this template was adapted to provide an overview of the game that is being developed.

3.1 Background

Neuropol is a mobile game developed to raise awareness of the principal risks of spinal cord injuries. To achieve this, it was idealised a gameplay mechanic that would expose these risky situations and incite the player to enforce safe practices. The game will be available for mobile devices, both Android and iOS.

The game will be developed in alliance with the project promoters, the Institute of Molecular Medicine and Associação Viver a Ciência. Furthermore, professional entities, the FAVO studio and Valter Abreu, produced the visual and audio assets, respectively.

3.1.1 Prototype

An initial prototype was developed in the semester preceding this dissertation in the context of the course Project Management Laboratory (LGP) at FEUP. It contained two small levels that illustrate the *click and grab* mechanics. Each level had two interactions, displayed on the screen's bottom-left corner to aid the player. In the first level, the player has to grab an apple and a helmet to escape their home safely. This first interaction can be seen in Figure 3.1.

At the end of each level, the initial prototype also included a nervous system quiz to test the player on matters regarding the spinal cord. An example of the stated quiz can be seen in Figure 3.2.



Figure 3.1: Early prototype first interaction



Figure 3.2: Early prototype quiz

The last level begins with the player removing a banana peel from the ground and exiting the house. Afterwards, the player enters a scooter and has to cross several intersections without hurting oneself. Figure 3.3 illustrates this environment.

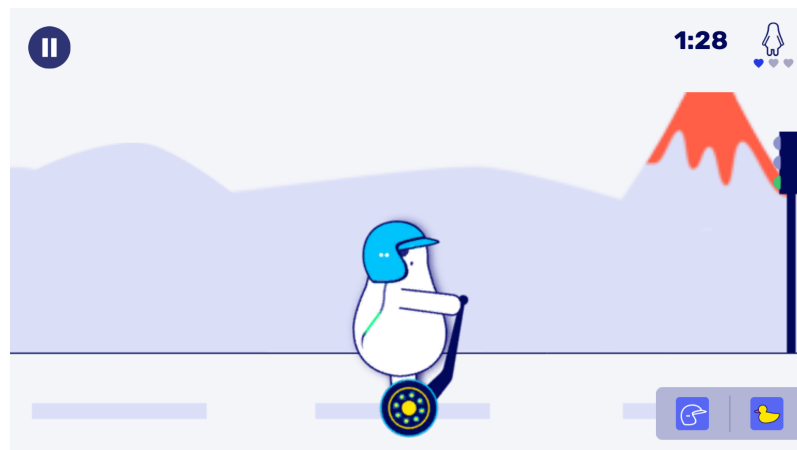


Figure 3.3: Early prototype second level

The initial prototype also contained the main menu (a), a settings menu (b) where the player can adjust the sound and language and the level selection screen (c). Figure 3.4 shows these screens.



Figure 3.4: Initial prototype screens

3.1.2 Game elements relevant to the final idea

The game idea was reevaluated after considering the prototype. The initial levels were discarded, with only the *click and grab* mechanic remaining a staple of the gameplay. The quiz at the end of each level was also dismissed, as it did not evaluate any knowledge from the game itself. Thereupon, several game elements were outlined to ensure the embodiment of the new game idea:

- The use of scores to grant immediate feedback to the player whilst providing extra information in a post-analysis. A high score will reflect the completion of the game's actions, whereas a low score may result from wasted time or too many activities failed;
- Provide feedback on the different interactions to highlight the impact of the player's actions. A bar of interactions will fill as the player completes the game's milestones, and accidents will prompt a comic strip, showcasing the consequences of the failed action;
- The aforementioned bar of interactions will present small visual clues about the following step without plainly displaying it to the player.

3.1.3 Pedagogical objectives

Being a serious game, the present project intends to emphasise a purpose beyond entertainment: underline different situations that can result in spinal cord injuries if addressed inadequately. The game allows the player to manage these situations independently, thus encouraging learning by doing. Through trial and error, the player will realise the correct path to address those situations, and through repetition, these concepts will become inherent to the individual.

3.2 Project Description

The proposed idea is to design a 2D exploration game where the player must escape his/her home island due to a volcano eruption. The player's character is named *Neuropol*. The game also has a secondary character, *Neuro*, which has deactivated his/her nervous system to rest in a secluded area ¹. Whilst escaping, the player will also need to answer a series of questions to reactivate *Neuro* so that they may escape together. As the player crosses different areas, he/she will interact with several objects and trigger various behaviours. These behaviours invite the player to tackle them in the safest way possible. A poorly timed action or interacting with the wrong object will trigger an accident for the player or other characters.

The development of a game requires a multidisciplinary team, and *Neuropol* was no exception. Given the prolonged process of aligning the outside teams, the established timetables were delayed. Thereby, despite having the six levels devised and developed, only one level was implemented in the current game version.

3.3 Game Overview

3.3.1 Concept

Neuropol is a 2D exploration mobile game where the player interacts with the environment to address various situations in a safer fashion whilst awaking *Neuro* so that both characters can escape the volcano eruption.

3.3.2 Genre

Neuropol is primarily a serious game, given the gameplay layout to highlight unsafe situations that can contribute to spinal cord injuries. Notwithstanding, this game is also encompassed in the adventure genre as there is a strong emphasis on the game's narrative and puzzle-solving aspects.

3.3.3 Target audience

The initial prototype embraced a chill and cartoonish environment with simple and easy to use mechanics. As this design was carried to the final product, it was decided that a younger crowd would

¹Further information regarding these characters can be found in Section [3.6.3](#)

be a more favourable audience for this game. The established audience was children between the ages of eight and twelve.

3.4 Gameplay

The game is subdivided into six levels, each with five main interactions. These actions require the player to engage them while holding the correct auxiliary object or interact with the right timing. This auxiliary object can be something used to reach an area or to unblock a path. This approach creates an interactive game settled on action repetition to reinforce safe behaviours.

At the end of each level, except level 1, the player must answer a small quiz to progress to the next. These questions regard the behaviours that the player explored throughout the level. After submitting each answer, the player is shown some related information about the correct response. One question answered correctly also awakens a part of Neuro's nervous system, thus a correct answer per level fully awakens Neuro by the end of the game.

Each level has three lives that can be spent upon unsafe behaviour. The player may earn an extra life by correctly answering two questions at the level quiz.

3.4.1 Core mechanics

The *click and interact* mechanic is a core component of the game. The majority of the game's interactions require the player to interact with their surroundings to progress. The interaction's locations are slightly detached from the environment and highlighted when the player approaches them. It allows for greater immersion in the game world and hinders the sequence of interactions from becoming overly pronounced. If the stated object does not constitute a main interaction, only the highlight colour is showcased. In this way, the main interaction's objects are more emphasised than the remaining ones. The interactable objects are highlighted as the player gets in range, as seen in Figure 3.5. This range varies depending on the object.

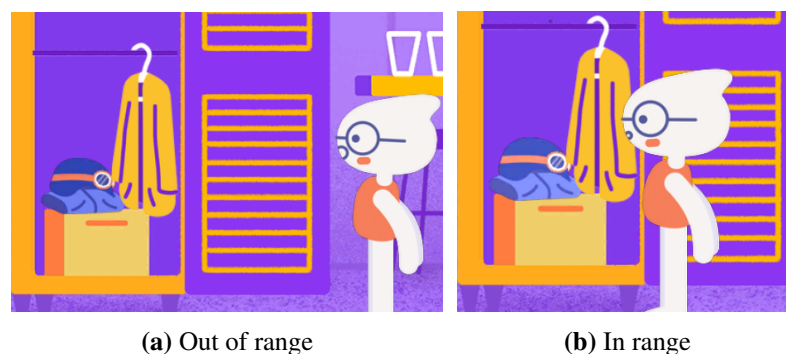


Figure 3.5: Highlight of a main interaction object. The highlight of the helmet has a subtle colour shift and an animated size change.

This main interaction can happen in two ways, as seen in Figure 3.6: the player interacts with the object (a), thus completing the action, or to gain access the stated object, the player needs

to place an auxiliary object (b). When the latter occurs and the player has that object in his/her inventory, a silhouette of the object appears to inform the player of its location.

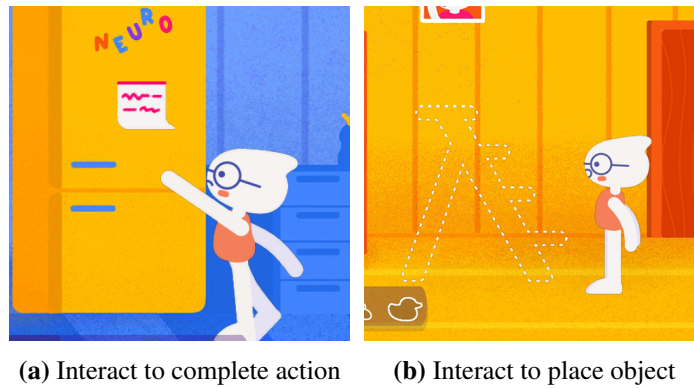


Figure 3.6: Types of interactions

To accommodate more road-oriented interactions, a second form of interaction was devised. Instead of the standard *click and interact*, when the player reaches an interaction area, he/she has to stop promptly to avoid an accident.

The change of floors mechanic is another extension of the interaction's system. When the level is designed as such, the player interacts with the stairs (a) and is then placed in the next room (b). Figure 3.7 illustrates this mechanic ².

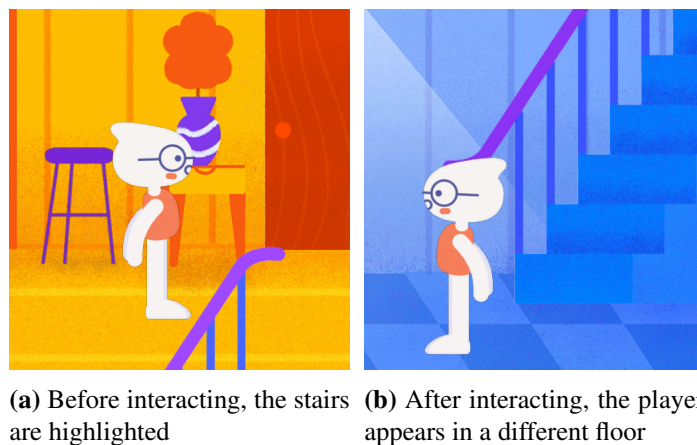
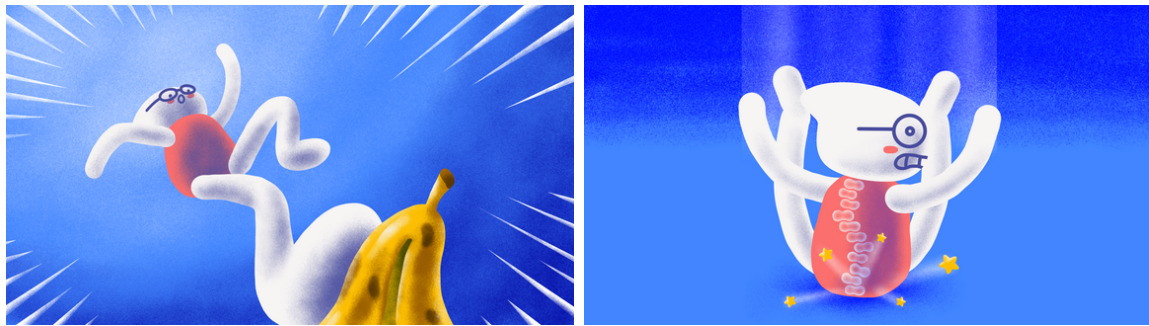


Figure 3.7: Change of room mechanic

Accidents occur concerning these interactions. There are three types of accidents:

1. The player interacts with something with the wrong helper object;
2. The player crosses an interaction without protecting the area or oneself;
3. The player does not stop in time.

²The animation for effectively climbing or descending the stairs is still in progress.



(a) Strip 1 - The causes of the accident

(b) Strip 2 - The consequences of the accident

Figure 3.8: Accident sequence when crossing the banana peel without picking it up

Following each accident, an accident illustration is shown, and the player is placed in the last interaction location. This location is stored by the saving system, which will be further explained in the following chapter. These illustrations contain two strips: the first one denotes the motion that will cause the accident, and the second one marks the consequences of the accident, as depicted in Figure 3.8. Each accident costs one life. If the player loses all lives, the level is lost, and it can be restarted.

3.4.2 Player controls

The player can only move horizontally, and Neuropal will keep walking as long as one side of the screen is being pressed. This type of movement is aligned with the *click and interact* premise, providing efficient and straightforward mechanics.

If two interactions are within the player's range, only the closest is highlighted and thus enabled to be clicked.

3.4.3 Inventory

The inventory can hold up to one item at a time. This simplistic approach denotes that each item has a utility, even if the stated utility is the cause of an accident. Notwithstanding, the objects considered to be a main action do not occupy inventory space as they are accounted for in the main interactions bar.

3.4.4 Challenges

Two types of puzzles were created to add extra challenge and fun elements to the game, endorsing the incremental level of difficulty usually found in games without increasing the actions' difficulty. As this game's focus is to showcase dangerous behaviours for the spinal cord, the game's challenge should be present in the additional elements, not in the behaviours themselves.

Puzzle

The first type of challenge is a standard puzzle, where the player needs to find all the puzzle pieces in the world and then place them in their correct positions. An example of its visualisation in the game world can be seen in Figure 3.9. As this challenge is being used in increasingly more complex levels, the number of puzzle pieces likewise increases.

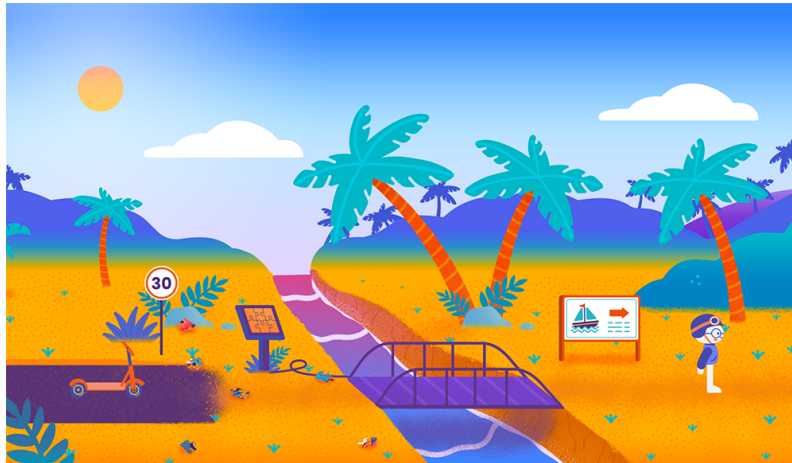


Figure 3.9: Puzzle pieces location on a mockup from level 3

Sequence puzzle

This type of challenge can be completed by pressing the keypad buttons in the correct order. This can appear in two ways: a four colour keypad and a nine number keypad. Stated order will be illustrated in the environment. Figure 3.10 illustrates an example of the colour puzzle.

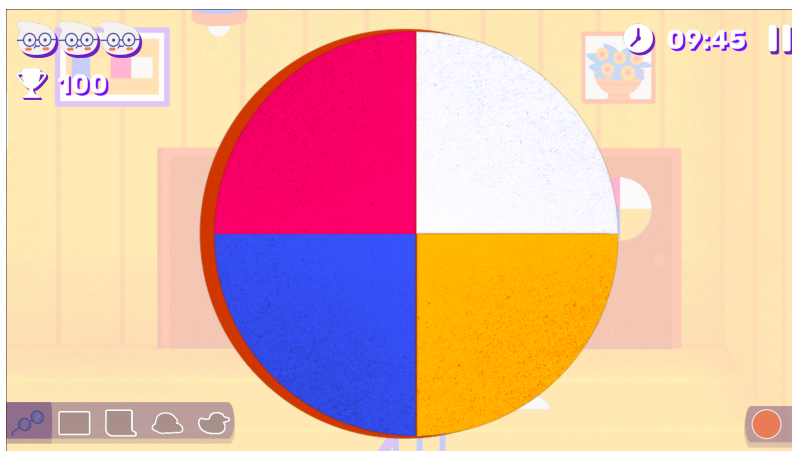


Figure 3.10: Colour puzzle found at level 2

3.4.5 Points

The player earns points with each action completed, be it a primary or secondary action, each challenge completed and each correct question at the end of the level quiz. In opposition, the player loses points per accident suffered and per wrong question. Table 3.1 showcases the number of points associated with their respective action.

Table 3.1: Number of points per game action

Game action	Points
Primary action completed	100
Secondary action completed	50
Challenge completed	25
Question answered correctly	50
Question answered incorrectly	-50
Accident	-150

This scoring system is meant to punish the player for each accident, embodying the severity of the resulted injury.

The points representation in the Heads-Up Display (HUD) is lined up with the feedback it provides. As illustrated in Figure 3.11, the number of points resulted from a specific activity always appears on the screen. If this is a positive value, the points indicator follows an upper motion to symbolise the addition to the current score. Otherwise, the indicator travels downwards to mimic the loss of points.



Figure 3.11: Visual clue when gaining or losing points

Depending on the time taken to complete each level, the player may also earn a maximum of points according to the following expression:

$$5 * (totalTime - toleranceTime)$$

where *totalTime* refers to the total time of the level, and *toleranceTime* refers to time considered to be the bare minimum amount to complete the level.

This formula rewards the player with the total available points if the level is completed during the *toleranceTime*. After this time has elapsed, for each passing minute, the time points are reduced by five. If, for example, the level has a *totalTime* of ten minutes and a *toleranceTime* of four minutes, the maximum amount of points equals thirty points. Should the player complete the level within four minutes, he/she is awarded the total points. In this way, the player has a comfortable amount of time to complete the level without being penalised.

3.4.6 Leaderboard

The social component of the game includes two types of leaderboards, global and private. The former displays the top ten players currently playing the game whilst the latter has a smaller scope of users. The player can join at most one private leaderboard. The player will be added to that entity's leaderboard by entering a code specific for each leaderboard. A high position in the leaderboard will validate compliance with the game's objectives.

This layout allows the player to view its performance compared to all players and against players from the same leaderboard. It carries a similar value to one of the points, representing the impact of one's decisions. However, this comparative metric is not heavily highlighted and emphasised to avoid pressuring the players to play solely for the leaderboard.

3.4.7 Quiz

To validate the behaviours showcased on each level, the player must answer a small quiz at the end. These questions carry a low difficulty level as they are meant to emphasise gameplay moments, not to test the player on the matter. Figure 3.12 exemplifies a question from level 2.

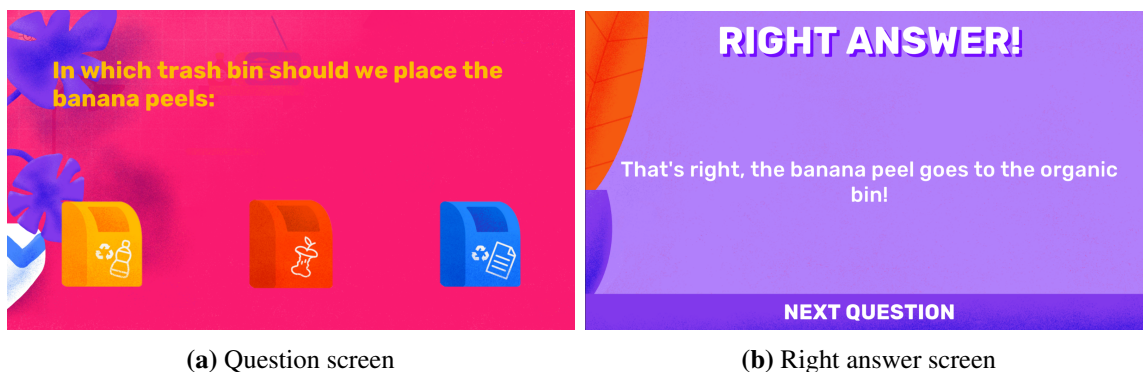


Figure 3.12: Quiz screens

The quiz also plays a significant role in the story, as it is the path to awakening Neuro. When the player answers one correct question per level, a nervous system part of Neuro is enabled. If the player reaches the final level and Neuro cannot be fully awakened, the player will be given another quiz and answer as many questions as necessary per locked part.

Each end of level quiz is composed of two questions. If the player answers two correctly, he/she is awarded an extra life and proceeds to the next level. If he/she fails every question, the player still advances to the next level without any bonification.

3.5 Levels

Each level has three central moments: the *introductory cinematic*, the *gameplay phase* and the *quiz phase*. The *introductory cinematic* situates the player in each level, describing the level's main lore and the mission ahead of Neuropal. This cinematic zooms through the respective level, whilst a narration prompt appears on the top of the screen, as seen in Figure 3.13. The zoom ends when the camera has reached Neuropal.

During the *gameplay phase*, the player must find and grab different objects to compel with the required behaviours or secure an area. An additional challenge may control the access to each object. These challenges were described in the previous chapter. Failure to secure an area or compel with the required behaviours will lead the player or another character to have an accident. The actions and added challenges are repeated throughout the levels to reinforce the mechanics and intended behaviours. The initial schematics for each level can be found in Appendix A.

The *quiz phase* encloses each level. In this moment, the player is presented with two questions, regarding the behaviours showcased throughout the level.

Each level's specifications are described in the succeeding sections, accompanied by some illustrations. However, only the pictures from level 2 are present in the existing game version. The remaining images are sketches of what the level will look like and are not yet implemented.

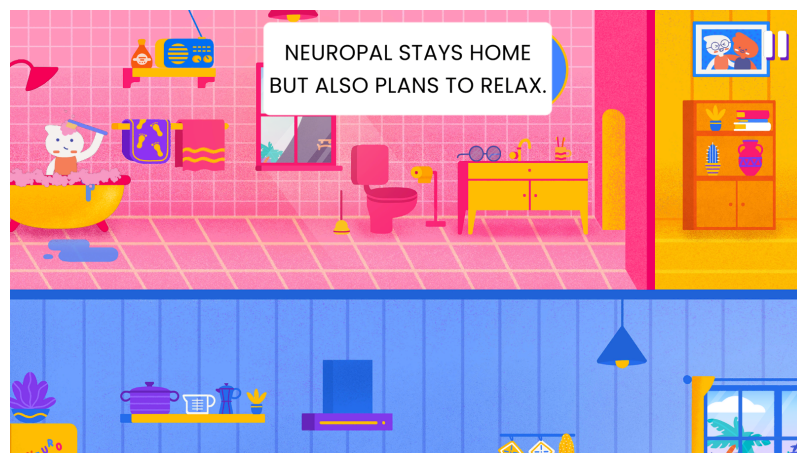


Figure 3.13: Introductory cinematic - Level 2 cutscene

3.5.1 Level 1: The Pool Party

This is the introductory level and thus encompasses the game tutorial. The first interaction is guided to teach the player about the base mechanics. Here, the player must place an anti-slip to prevent people from falling down the stairs. The second interaction is to close a protection gate, to prevent young children from crossing the stairs. The third interaction always showcases an accident: someone trips on an outside shower due to the lack of a safety pole. This accident is meant to teach the player about the consequences of the interactions. This accident is then rewinded, and the player is allowed to protect the area.

The subsequent three actions are about protecting areas around the pool by cleaning water puddles with a mop, placing a wet floor sign, and having a no diving sign. All of the needed objects can be found in a closed cabinet. To unlock the cabinet, the player must find all the puzzle pieces, and once the puzzle is completed, the cabinet is opened.

This level does not have the time pressure experienced in the following levels, as the volcano has not erupted yet. Besides encompassing the tutorial, this level represents some important situations, not so adequate to illustrate in the forthcoming levels. Furthermore, this level also allowed to demonstrate that individual actions can have consequences for other beings.

3.5.2 Level 2: The Escape

This level is entirely indoors. The level's main objective is to raise awareness for day-to-day tasks resulting in more serious injuries, thus showcasing different dangers inside one's home. The main interactions for this level are tied to the objects that the player needs to collect before leaving the house.

The second level begins with the player learning about the volcano eruption. Neuropal can be found inside the bathtub on the top floor of the house. The first interaction requires the player to safely exit the bathtub by placing down a rug to avoid slipping (a). Afterwards, he/she can grab the glasses (b), located near the bathroom sink, thus completing the first main action. The following interaction entails the player grabbing a painting of Neuropal and Neuro (e). To reach the artwork, the player lacks a ladder located in a locked closet (c). To access the state closed, the player needs to solve a colour puzzle whose solution is illustrated in the hallway. Instead of using a ladder, the player can also grab a stool (d) and attempt to reach the painting. By doing so, the player is engaging in dangerous behaviour, resulting in an accident. On this floor, the player can also interact with another closet. Upon this interaction, the player is informed that the closet is empty and not worth the exploration. On top of this empty closet, the solution to the colour puzzle can be seen. These interactions can be seen in [Figure 3.14](#).



Figure 3.14: Top floor interactions

On the floor below, the radio informs the player of some information regarding safe behaviours during a volcano eruption: closing the windows when inside and protecting one's body when outside. Moving forward, the player must remove a banana peel from the floor to proceed (a). A crumpled paper is placed afterwards and can too be removed from the floor (b). Both of these objects can then be recycled. Refusal to remove the banana peel will result in an accident. The player is then able to grab the emergency numbers, thus completing the third interaction (c). Figure 3.15 illustrates these interactions.

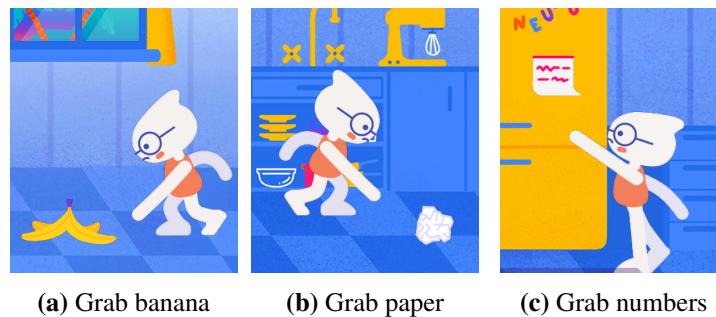


Figure 3.15: Middle floor interactions

Arriving at the ground floor, the player can interact with two closets. The first closet, once opened, displays a yellow coat. Clicking on it will remove the yellow coat and reveal a helmet and jacket, that the player can pick up (a). The final interaction regards a rubber duck located on a shelf (b). The ladder required is in the second closet (c). If the player is not wearing a helmet when crossing the living room, a lamp will fall and trigger an accident. Similarly to the grabbing of the painting in the first floor, the player can use a stool (d) or a chair (e) to reach the rubber

duck. However, this will likewise result in an accident. Additionally, there is a window open, which lets smoke come in. Until it is closed, the living room will continuously fill with volcano ash (f). These interactions are shown in Figure 3.16;

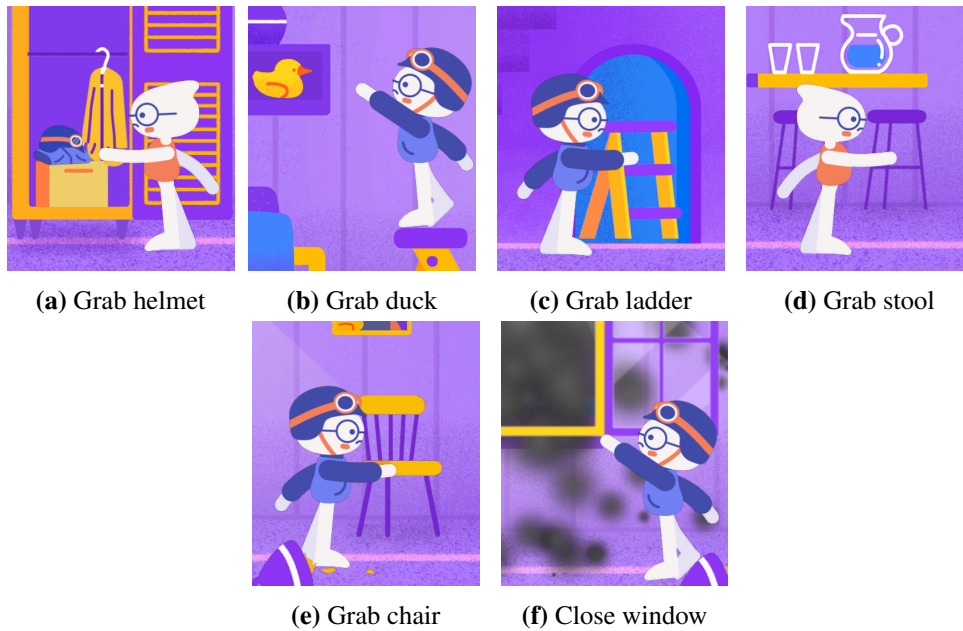


Figure 3.16: Bottom floor interactions

Having completed all interactions, the player can exit the house, which can be seen in Figure 3.17. An additional message will appear when this is available. When crossing the door, he/she will face the first quiz and learn about the necessity to awake Neuro.

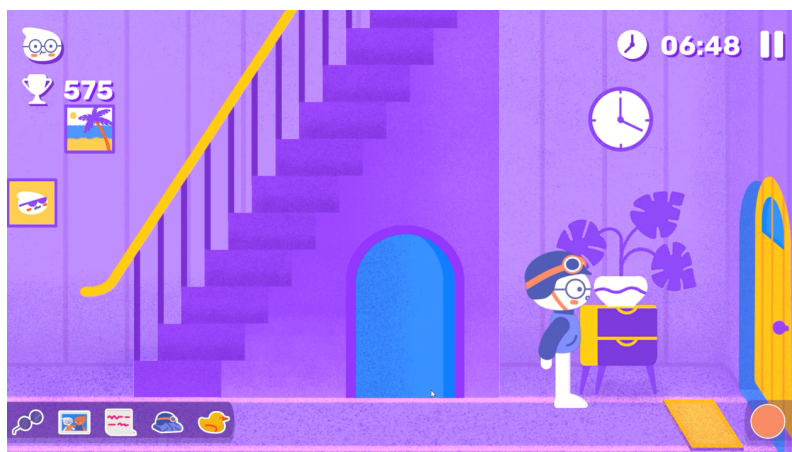


Figure 3.17: Level 2 screenshot with a bar full of interactions

3.5.3 Level 3: The Bridge

This is a road safety level and thus is wholly outside. This is also the level where the player begins the journey to travel towards his/her friend while driving a scooter.

The majority of the interactions follow a different mechanic from the previous levels. Upon nearing the interaction's location, the player must stop moving instead of interacting normally. During the entirety of the level, the player must comply with the established speed limit, which is depicted by a traffic sign at the beginning of the road. A constant popup appears on the screen, telling the player of their current speed. This speed increases as the player is pressing the screen. This approach compels with the simplified mechanics whilst punishing the player from driving without care for their surroundings.

At the beginning of the level, the player needs to stop at a stop sign (a). Then, the player must stop at a crosswalk (b). The following interaction is to stop at a traffic light if the light is not green (c). These lights are constantly changing, no matter where the player is. If the light is green, the player can keep going, and the interaction will be count as completed. As the player travels through the road, the volcano can be seen getting angrier, symbolising an imminent explosion. After the eruption occurs, the player must stop whenever he/she sees a volcanic bomb falling from the sky (d). Figure 3.18 showcases the mockups for these interactions.

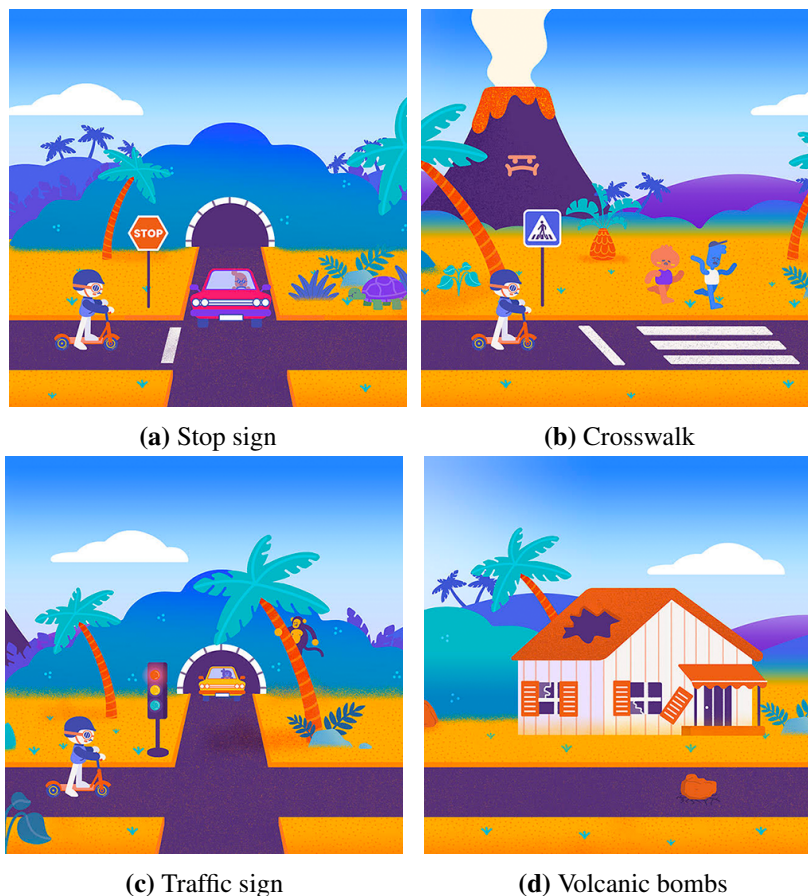


Figure 3.18: Mockups of the interactions from level 3

At the end of the level, the player is asked once again to stop at a crosswalk, denoted as the level's final primary interaction. This interaction can be previewed in Figure 3.19. Lastly, the player arrives at a lifted bridge, whose controls are locked by a puzzle challenge. Neuropal exists the scooter, and the player can search for the pieces laid nearby. Upon finding all six pieces, a text prompt pops up, informing the player that he/she is able to access the bridge controls and thus lower the bridge.



Figure 3.19: Mockup of the second crosswalk interaction

3.5.4 Level 4: The Port

At the beginning of level four, the player proceeds on foot to the port. As the player moves on, the first interaction is a reverse of the crosswalks on the previous level: the player must stop at the crosswalk to avoid being run over (a). Thereafter, the player arrives at the port entrance. There is a helmet nearby which the player must grab, otherwise, the player will not be able to enter the port (b).

Afterwards, the player needs to avoid crossing over a couple of broken wooden planks by lowering alternative passage (c). To unlock the lowering system, the player has to input the correct PIN, whose right combination is painted at the beginning of the port. The following interaction is analogous to the first: the player needs to stop at the appropriate time to avoid getting hit by a vehicle (d). This section is less demarcate as the crosswalk to blend in the port environment.

Finally, the player is required to set sail. To achieve this goal, the player needs first to unlock the path that leads to the boat, which are blocked by a colour puzzle whose solution is conveyed by nearby ships (e). All of these interactions are showcased in Figure 3.20;

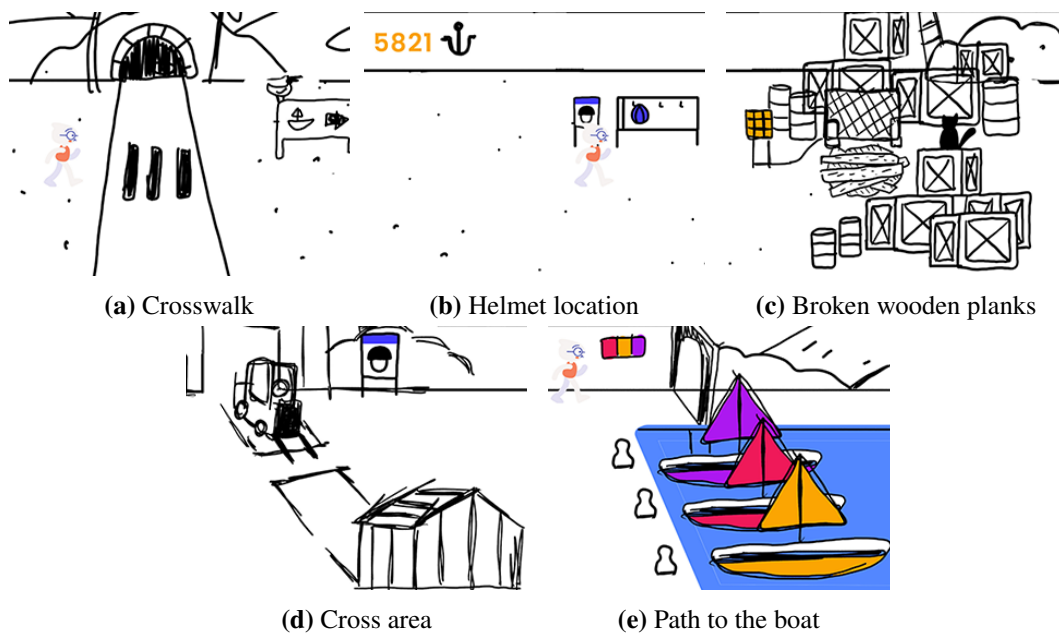


Figure 3.20: Mockups of the interactions from level 4

3.5.5 Level 5: The Voyage

The player can be seen standing on the boat, as shown in Figure 3.21. Prior to the beginning of the voyage, the player must clean water puddles on the deck and put a life jacket. Before getting close to the life jacket, a prompt appears warning to double-check if everything is protected for the voyage. This foreshadows a cabinet on the bottom floor that needs to be closed beforehand, or it will cause an accident when the player attempts to cross it.



Figure 3.21: Mockup of the environment from level 5

When the voyage begins, the player needs to avoid a moving sail, analogously to the falling of volcanic bombs. However, despite its similar interaction, this one is not part of the five main level interactions. This design choice is justified both by the environment and the increasing level of difficulty. The player will wander through the boat, crossing the same location multiple times, thus the moving sail will be a constant factor.

As the player's phone starts ringing, he/she can follow the sound to find it. The phone is located in the kitchen, below deck, after the cabinet required to be closed beforehand. The player has to input the correct PIN to unlock the phone, corresponding to another variant of the sequence challenge, which is written on the sails on the upper deck.

The subsequent action asks the player to take a selfie. There are three different locations for the selfie, all located on the upper deck. However, two of the possible locations will cause an accident.

After the final interaction is completed, the boat will arrive at the following location, and the level will be concluded.

3.5.6 Level 6: The Reunion

Upon arriving at the next region, the player needs to surpass a cave maze. A helmet is placed nearby, and again, the player cannot proceed without the stated helmet. Walking through the labyrinth uses the moving between rooms mechanic.

After exiting the maze, the surroundings leading to the next interaction contain a colour sequence needed to unlock the puzzle in the next location. The player's third interaction is to rappel down with a safety harness. The stated puzzle locks this harness. Following the player's descend, the quiz prompt appears. Contrary to the previous levels, the quiz occurs mid-level to awaken Neuro before the end of the level.

The player then descends a tree, constituting the fourth interaction, and arrives near Neuro. An air balloon is stationed nearby, which the player may use to escape. Both characters can then enter the balloon, and if they both have the seat belt on, the interaction is successful, and the level is completed.

The game's final screen displays Neuropal and Neuro safely floating away whilst the island explodes in the background.

3.6 Story and progression

3.6.1 Storyline

The game follows Neuropal, a humanoid being that needs to escape its home island due to a volcano explosion. After the second level, the player moves between different scenarios to reach Neuro, Neuropal's friend who is resting in a secluded location, as soon as possible.

3.6.2 Game setting

The game's pre-eminent environment is based on a tropical climate in an island-like scenery. Each level then has distinct locations to match the various expected tasks. Neuropal's house is featured in the first two levels: the first one being focused on the backyard, while the second level utilises the whole interior of the house (a). On the next level, the environment is mainly composed of a road segment that is carried to the beginning of the fourth level (b). Here, the player will arrive at a port (c) containing a boat that foreshadows the succeeding level (d). The last scenery is mainly composed of a cave environment. The existing environments can be seen in Figure 3.22.

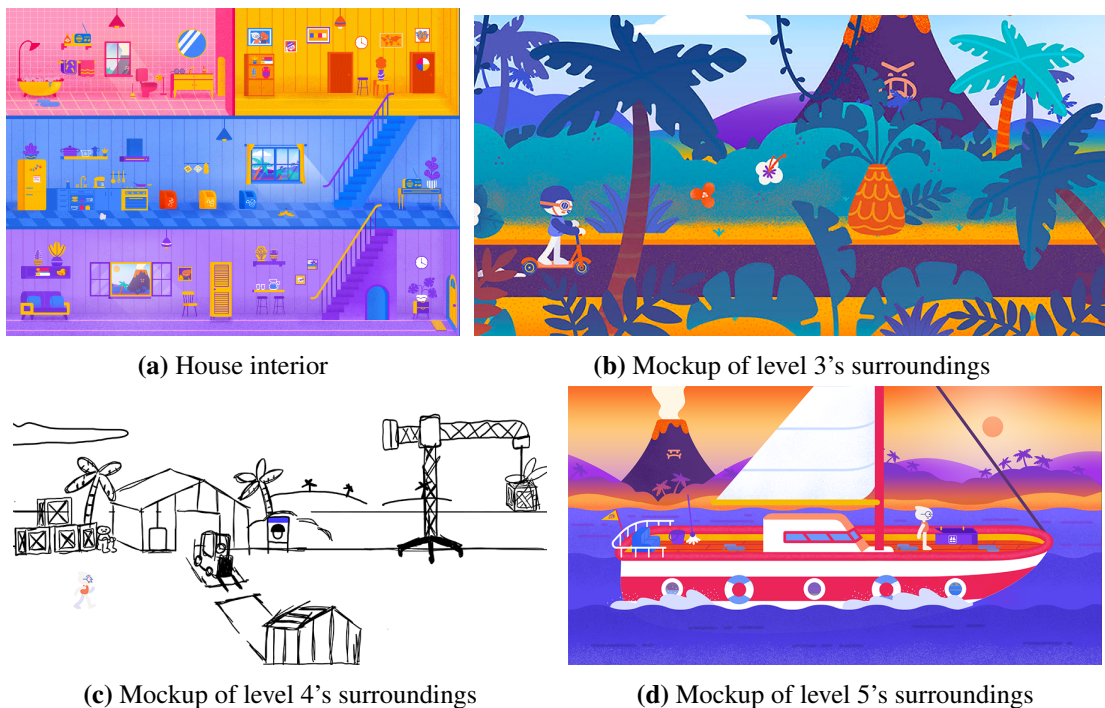


Figure 3.22: Game environments

3.6.3 Characters

Neuropal

The primary playable character. Neuropal is a bit clumsy and has a cheerful personality, emphasised by their funky walk style. This character is a humanoid being without colour and a gender-neutral appearance. Thus, all players will be able to relate to the main character. Figure 3.23 showcases Neuropal's image within the game. This figure only displays three frames of each animation. Inside the game, each animation has a sprite sheet between 20 and 40 frames. Neuropal has three possible walk animations depending on his/her outfit (a)(b)(c). The character also has three different idle animation: the main one where Neuropal is standing still, breathing in and out (d), one where he/she is straightening the glasses (e) and one where the player is being called into action (f). These animations are also replicated when the character is without glasses and while

wearing the scooter outfit. Likewise, the grab animations (g)(h)(i) have a sprite sheet for each clothing type. The bath animation (j) only showcases the character's torso since the remaining body parts would have been hidden by the bathtub. At last, the player has two climb animations (k)(l) depending on the ladder size. These animations have an analogous motion for the descend.



Figure 3.23: Neuropal sprites

Neuro

The second main character. Neuro is the friend of the main character who must be awoken before the end of the game. The character's proposal sprite is displayed in Figure 3.24.

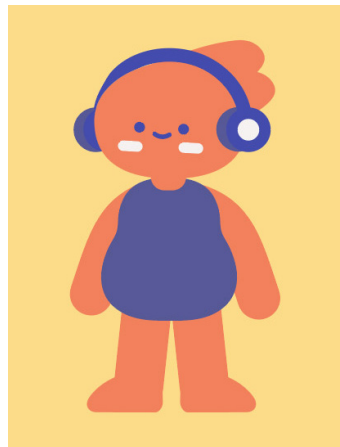


Figure 3.24: Mockup of Neuro

NPCs

Similar to the main character, the majority of NPC's are humanoid creatures. They appear on level one as the party-goers and levels 3 and 4 as the people on the streets. Some animals are also featured as NPC throughout the levels. Some examples of these characters can be seen in Figure 3.25.

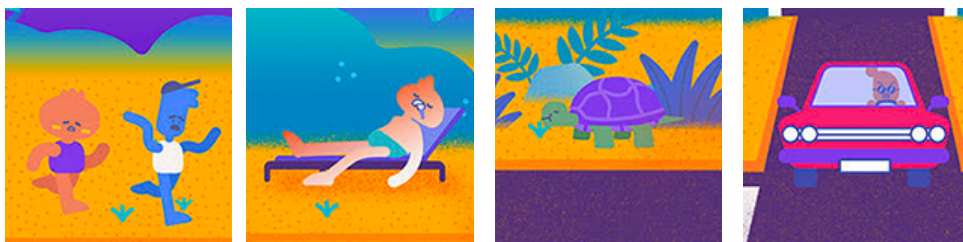


Figure 3.25: Mockups of NPC from level 3

3.7 Tools and resources

3.7.1 2D Assets

The visual element of the game carries high value in the overall product, as this materialises the gameplay mechanics and directly impacts the player's first impression of the application.

The first steps to compose Neuropal's image relate to choosing a colour palette. The initial iterations experimented with soft, pastel colours, with varied patterns per element. To create a more vibrant experience, this colour palette evolved to more saturated tones, with fewer patterns per element and a thinner colour range overall.

The subsequent stages included creating the main character's appearance alongside the general look of the second level and game interface. The time constraints deemed necessary to prioritise level two over level one, given the latter's volume of assets.

3.7.2 Sound

The FMOD was the sound effects engine used by the sound team³. The engine itself has an integration package for Unity, easing the initial project setup.

The FMOD project was kept in a shared folder via Dropbox.⁴ This approach bridges the programming and the sound components, enabling them to work independently without hardening the incorporation. On the Unity side, the audio events were placed in their respective locations. On the FMOD side, the audio files were created and adjusted and linked to the stated events. When that audio was deemed ready, the project was automatically updated, thanks to the preexisting shared folder.

Since a game's audio is directly tied to its appearance, the audio assets' development had to wait until the game image was produced.

3.8 Visual and audio style

The game's image is characterised by intense, saturated colours: this choice creates an exciting environment suitable for the target audience. The game's predominant colours are blue, purple, yellow and white.

The in-game HUD includes the pause button, the time counter, lives counter, points counter, the interaction bar and the inventory, as seen in Figure 3.26.

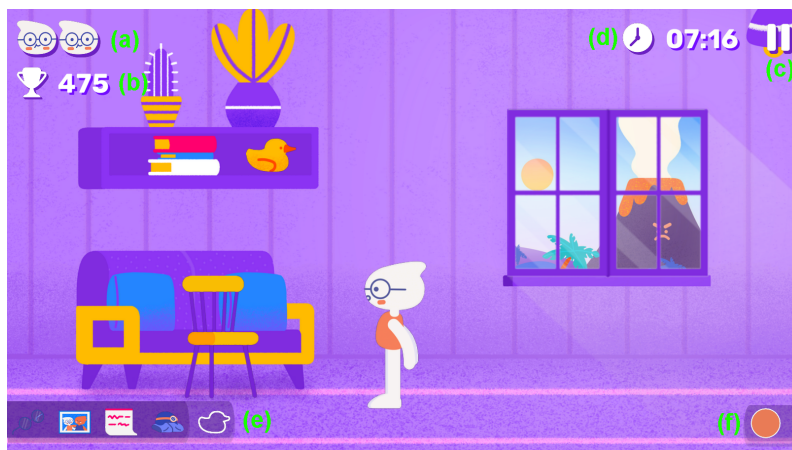


Figure 3.26: In-game HUD

The player's remaining lives can be seen on the top left (a), with the score right below (b). On the opposite top corner, the pause button (c) is placed near the time counter (d). The aforementioned button opens the pause menu, from where the player can return to the main menu or resume the game. An appropriate icon accompanies both the time and the score counters. On the bottom left corner (e), the bar of interactions is shown. This bar is initially empty, only displaying

³<https://www.fmod.com> [Access date: May 29, 2021]

⁴<https://dropbox.com> [Access date: June 27, 2021]

a silhouette of the level's actions. As the player progresses in the level, this bar is likewise updated. The last HUD element is the inventory bar (f), which displays the item currently being held.

As described in Section 3.4.1, there were also created visual representations of the highlight mechanism. As the player gets in range of an object, the stated object changes colour periodically to showcase its availability. If the object is a main interaction, this object's size will alter slightly.

The game's audio has a strong cartoon vibe to match the visual style. The background music contrasts with the remaining audio, as it carries an ambience melody. This softer theme enables the highlighting of the sound effects that appear throughout the game. Given the complexity of the game, the sound can be encompassed into three different categories:

- Diegetic sound: The type of sound that issues from the game's narrative. It can be found in the player's footsteps, upon a radio warning and to emphasise the volcano explosions;
- Non-diegetic sound: Refers to sounds that do not originate in the game world, as they are meant for the player, not the characters. This includes sound linked to the background music, accidents, the appearance of a text prompt, a button pressing, time alert and scene transition;
- Dynamic sound: Any sound that functions as a reaction to player input. This is tied to the player interaction, with different sounds for main actions, door interacts, and other objects.

3.8.1 Main menu

The main menu is perceived as the starting point of any game. Figure 3.27 illustrates the main menu version employed in the game version used for testing. It includes buttons for starting the actual playthrough, accessing the leaderboard and viewing the settings menu. A fourth button would appear if a save file exists, enabling the player to continue the game.

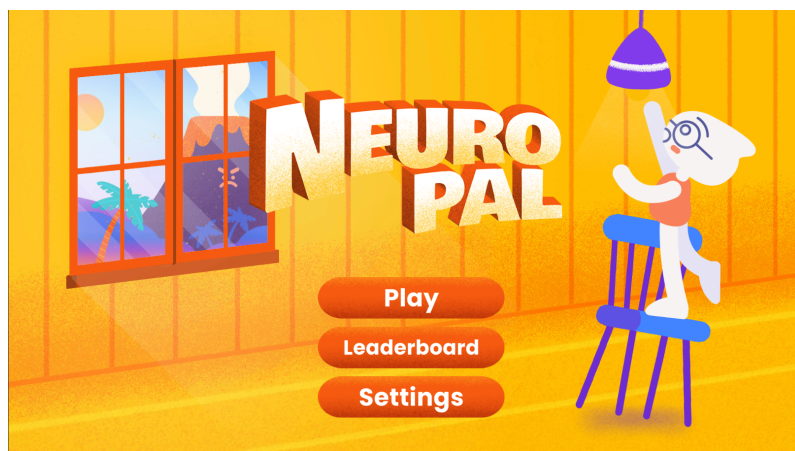


Figure 3.27: Main menu

The settings and leaderboard sub-menus can be viewed in Figure 3.28. Their look is likewise temporary. The settings menu allows the player to change the game's language, delete the save file and change their username, if one exists.

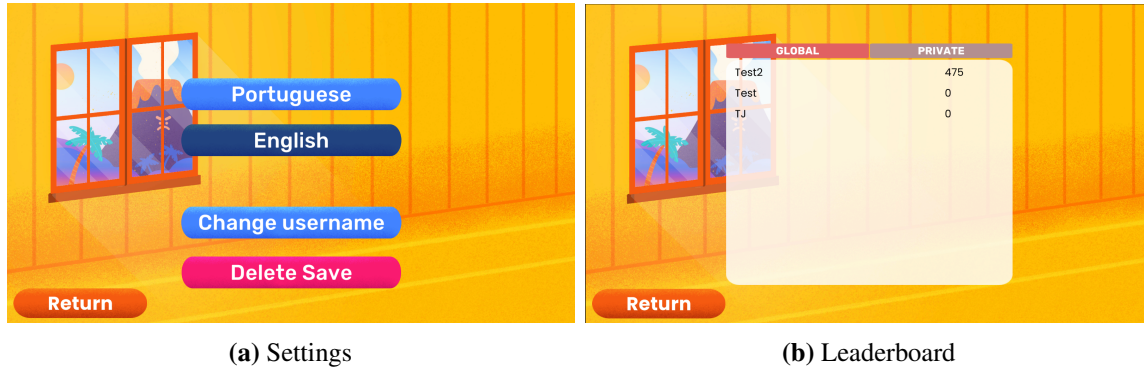


Figure 3.28: Sub-menus

3.8.2 Prompts

This game includes several types of messages that are useful to provide to the player. As such, to accommodate the varied kinds of information, a selection of prompts was created to link the stated types to a unique visual clue:

- a Text prompts, which provide feedback about the player's actions. This includes hints about what the next interaction is, the fulfilment of a floor's interactions, the wrong placement of an item or a correct action;
- b Narration prompts situate the player in the story and give clues about the progression in the level. These prompts are also used to provide some safety guidelines, given the player's current location;
- c Radio prompts give information on the volcano state.

All of these prompts can be view in Figure 3.29. The text prompts (a) and the narration prompts (b) appear in the game's HUD, with the former appearing from the left side of the screen and the latter appearing on the top. The radio prompts (c) are placed in the world.

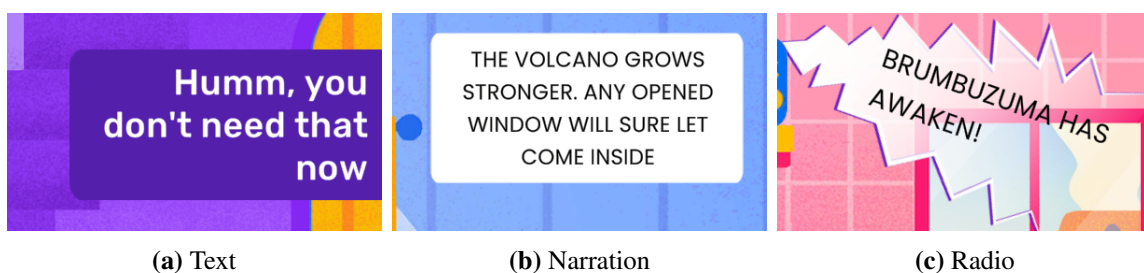


Figure 3.29: Different type of prompts

3.9 Game engine

A game engine is at the core of any game, as it eases the construction of the application by providing an environment that handles all the backbone of development, such as rendering, physics and memory management.

Given the prototype had been developed using the Unity Engine, it was decided to carry on with the same game engine to ease the initial setup. Unity is a cross-platform game engine that allows the creation of both 3D and 2D games. The ease in developing for multiple platforms also played a significant role in remaining with the Unity engine.⁵ In addition, Unity supports the programming languages C#, an object-oriented language that carries inspiration from C++ and Java.

Furthermore, Unity provides several valuable features to the creation of a game, namely the embedded analytics system and its asset store. The former enables a thorough analysis of the player's progress in-game, which can aid in the validation of the game mechanics. The asset store stores hundreds of free assets, from 3D figures to scripts that can facilitate the creation of a game with fewer resources. The project in question did not use this store, as it was fortunate to have professional entities involved.

3.10 Summary

The present chapter utilised the structure of the GDD to describe the game currently being developed. The first sections gave a global idea of the game's concept, explaining the intricacies of the project, followed by an analysis of the actual gameplay. Afterwards, the levels were described, enumerating the interactions' logic and the player's path on each level. The final sections of this chapter related the tangible aspects of the game, analysing the art guidelines and the sound vibes. The workflows for working with the two teams were also described.

⁵<https://unity.com> [Access date: May 11, 2021]

Chapter 4

Game logic

Following the game design document analysis in the preceding chapter, it is befitting to assess the game logic from a programmatic view. The current chapter delves into the stated logic and the relations between the different Unity classes that compose the game.

Figure 4.1 summarises the flow of the full game, starting in the main menu up to the final level. The boxes highlighted in green mark the implemented scenes at the time of writing this dissertation.

4.1 Player

The `PlayerManager` class is responsible for controlling the player's movement, collisions and animations. The mobile controls use Unity's new input system, particularly the `EnhancedTouch` feature. When one finger touches the screen, the class begins by verifying if that touch corresponds to its last input, hence the finger has been lifted, and the character will stop moving. Afterwards, it is checked whether the finger is touching the game world or an available interaction. When the former occurs, the player will move to the left if the touch happens on the left side of the screen or to the right, otherwise.

As the player walks in the world, a list of interactable objects is kept updated. Whenever this list is refreshed, solely the closest item is highlighted and available to interact. These objects belong to the `Interactable` class, which will be explored in a later section.

When an object is interacted with, the system verifies the order of the interaction. Items specific to the level's core interactions can only be interacted with in accordance with the pre-established sequence. Thereafter, the pending interaction awaits the conclusion of the grab animation. An exception to this logic lies with the stairs interactions, as upon clicking, the player is teleported to the following floor.

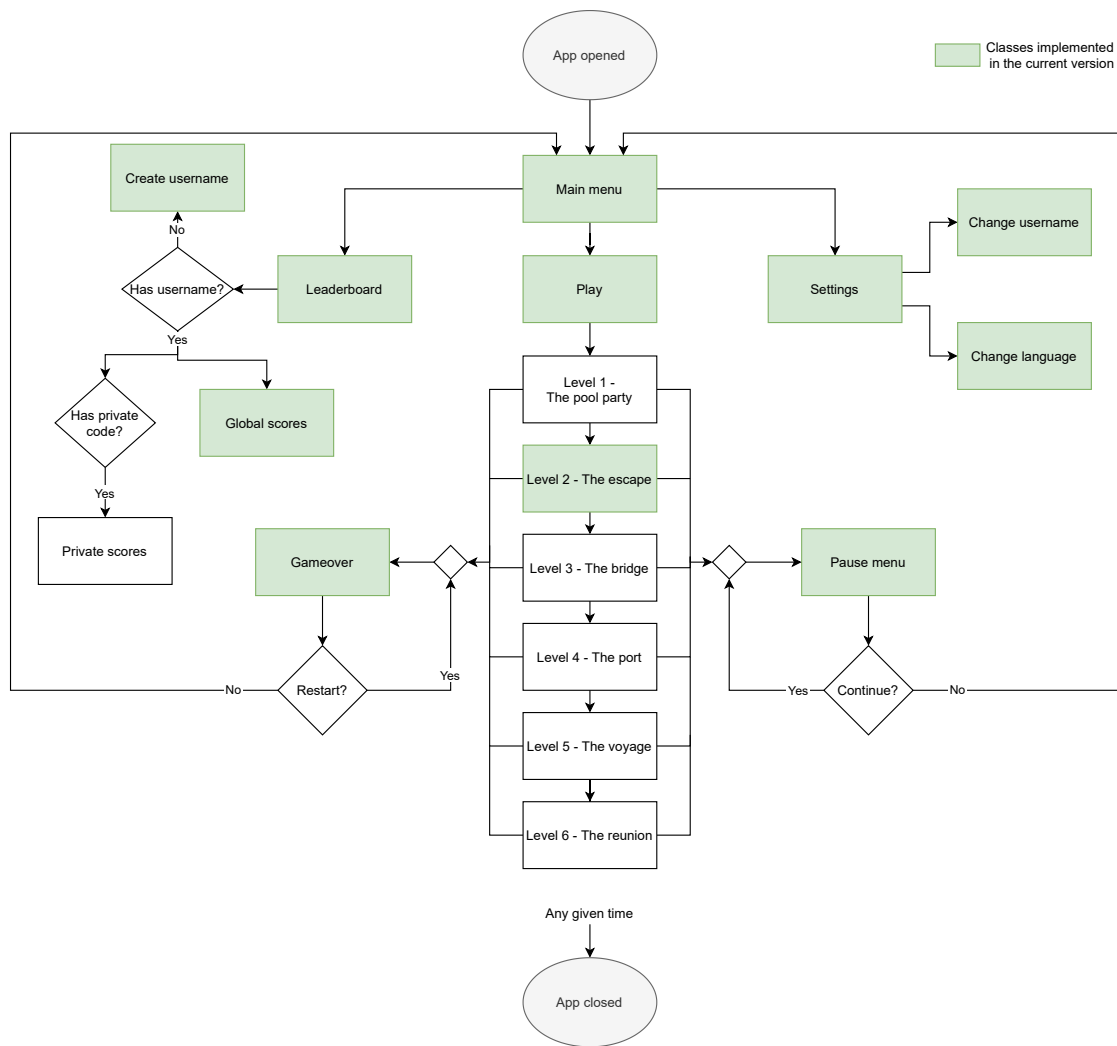


Figure 4.1: Game flow diagram

4.2 Game controller

All of the gameplay logic is coordinated by the `GameController`. This class follows a singleton pattern, defined as a design pattern to limit one's instantiation to a single occurrence. The core mechanic relies on a state machine with seven possible states: one for each level and one for the cutscenes. This approach enables the capsulation of the level's logic into an auxiliary class while maintaining the `GameController` class's global functions.

At the beginning of each level, the `CutsceneAssistant` initialises and handles all the cutscene logic and text. Its completion is signalled to the `GameController`, that concludes the cutscene state and boots the actual level. Each level state then starts by updating the interaction bar, the level's challenge and the total time.

This controller keeps track of every player interaction during each level and constantly validates whether one of the main actions has been issued in the expected order. Further verifications

manage the presence or absence of the correct items for those interactions. Once the action is validated, a call is made to the interaction progress bar, updating the number of activities completed thus far.

Every step that involves the interaction bar is managed by the `InteractionProgress` class. This class updates the interface icons per number of interactions and maintains the visualisation of the level progress.

The `PointsHandler`, as the name indicates, controls the score number and their respective display. Upon an addition or subtraction, this operation is accompanied by an animation that emphasises the points gained or lost.

An auxiliary class handles the player's lives, noted as `LivesController`. Besides overseeing the number of lives, the stated class manipulates the corresponding interface. When all lives are spent, this system informs the `GameController`, which ends the current level, displaying a game over screen.

All of the classes mentioned above, despite their individual nature, are supervised by the `GameController`, the central entity of the game. Figure 4.2 illustrates the logic between the `GameController` and the other auxiliary classes mentioned above.

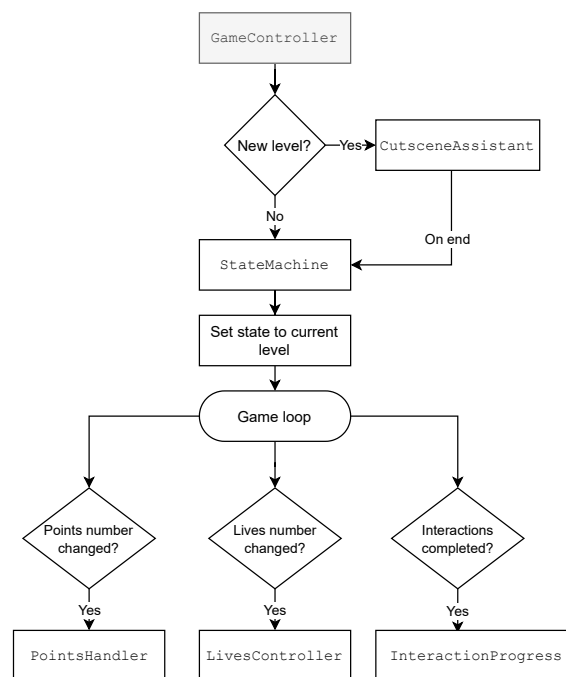


Figure 4.2: GameController logic

4.2.1 Quiz controller

The `QuizController` encapsulates the logic for the quizzes at the end of each level. It holds the list of questions per level whose objects belong to the `Question` class. This auxiliary class has

a question name, which is used as a reference in the localisation system; the name of the correct answer, the question type and whether it has been answered or not. This type can be:

- `TextText`, if both the title and answers are written words;
- `TextImage`, when the title is in written form, and the answers are images;
- `ImageText`, granted that the title is an image, and the answers are text.

The system then tracks the number of answered questions, both wrong and correct. As previously discussed, one correct answer will lead to a partial awakening of Neuro, while two correct answers will reward the player with an extra life. These results are verified by the `GameController`. Figure 4.3 displays the logic of this class.

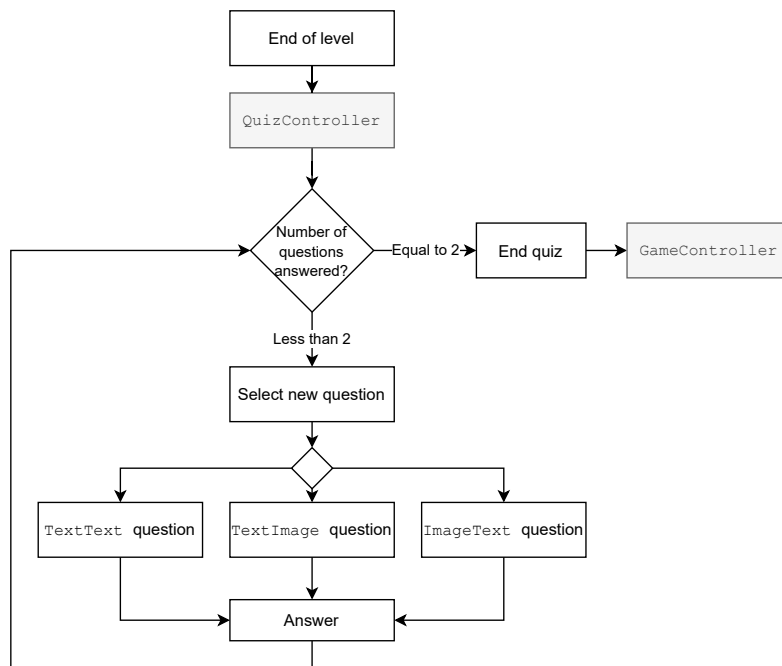


Figure 4.3: `QuizController` logic

4.2.2 Sound

The FMOD plugin for Unity eases the process of emitting sounds, as this can be achieved simply via the engine's editor. However, for more robust events, a class was created to store all the references to the needed sounds. For each sound, the class keeps a static function that calls another function with all the required calls to the FMOD system. The static method enables calling the stated function anywhere in the code without initialising the encapsulating class, thus easing access to this functionality.

4.2.3 Prompt manager

This system handles every message that pops up on the screen, either as a part of the tutorial, to explain why the player is fulfilling that action or to expose parts of the story. The `PromptManager` class contains a list with every available prompt, whose objects have a reference to the localisation system and a variable that defines the on-screen duration.

Each prompt name has a prefix that refers to the prompt type, whose value can be text, narration or radio. The first two sorts appear in the game HUD, whereas the radio type appears in the game world. When the latter type is required, the class searches for the nearest radio object in the world, as the text message will appear linked to the stated radio. As this message will be a short and strong idea, a text prompt will appear with complementary information. Figure 4.4 illustrates the logic behind this class.

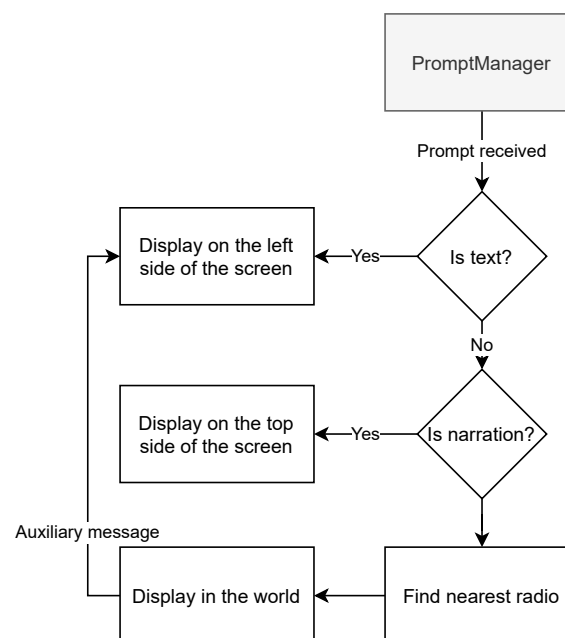


Figure 4.4: `PromptManager` logic

4.3 Items and inventory

All interactions in the game share a base class called `Interactable`. Every instance of this class contains a scriptable object named `Interaction` that works as a template data holder. This particular asset bears a name, location and if this is a main, static or completed action.

To accommodate every action type in the game, seven extension classes were created:

- `Closet` - The interaction opens the closet, revealing its content. Further customisation allows the cabinet to be locked, requiring the completion of a challenge to unlock it;

- `Crossable` - Standard interaction is replaced by a timed action: the player must stop inside the object's collider, to complete the interaction;
- `Pickable` - Extra functionality allows for the addition of the stated item to the inventory;
- `PickPlace` - Combines the `Pickable` and `Placeable` classes. Usually used by auxiliary objects, this class allows for the `Pickable` items to be placed again in the world after being picked up;
- `Placeable` - Used to specify where to place particular objects. A silhouette of the object replaces the standard highlight material;
- `Stairs` - Moves the player to the next floor upon the interaction.

The `InventoryManager` handles the inventory logic. It contains all functions necessary to add and remove items during the game and reset the inventory after a saved file is loaded. Each operation originates a callback to the `InventoryUI` class, responsible for displaying the inventory items on the interface.

4.4 Challenges

4.4.1 Puzzle challenge

The `PuzzleManager` class coordinates the puzzle challenge. This class can be extended to puzzles with any number of pieces. The `GameController` restricts the initialisation of the puzzle: The player only visualises the puzzle interface when they find all the puzzle pieces in the world.

The puzzle mechanic follows a standard approach: A piece can be dragged to any available spot, and if it does not fit, the piece bounces to its original location. This logic is repeated until the puzzle is reassembled. Upon completion, the `GameController` receives this information and unlocks whatever object the puzzle was locking.

4.4.2 Sequence challenge

The sequence challenge encompasses a colour and PIN version, as they share a similar logic. The `GameController` sets the expected order of the sequence.

The interface component has buttons for each of the numbers or colours, and it's up to the player to press them in the correct order. Stated order is showcased in the environment of the respective level. Similarly to the puzzle logic, the `GameController` is responsible for continuing with the game when the sequence is completed.

4.5 Camera movement

The main camera's logic makes use of `Cinemachine`, a toolset inherent to Unity, designed to create and control dynamic cameras in real-time. During the initial stages of each level, a first `Cinemachine` camera denoted `CutsceneCam`, zooms through the level until it blends with the primary camera, called `PlayerCam`. Then, the second camera continuously follows the player as he/she moves in the world.

4.6 Scenes manager

The `ScenesManager` manages the scenes transition. This class is present on the first screen loaded when the game begins. The subsequent scenes are loaded asynchronously, meaning they are being loaded in the background while the former is still on the screen. With this outline, it is possible to present a loading screen during a scene transition in a malleable environment.

4.7 Localisation

A localisation system was created to handle the translation of the base text to a variety of languages. Currently, the system has two languages, English and Portuguese.

The approach for the present game expects the terms to be laid out in an excel file, with at least two columns: the first one is always the key column, and the following columns are one for each language to translate. An auxiliary class, the `CSVLoader`, reads the excel file and then stores this information in a C# dictionary. This process creates one dictionary for each distinct language, where each key is linked to the language's terminology. By default, the active dictionary will be selected in accordance with the device's language.

Each text field in the project has a `TextLocaliserUI` class. This class holds a variable named `key`. When this field is changed, a call is made to the localisation system. Afterwards, the given key accesses the active dictionary and returns the translated sentence.

4.8 Save system

The Unity Engine allows for different methods to store player progress between game sessions. For the current project, three possibilities were analysed. The most straightforward approach makes use of the embedded `PlayerPrefs`, primarily utilised to store single variables. The second option is to create a JSON or XML file, a standardised notation notable for storing multiple variables. However, these two options lack security as the file's content is easily modified. To overcome this problem, a third option was used in the present game: a custom binary file. It requires a unity class with serialisable variables, that is, an object that can be converted to binary and stored on a medium. Afterwards, a binary formatter turns the unity class into binary, a reversible

process. Given that each binary file is specific to its own game, it is nearly impossible to modify it without the game itself.

The save system specific to this game stores the score, current level, player position, inventory items, time remaining in the level, lives remaining and the next expected interaction. The game is saved upon completing each interaction and completing the level. The game is loaded when the application is started, and the player chooses to continue with a preexisting save.

4.9 Backend

The `APIHandler` class controls the communication between the game and the leaderboard API. The latter was created using the Django REST framework ¹, a customisable and flexible toolkit.

The API has three main routes: one to access single-player information; another to visualise a private leaderboard's name, alongside the sum of player's scores that belong to it and an access code, automatically generated, to allow the player to enter that leaderboard: and the last main route adds a score to the player and may associate the stated player with a leaderboard. This latter field is not mandatory. The global leaderboard is a result of all the results from the last route. These routes can be further visualised in Figure 4.5, which contains a diagram generated by Django.

Each request in-game uses Unity's `UnityWebRequest`, a specific class to handle the flow of HTTP communication. These requests' responses return a JSON file, decoded by creating an analogous Unity class with the same elements as the JSON file. To accommodate the leaderboard's functionality, there were defined three main groups:

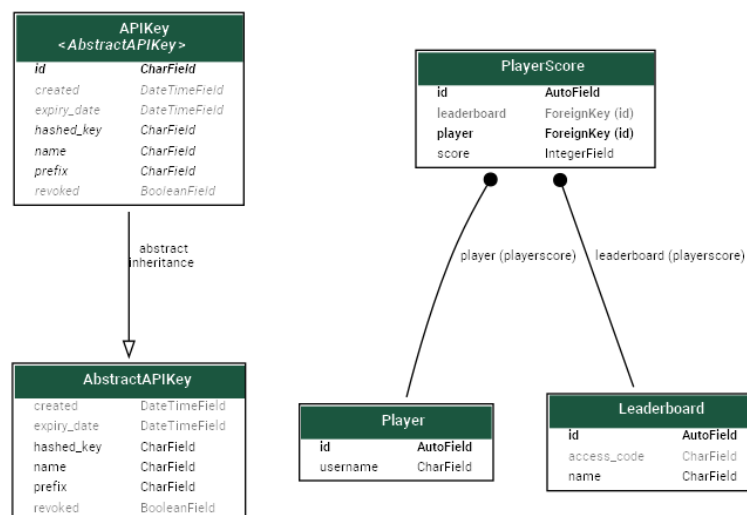


Figure 4.5: Backend UML

- **Player** - Contains the functions to create a new player and update the username of an existing player;

¹<https://www.django-rest-framework.org> [Access date: May 01, 2021]

- Global leaderboard - The server does not contain a specific global leaderboard. This designation is visualised in the game's environment by accessing all the players in the server, alongside their respective scores;
- Private leaderboard - A call can be made to return all private leaderboard's names. Each `playerScore` entrance may include a reference to a specific board, which then assembles the respective leaderboard. It is also possible to add an existing player to a private leaderboard.

This class is also responsible for transmitting this information to the leaderboard's interface and displaying both the global and the private scorings. For increased readability, only the first ten players are shown on each board.

4.10 Game Analytics

Unity Analytics is a cloud-based tool, helpful in providing insights as to how the players behave in the game.² This information was particularly useful in the data analysis to be described in the following chapter. As one would expect, the free version has some limitations, such as having a limit of 100 requests per hours and ten parameters per event.

For the purposes of this work, the class `GameAnalytics` was created to handle all the request with Unity's system. The established limitations were easily overlooked by defining two main events, one for level statistics and one for tracking accidents.

The level tracker event saves information regarding the level completion: whether the level was cleared or not, the number of accidents, the number of right and wrong answers, the time spent and the player age. This last parameter is only used to enable data comparison with other datasets in the testing section. The remaining four parameters specify which answers were answered in the level. Since the game version used for testing only encompassed one level, no level parameter was added to the tracker to utilise the parameters for other matters.

The accident tracker is only sent when the `GameController` registers ten accidents or when the level is lost to minimise the number of events sent. This event contains which interactions originated the accident.

4.11 Tweening library

A tweening library was used to ease the process of devising some animations in the interface.³ Tweening is the process of creating intermediate frames between two sprites to illude the moving of the first image onto the second [31].

Compared with Unity's animation system, this library provides less demanding animations, especially when animating the elements of the interface. For this reason, tweens are used to animate the appearance of text prompts and the challenges menu.

²<https://unity.com/features/analytics> [Access date: May 12, 2021]

³<http://dotween.demigiant.com/getstarted.php> [Access date: April 12, 2021]

4.12 Summary

Chapter 4 exposed the logic behind each aspect presented in the previous section. It was discussed the class responsible for controlling and supervising every part of the gameplay, alongside an analysis of its helper classes. The player's movement was also described, taking into consideration its interaction's with the world elements. Besides analysing the classes analogous to sections on Chapter 3, additional technical contents were explained, such as the save and localisation systems.

Chapter 5

Testing

One of the purposes of this dissertation is to validate whether Neuropal's mechanics are an engaging way to promote behavioural changes. As such, there were outlined three distinct testing phases.

The first phase consisted of a preliminary questionnaire to test the players on their knowledge of these dangerous situations. This phase was followed by playing the game, where the players playtest the game mechanics. The final stage encompassed another questionnaire to validate the overall experience. These phases took into account the age group of the target audience, hence the questionnaires were neither long nor arduous to read. The surveys were created in Portuguese, but the questions were translated for the present chapter. The original versions are present in appendixes [B](#) and [C](#).

The tests were conducted with children between the ages of eight and twelve years old, from a sample of opportunity. Given the pandemic state, the testing protocol was sent via email to the parents of these children. In addition, the questionnaires were available during a week.

5.1 Preliminary questionnaire

Behavioural change occurs over a shift in time, and as such, it cannot be thoroughly evaluated in the scope of this masters. Yet, efforts were made to assess the childrens' literacy prior to and after playing the game. The small questionnaire before the game gathered the average familiarity of the audience with the behaviours to be showcased. This information will then be compared with the aftermath results and can carry value in estimating the potential of this game.

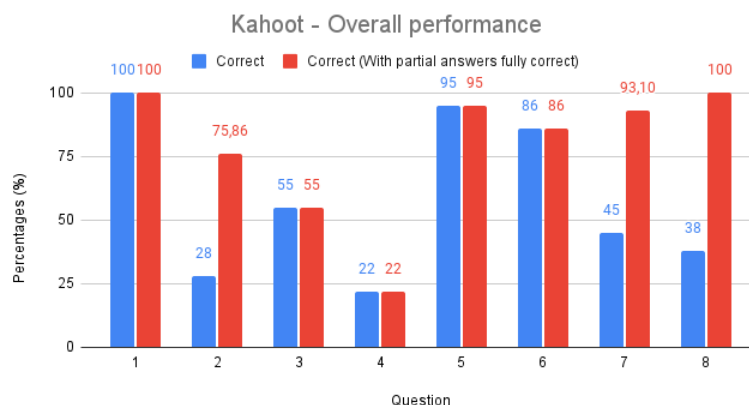
The creation of this survey was achieved by using the platform Kahoot.¹ Kahoot is a game-based learning platform, mainly used to provide questionnaires in an engaging and interactive matter. A total of 64 responses was received, but the players whose quizzes were exited without finishing were discarded, reducing the sample size to 58 replies. This survey can be found in [Appendix B](#).

¹<https://kahoot.com/> [Access date: Jun 15, 2021]

Table 5.1: Kahoot demographic information

Age range	Number of participants
7-8 years old	16
9-10 years old	18
11-12 years old	14
Over 12 years old	10

The initial question inquired about the ages of the players, whose results can be seen on Table 5.1. All remaining questions awarded points, adding a layer of excitement to the quiz. The majority of the questions were one of two types: standard multiple-choice with one correct answer or multiple choice with various correct answers. The latter existed not to challenge the player to respond with all the right alternatives but to verify if, given a choice, the player would choose the wrong answer. For this reason, the calculations of the winning percentages had two alternatives: the one provided by Kahoot and one that considered partially correct answers entirely correct. Both ratios can be seen in Figure 5.1.

**Figure 5.1:** Kahoot overall performance

The numbers of this graph have the following question's correspondence. The answers to these questions are also displayed for increased readability, with the correct answers underlined:

1. What is your age? 7-8 years old / 9-10 years old / 11-12 years old / Over 12 years old
2. A chair is suitable for: Having a class / Reaching a tall place / Playing in the computer / Taking a nap
3. Which of these objects is essential for a safe bathroom? A helmet / A rug / A radio / A towel
4. A helmet does not protect you: During a volcano eruption / While running / While driving a scooter / While rock climbing

5. When we need to reach an object in a tall location, we should: Use a stool / Build a pillow tower / Jump as high as we can on the couch / Use a ladder
6. This bin is for: General waste / Glass / Paper / Plastic
7. When a volcano erupts, we should: Turn on the radio / Close the doors and windows / Eat an ice cream / Go for a swim
8. Leaving trash on the floor: Can cause an accident / Is unsanitary / Does not bother anyone / Pollutes the environment

From this data, it was essential to analyse the average of correct answers and which questions had the most wrong answers. This entitled an average of 58,63% correct answers, which increased to 78,37% when the partially correct answers were valued as complete. These results show that the participants were familiar with the mentioned practices, particularly with the wrong ones, as the loss of points mainly came from not selecting all the correct options. This percentage difference is most notable in questions 2, 7 and 8, as they are the ones with multiple correct answers.

Question 4 is clearly seen as the one with the most wrong answers. As this question regarded safety rules during a volcano eruption, it is justifiable that most participants got it wrong, given the lack of familiarity with these eruptions in Portugal, the participants' location.

5.2 Game phase

From the Unity analytics, it was possible to extract some information, namely the average amount of accidents, time spent and questions answered wrongly.

The most relevant information regards the number of occurrences of each accident, which is displayed in Figure 5.2. Each number on the graph is related to the following accidents:

1. Failure to place the rug;
2. Using a stool to reach the painting;
3. Slipping on the banana peel;
4. Crossing the lamp area without wearing the helmet;
5. Using a stool or chair to reach the painting.

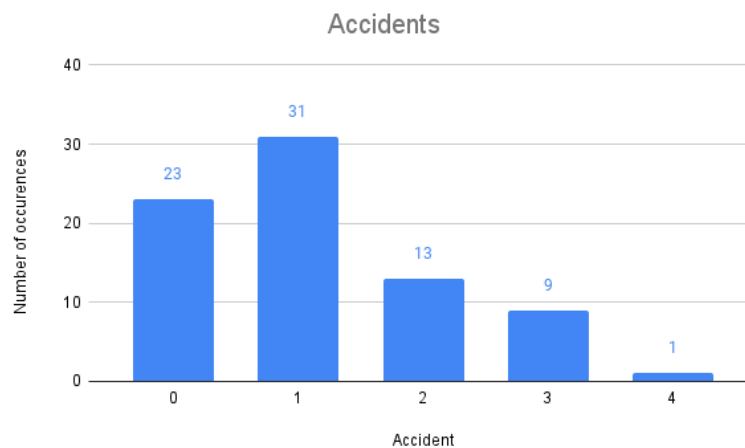


Figure 5.2: Number of occurrences per accidents

From this graph, it is possible to ascertain that the majority of accidents tend to happen at the beginning of the level. Moreover, it is worth noting the relation between accidents 1 and 4, as they both occur from using an incorrect object: whilst the former has very high values, the latter rarely happens, indicating that the players may understand the harm in the poor choice of an auxiliary object.

The first and the second accidents, the two most recurrent ones, were foreshadowed by questions 3 and 2 from the previous quiz, respectively. The second question, when considering the partially correct answers, has a very high success rate. This could signify that the participants inherently consider it dangerous to use an unsafe object to reach something but do consider enacting that unsafe behaviour, and only answered in such a way to avoid losing points. On the contrary, the number of correct answers on question 3 is aligned with the number of accidents regarding the failure to place down a rug.

Further analysis from the game analytics provides an average time to complete the level of 285.885 seconds, which can be rounded to 4 minutes and 46 seconds. Considering the points formula from Chapter 3, for level 2, the player had a tolerance time to complete the level of 3 minutes. The proximity of these two values validates the expected time to fulfil the level.

The average of wrong answers achieved a count of 0.42 occurrences, indicating that the players rarely failed to respond to the questions at the end of the level.

From the in-game leaderboard, an average score of 817.31 was extracted. Most scores equalled 875 points, which, due to an error in the backend, was the maximum possible score. This could mean that the players who entered the leaderboard replayed the game to achieve a higher scoring and thus improve their position in the leaderboard.

5.3 Post-game questionnaire

Game experience is not a linear concept as this experience has a one-to-one relationship with the player [32]. However, it is possible to establish common factors that, when evaluated together, can perceive a definition of the game experience. For assessing the experience of *Neuropal*, it was chosen the Game Experience Questionnaire (GEQ) [33]. This questionnaire, widely used in the game industry, defines three core modules to evaluate the player experience: core, social and post-game. This modular questionnaire is designed to assess the game experience as the sum of several components.

5.3.1 Preparation

A preliminary survey overview was done to understand the best way to adapt the standard GEQ to a version more suitable for younger ages.

The first option was to map each component from the core part of the GEQ to a single question. This significantly reduces the number of questions and adds a more natural language. From the original modules, the social and in-game modules were discarded as they were not relevant for evaluating the present game: this is a single-player game without relevant NPC and the game experience is only being assessed in one moment. Even though the game presents one major NPC, Neuro, the game version used during the testing possessed limited interaction between Neuro and the player, thus not justifying the use of the social module. Both the core and post-game modules evaluate how the players felt. Furthermore, the post-game section is deemed more worthwhile when assessing naturalistic gaming. As such, the post-game module was discarded.

Table 5.2 enumerates the mapping of each component with what it was deemed valuable to evaluate with children.

Table 5.2: Mapping GEQ modules to a single idea

GEQ Modules	What is important to assess
Competence	The player's success rate in completing the game's objectives
Sensory and Imaginative Immersion	The game's aesthetics
Flow	If the game's experience is immersive
Tension/Annoyance	How difficult is the game
Challenge	How difficult is the game
Negative affect	If the game's experience was boring and tiring
Positive affect	If the game's experience was pleasant and fun

This option yields a global vision of the game's experience, allowing the understanding of how the game works as a whole. However, this global approach lacks a detailed analysis of the modules, thus simplifying the conclusions from each module.

In accordance with this analysis, the three components that provide the most valuable information to validate the game design were *competence*, *challenge*, and *positive/negative affect*. Thus, three test questionnaires were created, one for each component. The first questionnaires allowed the understanding of how successful were the players in the game and if the mechanics are balanced. Thereafter, a quiz focused on the challenge module outlined the suitability of the gameplay to the target audience whilst assessing the game's degree of difficulty. Lastly, the positive and negative affects were combined into one preliminary questionnaire as they both focus on the player's experience, more so than the gameplay experience. While this approach is very heavy on player analysis, it provides little information regarding the game's actual play.

Notwithstanding the value in assessing a component with great detail, every one of these component-specific quizzes provided no information relative to other modules. For this reason, the global questionnaire was chosen for the target audience, and this version is available in Appendix C.

5.3.2 Results analysis

As the tests were conducted remotely, it was unmanageable to control whether all participants answered both questionnaires. As a result, the second questionnaire had fewer responses than the first one, coming up to 36 replies.

Table 5.3: Post-game questionnaire demographic information

	Number of participants
Age range	
Less than 8 years old	4
8 years old	4
9 years old	5
10 years old	7
11 years old	7
12 years old	4
Over 12 years old	5
Gender	
Female	19
Male	17
School year	
2nd grade	4
3rd grade	5
4th grade	3
5th grade	8
6th grade	9
Other	7

The demographic data from Table 5.3 shows an even number of females and males and a majority of ten and eleven years old. The school years information appears in accordance with the age ranges.

The results from the questionnaires were grouped in a series of graph bars to aid the analysis of the responses. Each graph will have two dimensions, one for the number of answers and another for each of the possible answers.



Figure 5.3: Answers to the question "Were you able to complete the game's tasks?"

The graph in Figure 5.3 evaluates the competence element from the GEQ, as in, how well the players were able to complete the game's main action. The results showcase that the majority of the inquiries either had no issues or had minor problems completing the activities. This may indicate the overall balancing of the game's actions, as there were very few responses on either extreme of the graph.

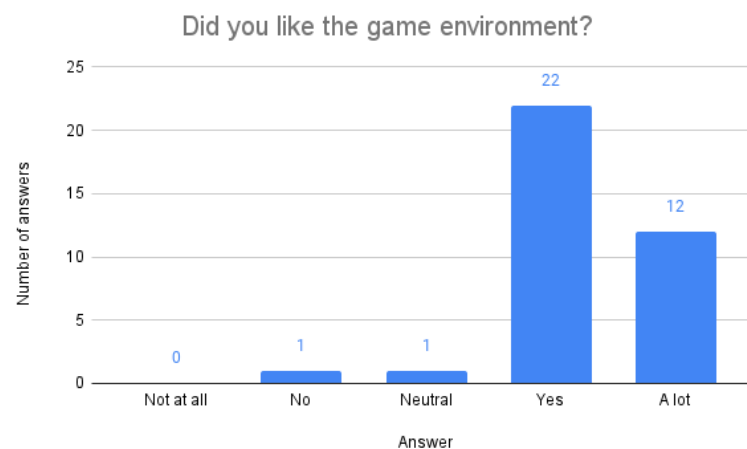


Figure 5.4: Answers to the question "Did you like the game environment?"

As seen in Figure 5.4, the game is appraised from an aesthetic perspective. Apart from two players, everyone else enjoyed the game look, with 22 players liking it and 12 players liking it a lot. This indicates that the visual design and audio effects are aligned with the target audience's preferences.



Figure 5.5: Answers to the question "Did you find the game challenging?"

The following question measures the degree of challenge within the game. Figure 5.5 displays that players vary between the three middle levels. This can be the result of each player's inherent level of ability. Regardless, the slight majority on the second to the last column can indicate that the played level still has room for improvement. Being one of the early levels in the complete game, this section could have additional prompts to help guide the player and even some warnings if the player appears to be stuck on a segment.

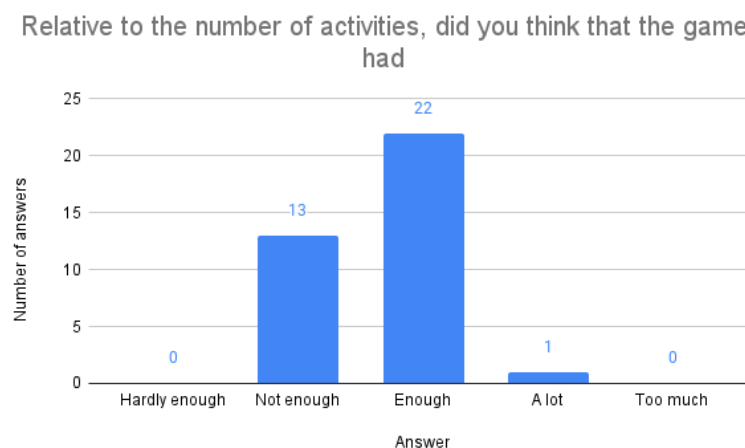


Figure 5.6: Answers to the question "Relative to the number of activities, did you think that the game had"

Figure 5.6 shows the participants' opinion regarding the amount of tasks throughout the level. The majority of the players indicate that the prototype had a sufficient number of activities, symbolising a good balancing in the level's core activities. This could mean that the number of actions is proportional to the level of difficulty and that this prototype level will transition well when encompassed in the complete game. The second option was the second-highest, which is understandable given that the prototype only consists of one level. With the extension of the game to its full potential, the lack of activities will most likely be overturned.



Figure 5.7: Answers to the question "What did you think of the game experience?"

The last multiple-choice question regarded the overall experience of the game, as seen in Figure 5.7. The vast number of players agreed that the game experience could be perceived as fun or even very fun. This is an excellent validation of the game mechanics, as the players claim to have enjoyed the game. The person who disliked the game experience was also the one who disliked the game ambience. However, no comments were left as to the reasoning of the discontent.

The remaining two questions were of open answer, with the first one regarding the favourite element from the game and the second functioning as a place to leave an optional comment. As expected, the results were varied, but several participants said they enjoyed the small challenges linked to finding the auxiliary objects required for each action. There were also some compliments on the security aspects of the game and the small task regarding recycling. The most common answer to the optional question stated that they wished for more content, which is an excellent indicator of the game's future.

To further understand the game's appropriateness for its current target audience, some topics were grouped per age. The dimensions that evaluate the competence to fulfil the tasks and the game's challenge were chosen given their variety of answers. These graphs present percentages, divided by age, for each possible answer.

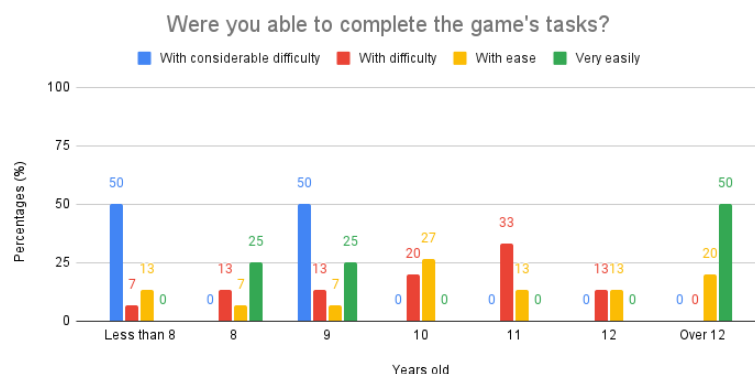


Figure 5.8: Answers to the question "Were you able to complete the game's tasks?" organised by ages

The competence aspect is once again evaluated, as showcased in Figure 5.8. The younger crowds struggled to fulfil the game's objectives, deeming that younger groups might struggle to complete the game. This hypothesis makes sense, given the strong narrative present in the game and considering that those ages could still be learning how to read. From the age of 10 forward, the participants vary their responses between the middle levels, with the older participants completing the game with ease.

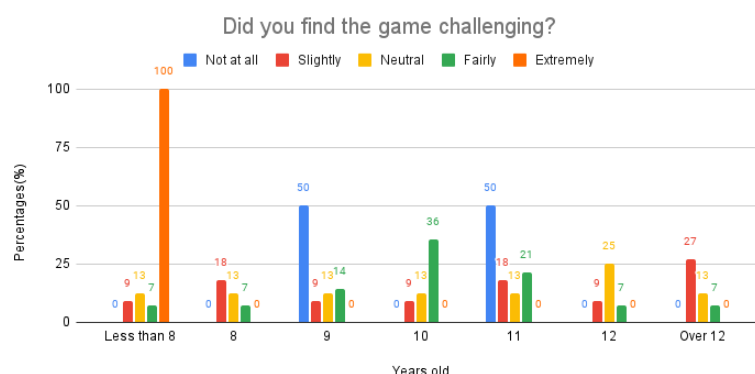


Figure 5.9: Answers to the question "Did you find the game challenging" organised by ages

Figure 5.9 displays the percentages for the answers regarding the game's difficulty. The extremely challenging option was only selected, once more, by the participants with ages below 8, which were outside of this project's target audience. Justifying the defined audience, the game proved to be better received between the ages of 8 and 12, stating that children still in the first/second grades were too young to play the game in its current state. The ages of 9 and 11 felt the game to be not at all challenging, which reveals a peculiar lack of a trend. The older children also agreed the game to be slightly challenging, without much disparity towards other values.

In comparison with Figure 5.8, the ages of 9 provide some contradictory data, as the majority agree to have struggled to complete the game's tasks but then agree that the game is not at all challenging. Furthermore, the most extreme answers were mostly provided by the participants outside the target audience.

5.4 Conclusions

The first testing phase allowed the gathering of information regarding the audience's previous knowledge. The data analysis showed that the participants were indeed familiarised with the theory of the correct practices, but the game data hints at the lack of carrying out those practices.

The game itself received a very appraised response, with the majority of the participants enjoying the mechanics and the look and feel of the level. The challenges did not feel overly complicated, nor did the gameplay feel uninteresting, which approves the mechanics implemented thus far. The analysis per age shows that the younger participants struggled to play through the level, indicating that the game is not suited for children below the age of 8. However, the game shows promise from the age of 10, as most players found the game fairly balanced. Globally, the players also took the game as engaging and enjoyable.

Chapter 6

Conclusions and Future Work

The present chapter enumerates the primary challenges of the project, alongside the conclusions and what is expected to happen as future work.

6.1 Conclusions

This dissertation consisted of creating a game with an environment capable of increasing literacy regarding spinal cord injuries. The earliest stages were focused on analysing the initial prototype and enumerating the game ideas worth keeping. This first version of the game showed promise, but the gameplay was straightforward and limited, which was expected given the initial prototype development timeline. The main game ideas from this prototype were the integration of the correct practices into the actual gameplay and the *click and interact* mechanic. Afterwards, a brand new game was initialised, with modular mechanics and functionalities that conveyed the game's skeleton. The *click and interact* mechanic was extended to display a silhouette of the auxiliary object to be placed and to include road-oriented interactions. Further functionalities include the addition of two different types of challenges to accommodate an increased degree of difficulty throughout the levels without hardening the completion of the safe behaviours. These challenges are composed of a keypad version, where the player has to input the correct sequence of colours or numbers, and a puzzle version that consists of placing the puzzle pieces in their proper positions. Each level had five main interactions, all tied to behaviours that could lead to spinal cord injuries. The six levels were devised with temporary assets, and several early versions were tested by the team elements to align the mechanics and display of the level. As the visual and audio assets were delivered, these were adjusted per the team's feedback and then implemented into the game. Thus, the process for the development of both of these assets followed an interactive approach.

Just before the testing phase, level 2 was entirely designed and functional. Prior to the release of the prototype, some problems arose with the mobile versions. As the game was highly inefficient, some devices were unable to run the application. This inefficiency prevailed with the visual

assets' resolution and with the elevated number of individual assets. Having discovered the source of this problem, this issue was overcome by reducing the assets' size and creating one sprite sheet for each animation. Afterwards, the game was built successfully and sent to the playtesters.

The tests showed positive indicators that the game has potential to work as a behaviour change promotor, given the overall reactions. The gameplay itself and the game environment received very positive responses, as the vast majority of participants enjoyed them both. The younger crowds of the spectrum found the game to be rather challenging and struggled to complete the required actions. The remaining ages disagreed on a difficulty level, as the results were quite varied. Notwithstanding, they were able to achieve the game's objectives without too much struggle, and comments from the latter questions praise the current design and express a desire for the remaining levels.

What triggers behaviour change for avoiding risky behaviours?

As seen in Section 2.1.1, behaviour change can occur linked to a number of factors. FBM explains that a behaviour will only happen by the convergence of motivation, ability and a prompt. The motivation and ability experience a trade-off relationship, where a high value of one can be outweighed by the other: a simple task will be addressed even if one is not highly motivated, whereas a more challenging endeavour will require a more substantial source of motivation. The prompt or trigger is the last element in effecting the behaviour when the two aforementioned components are met.

SDT claims that one's autonomy and personal goals guide a behaviour: one's necessities are the foundation of one's actions. It also defends that external rewards can have a discouraging reaction when applied to a personal goal since that compensation diminishes the sense of autonomy. However, when these occur at an expontaneous moment, external factors may increase one's motivation and confidence.

These theories highlight the importance of the source of motivation, the basis of one's persistence and self-initiation. Extrinsic motivation is linked to the completion of a task in exchange for a reward, whilst intrinsic motivation is understood as doing an activity for the activity itself, heavily tied to one's personal goals. Thus, motivation levels tend to achieve higher stages when one does not feel control by external factors and is not reliant on compensation.

As such, behaviour change will happen when one is eager and able to comply with that behaviour. Furthermore, the more that behaviour is tied to the individuals' goal, the higher the individual's motivation will be. Compensation can also play a part in promoting behaviour change, but it should be used with care not to discourage the user altogether.

How can we design a serious game capable of increasing literacy of behaviours that may lead to spinal cord injuries?

The prevention of risky behaviours in a game environment requires first envisioning an immersive and interactive context where the player feels engaged and stimulated. Afterwards, the game

should balance the degree of difficulty of the game, providing the player with situations where he/she feels propel and able to complete the given activity. These ideas follow the guidelines from the behaviour change theories summarised in the section above. Furthermore, a game should not overly guide the player, as in, the player needs to feel like he/she has a choice within the game and that the stated intention will impact the game.

These premises were implemented in the present game. The repetition of mechanics familiarises the players with the gameplay and permits a slight variation of the difficulty levels with subtle tweaks. Thus, each level maintains the same *click and interact* mechanic at its core. Still, through the expansion of the level's environment and by adding obstacles to each primary interaction, the challenge increases. Extra elements, such as the colour puzzle, further aid in creating a challenging environment that does not discourage the player. The game's lore is then connected to the literacy that is intended to provide. As the player has to fulfil them to carry on, he/she is intrinsically motivated to comply with the safe practices. Moreover, one has the option to utilise various objects to address a situation, leaving it up to the player to learn the correct approach through trial and error. Lastly, the points mechanics added a layer of external compensation to the game and was carefully designed not to overtake the gameplay. The players win and lose points per action completed or failed, but these do not carry any extra value besides immediate feedback.

How to design a game adequate for children between the ages of eight and twelve-years-old?

It was embraced a vivid environment with cartoonish characters to suit the game world with the target audience's preferences: Neuropal had a cheerful look, highlighted by his/her walk animation, and the environments were decorated with details that enriched the visual image. The audio files were also designed to match this environment and emphasise the cartoonish vibe: the ambience music was soft and melodic, contrasting with the remaining sounds, which were powerful and humorous. These design choices were validated by the testing results, as the audience was highly pleased with the game's overall look and feel.

Furthermore, the mechanics themselves are not overly complicated, and there is not an excessive number of interactions to be completed. Each level has five mandatory interactions and a varied number of optional actions. In addition, the challenge that may accompany the main action follows an uncomplicated approach, with intuitive mechanics that have a more accessible version on the early levels. For instance, in the fully implemented level, the colour puzzle solution was close to the puzzle itself, and the colour sequence only had four elements. As the game is intended for a young target audience, the game encompasses some textual and visual clues. The former appears to inform the player of missing objects, completed interactions or to provide positive reinforcement, thus guiding the player throughout the level without being too prominent. The visual clues include the highlight mechanism, which differentiates the main objects from the remaining ones and informs the player of the available interactions.

In this regard, the primary goal of creating a serious game to increase literacy about spinal cord injuries was indeed achieved. The mechanics did not seem too arduous for the players, and the addition of challenges to create some extra interactions for the game proved to be a good decision. With these design choices, the level's size expanded without feeling too repetitive, and the player's felt challenged without discouraging the safe-conducts. The mechanics are also aligned to implement the remaining five levels, as they have a modular design. The testing results indicate that the number of activities may even be increased, which is a predicament that could be answered by the implementation of the remaining levels. Further analysis from the tests validated the game's look and feel and underlined the game's core mechanics, as most players were able to complete the game without too much struggle.

When the moment arose to enact the correct practices to prevent any accident, most players behaved as expected. Given that behaviour changes are not enacted instantly, at this moment, it cannot be guaranteed the long term effectiveness of the game. Nevertheless, the results and the implemented mechanics indicate that the players realise the game's intention, and thus far, the number of accidents reduces with the number of playthroughs. By comparing the two moments where the player may wrongly use a stool or chair to reach a tall place, it can be understood that while the first situation happens a few times, players tend not to repeat the same mistake, as the second situation rarely occurs. In sum, the developed game is believed to have increased the literacy of the target audience in the short term and will most likely be a promotor of behavioural change.

6.2 Limitations

Developing a game is a thorough process, as this type of application includes many details beyond the mechanics outlined. Furthermore, it requires the creation of compelling audio and an appropriate look, which were areas outside this dissertation's scope.

The idea of the game envisioned six levels, which were all devised and planned. Nonetheless, from early on, it was deemed unfeasible to implement them all, as this game was to be developed within a dissertation scope. Therefore, it was decided to only focus on three levels to allow for a more thorough approach. Following this line of thought, the development itself had to be restricted by adopting a pragmatic way of working. Several ideas that would enrich the game's animations had to be overlooked, as there was no time to complete them. An example of this would be to add more dynamism to the character's face, the addition of animation when changing between rooms and the creation of a customisable character. These ideas will be addressed in the future work section. Furthermore, the mechanics themselves and the accidents moments could not be further expanded due to the limitations mentioned above. This expansion meant designing a mechanic to illustrate a failed attempt to reach an object in a tall location. The accidents moments were envisioned to showcase the initial moment that would cause the accident, but it was reduced to

only display the accident strips. Also, the existing mechanics could not be thoroughly tuned from a programmatic view, leaving the current game version with some minor glitches.

The initial process of aligning the teams for the design and audio aspects took a long time, compromising the concretisation of the established three levels. Moreover, the first iterations of the art style proved to be more challenging than anticipated, namely the definition of the colour palette for the game. This hindered both the integration of the new assets as well as the production of the audio files. The focus had to be readjusted once again due to a lack of time, so it relied on a single level, fully implemented for this dissertation. Level two was chosen due to its variety of interactions and lack of other characters, which would demand numerous assets.

At last, the pandemic state which the country is going through restricted the testing phase of this project. The questionnaires had to be distributed remotely, and, as such, there was no control over whether the participants answered both surveys. This resulted in a discrepancy in the number of answers, particularly in the questionnaire made after playing the game.

6.3 Future work

This project has numerous enhancements planned and the next phase is focused on finishing the remaining five levels. In addition, further improvements could be made to the leaderboard, as the functionality to access private rankings is not yet implemented in the current game version. The quiz menu could also be improved by polishing its look and adding a greater variety of questions.

During development, several ideas arose to enrich the game, but they had to be overlooked due to the aforementioned constraints. These ideas, alongside some extra functionalities, are as follows:

1. Add a customisable main character with different clothing and skin tone options. Further enhancements to this character include adding dynamism to the his/her face to emphasise the evolution of the volcano eruption;
2. Create more dynamic and illustrated cutscenes that not only highlight the level to be played but also better report the storyline;
3. Add an animation when the player is trying to reach a location that is too far, thus enabling interacting with an object unreachable;
4. Convey an animation to the character's movement between floors instead of instantly moving the player to another floor;
5. Create animations to emphasise the action that leads to the stool and chair accidents: the player would place the stool or chair, begin climbing it and then the accident would occur to point out the cause of the accident.;
6. Refactor the lamp incident. The final two interactions will be swapped, so that the grabbing of the duck is the fourth interaction and the lamp will be positioned right before the yellow

closet. With this layout, the first time the player crosses the lamp an animation will shake it, symbolising the imminent fall. After the player grabs the duck, whenever he/she crosses the lamp area, another animation will trigger to showcase the falling motion;

7. The menus currently in the game will be subject to alterations. The buttons on the main menu will receive an updated look, followed by a redesign of the pause menu and the leader-board menu;
8. The in-game interfaces require an update to the pause, game over and level completed screens, as these were leveraged from the prototype;
9. Refactoring of the interaction system to be more consistent by creating a new method that allows two interactions to be overlapping without tempering with their interactivity. Currently, the interactable objects had to be carefully laid out to prevent any overlapping. With the aforementioned enhancement, the system would be able to distinguish between two available interactions without any apparent oddity to the user;
10. The displaying of the prompts can also be improved: the current system receives one prompt at a time, and if one is already being displayed, the system awaits its conclusion. Still, there are situations where the succeeding prompts are connected, and the system should guarantee their sequence;
11. Refactor the `PickPlace` interaction which is responsible for displaying the object's silhouette. By expanding this class it would be possible to place different objects in the same location, instead of the current version's logic, which requires a different location for each different silhouette;
12. The game mechanics from the future levels, such as the road-oriented interactions and the puzzle challenge, should too be refactored. Upon the integration with the assets, these mechanics are likely to require some adjustments, as the playtesting with the actual assets provides a different experience than the one with the placeholder assets.

At last, it is foreseen that this game will grow beyond the initially devised levels by adding more mechanics and showcasing additional behaviours that could endanger the spinal cord. This entitles a new set of levels, themed with a voyage around the world.

References

- [1] The Matador Review. An interview with eric barone, 2021. <http://www.matadorreview.com/eric-barone>. Accessed on 20.06.2021.
- [2] BJ Fogg. Behavior model. <https://behaviormodel.org/>. Accessed on 21.01.2021.
- [3] Sebastian Deterding, Dan Dixon, Rilla Khaled, and Lennart Nacke. From game design elements to gamefulness: Defining "gamification". pages 9–15, 2011.
- [4] Derek A. Kuipers, Bard O. Wartena, Boudewijn H. Dijkstra, Gijs Terlouw, Job T.B. van t Veer, Hylke W. van Dijk, Jelle T. Prins, and Jean Pierre E.N. Pierie. ilift: A health behavior change support system for lifting and transfer techniques to prevent lower-back injuries in healthcare. *International Journal of Medical Informatics*, 96:11–23, 12 2016.
- [5] S. N. Ihsan, T. A.A. Kadir, R. Benedict, and A. R. Abdullah. Preventive self-care serious games for diabetes: A game design. volume 769. Institute of Physics Publishing, 6 2020.
- [6] Bushra Tasnim Zahed, Gregory White, and John Quarles. Play it safe: An educational cyber safety game for children in elementary school. page 1DUUMY. Institute of Electrical and Electronics Engineers Inc., 9 2019.
- [7] Ricardo Rodrigues, Paula da Costa Ferreira, Rui Prada, Paula Paulino, and Ana Margarida Veiga Simao. Developing children’s regulation of learning in problem-solving with a serious game. *IEEE computer graphics and applications*, 40:26–40, 9 2020.
- [8] Victoria Guillén-Nieto and Marian Aleson-Carbonell. Serious games and learning effectiveness: The case of it’s a deal! *Computers and Education*, 58:435–448, 1 2012.
- [9] World Health Organization. Spinal cord injury: Key facts, 2013. <https://www.who.int/news-room/fact-sheets/detail/spinal-cord-injury>. Accessed on 28.11.2020.
- [10] Damien Djaouti, Julian Alvarez, and Jean-Pierre Jessel. Classifying serious games, 5 2011.
- [11] Gideon Dishon and Yasmin B. Kafai. Making more of games: Cultivating perspective-taking through game design. *Computers and Education*, 148:103810, 4 2020.
- [12] Elizabeth Boyle, Thomas M. Connolly, and Thomas Hainey. The role of psychology in understanding the impact of computer games. *Entertainment Computing*, 2:69–74, 2011.
- [13] Michael Sailer, Jan Ulrich Hense, Sarah Katharina Mayr, and Heinz Mandl. How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction. *Computers in Human Behavior*, 69:371–380, 4 2017.

- [14] Rita Orji and Karyn Moffatt. Persuasive technology for health and wellness: State-of-the-art and emerging trends. *Health Informatics Journal*, 24:66–91, 3 2018.
- [15] B J Fogg. A behavior model for persuasive design. ACM Press, 2009.
- [16] E.L. Deci and R.M. Ryan. *Handbook of Self-determination Research*. University of Rochester Press, 2004.
- [17] Patrick Buckley and Elaine Doyle. Gamification and student motivation. *Interactive Learning Environments*, 24:1162–1175, 8 2016. Intrinsic vs Extrinsic motivation.
- [18] Robert Mitchell, Lisa Schuster, and Hyun Seung Jin. Gamification and the impact of extrinsic motivation on needs satisfaction: Making work fun? *Journal of Business Research*, 106:323–330, 1 2020.
- [19] Nannan Xi and Juho Hamari. Does gamification satisfy needs? a study on the relationship between gamification features and intrinsic need satisfaction. *International Journal of Information Management*, 46:210–221, 6 2019.
- [20] Edward L. Deci, Richard Koestner, and Richard M. Ryan. Extrinsic rewards and intrinsic motivation in education: Reconsidered once again. *Review of Educational Research*, 71:1–27, 3 2001.
- [21] Judy Cameron and W. David Pierce. Reinforcement, reward, and intrinsic motivation: A meta-analysis. *Review of Educational Research*, 64(3):363–423, 1994.
- [22] Gabriel Barata, Sandra Gama, Joaquim Jorge, and Daniel Gonçalves. Improving participation and learning with gamification. pages 10–17. Association for Computing Machinery, 10 2013.
- [23] Juho Hamari. Do badges increase user activity? a field experiment on the effects of gamification. *Computers in Human Behavior*, 71:469–478, 6 2017.
- [24] Elisa D. Mekler, Florian Brühlmann, Klaus Opwis, and Alexandre N. Tuch. Do points, levels and leaderboards harm intrinsic motivation? an empirical analysis of common gamification elements. pages 66–73. Association for Computing Machinery, 10 2013.
- [25] Scott Nicholson. A user-centered theoretical framework for meaningful gamification. 2012.
- [26] Wei Peng. Design and evaluation of a computer game to promote a healthy diet for young adults. *Health Communication*, 24:115–127, 3 2009. The Element of Fun for Intrinsic Motivation.
- [27] Renee Garrett and Sean D. Young. Health care gamification: A study of game mechanics and elements. *Technology, Knowledge and Learning*, 24:341–353, 9 2019.
- [28] Gianvito D’aprile, Maria Beatrice Ligorio, · Antonio, and Ulloa Severino. How serious games for health enhance empowerment-related patient education: The impact of gender. *Technology, Knowledge and Learning*, 24, 2017.
- [29] Daniel Johnson, Ella Horton, Rory Mulcahy, and Marcus Foth. Gamification and serious games within the domain of domestic energy consumption: A systematic review, 2017.

- [30] N. Razali, N. A. Nasir, M. E. Ismail, N. M. Sari, and K. M. Salleh. Gamification elements in quizizz applications: Evaluating the impact on intrinsic and extrinsic student's motivation. volume 917, page 012024. IOP Publishing Ltd, 9 2020.
- [31] Vangie Beal. Tweening, 2021. <https://www.webopedia.com/definitions/tweening/>. Accessed on 14.05.2021.
- [32] Eduardo H. Calvillo Gámez, Paul Cairns, and Anna L. Cox. From the gaming experience to the wider user experience. pages 520–523, 2009.
- [33] W.A. IJsselsteijn, Y.A.W. de Kort, and K. Poels. *The Game Experience Questionnaire*. Technische Universiteit Eindhoven, 2013.

Appendix A

Level's Schemes

This appendix includes the schematics for the game's levels.

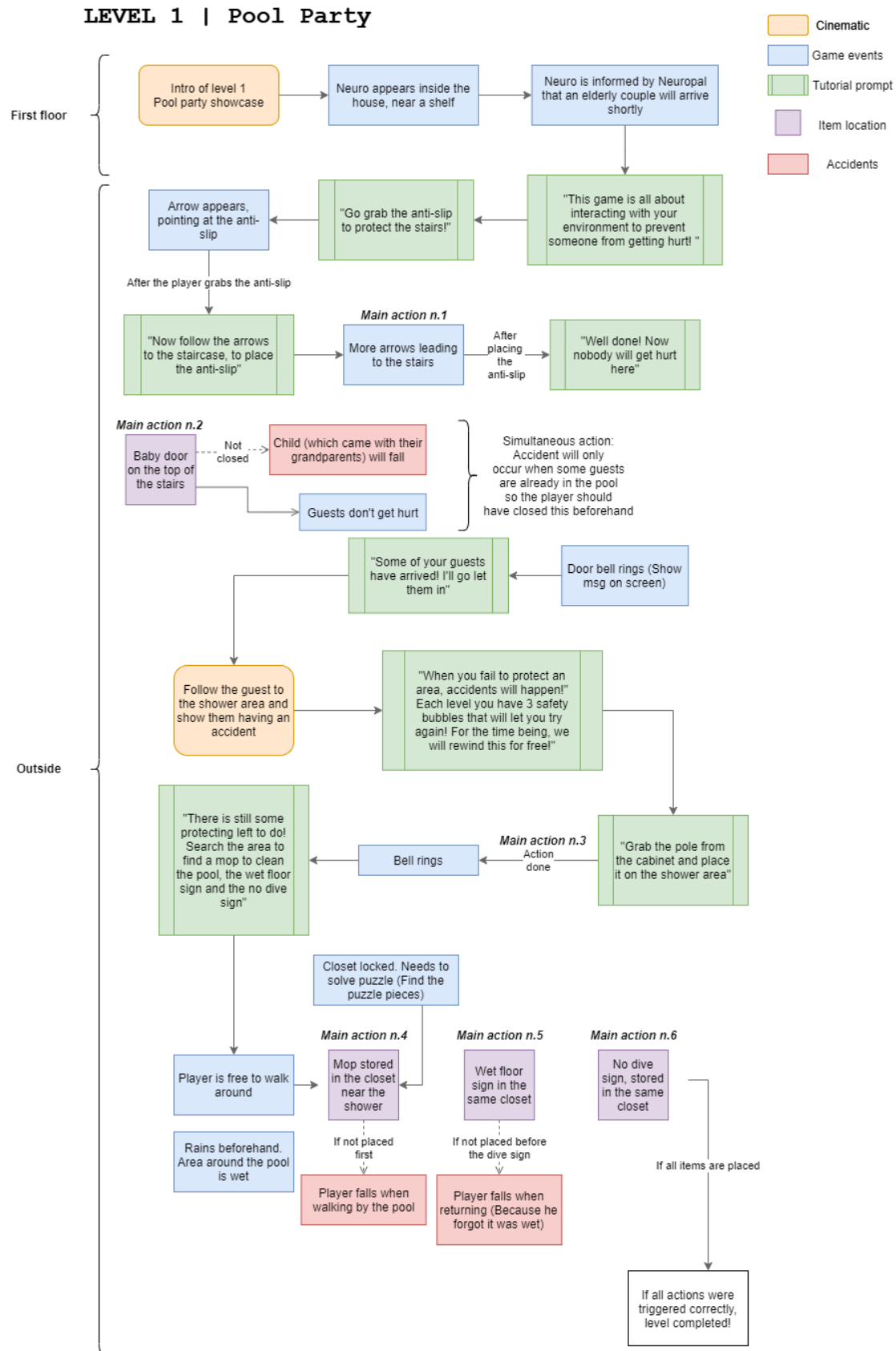


Figure A.1: Level one scheme

LEVEL 2 | The Escape

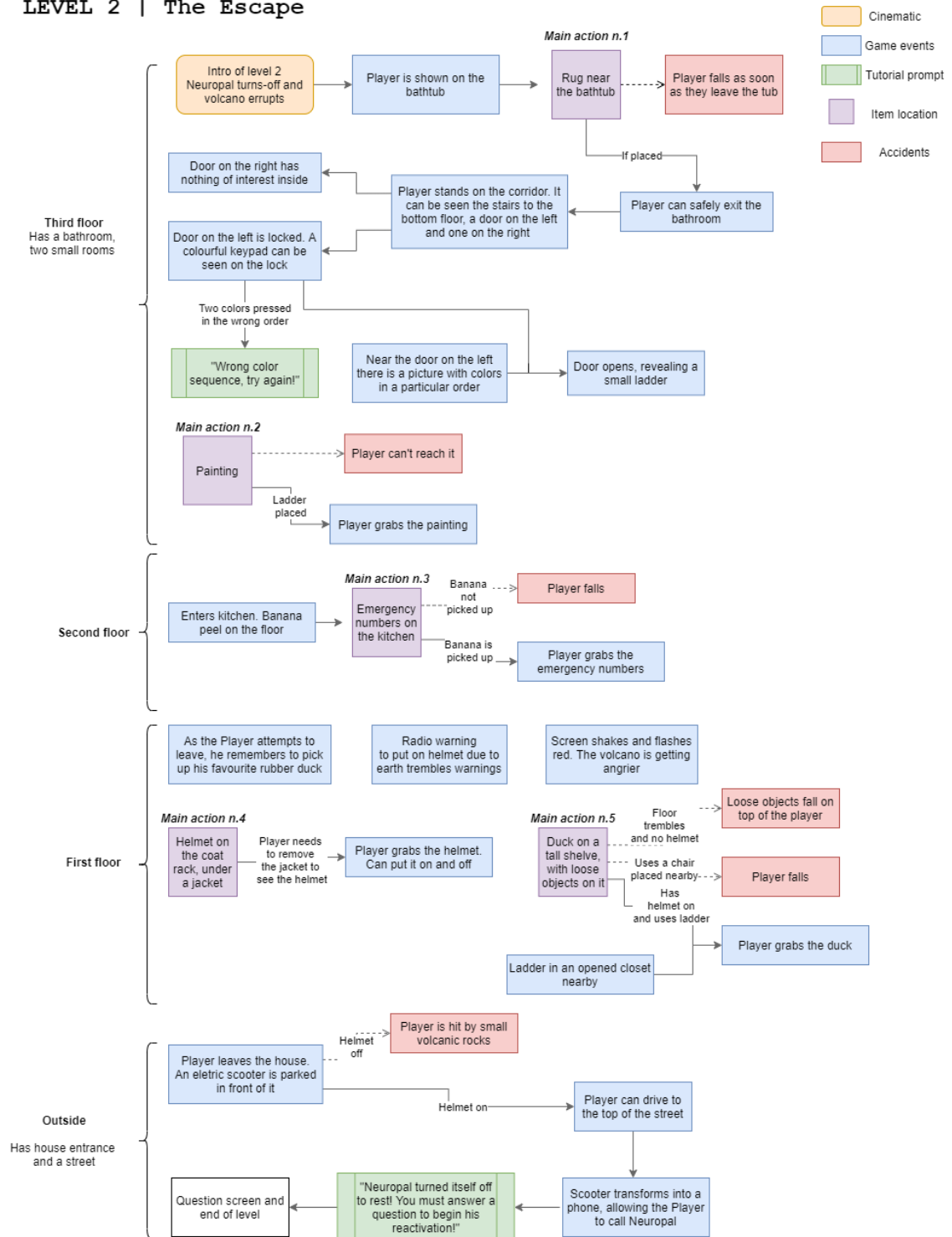


Figure A.2: Level two scheme

LEVEL 3 | The Bridge

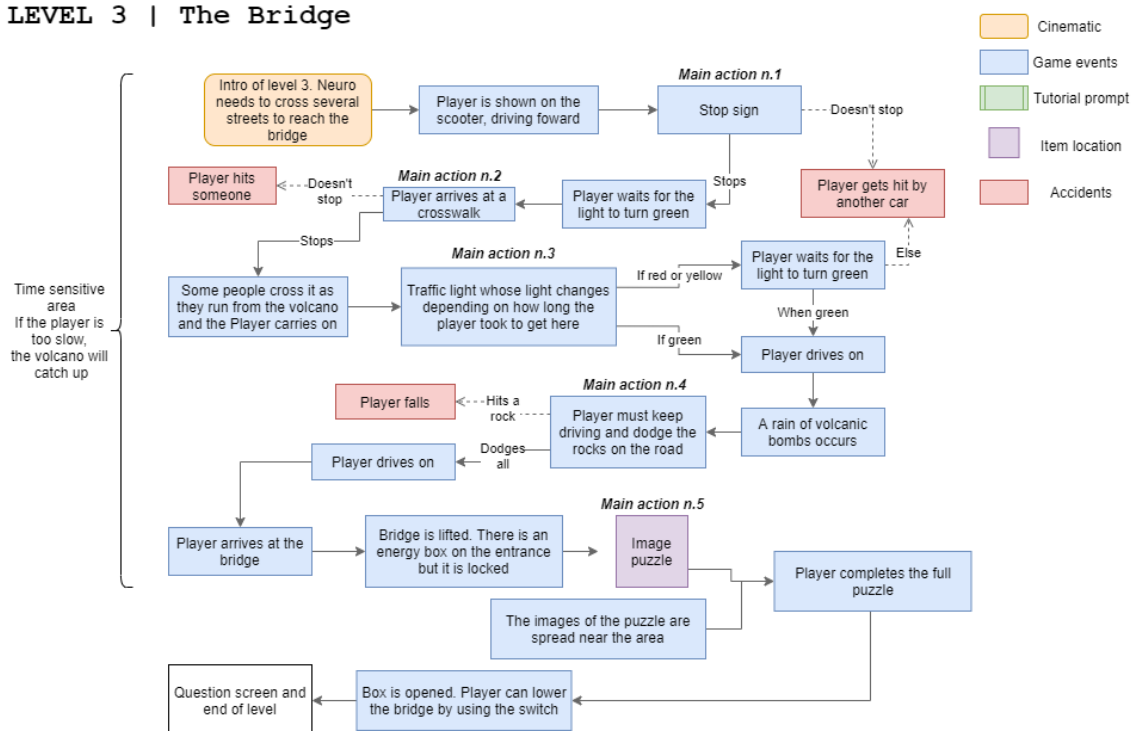


Figure A.3: Level three scheme

LEVEL 4 | The Port

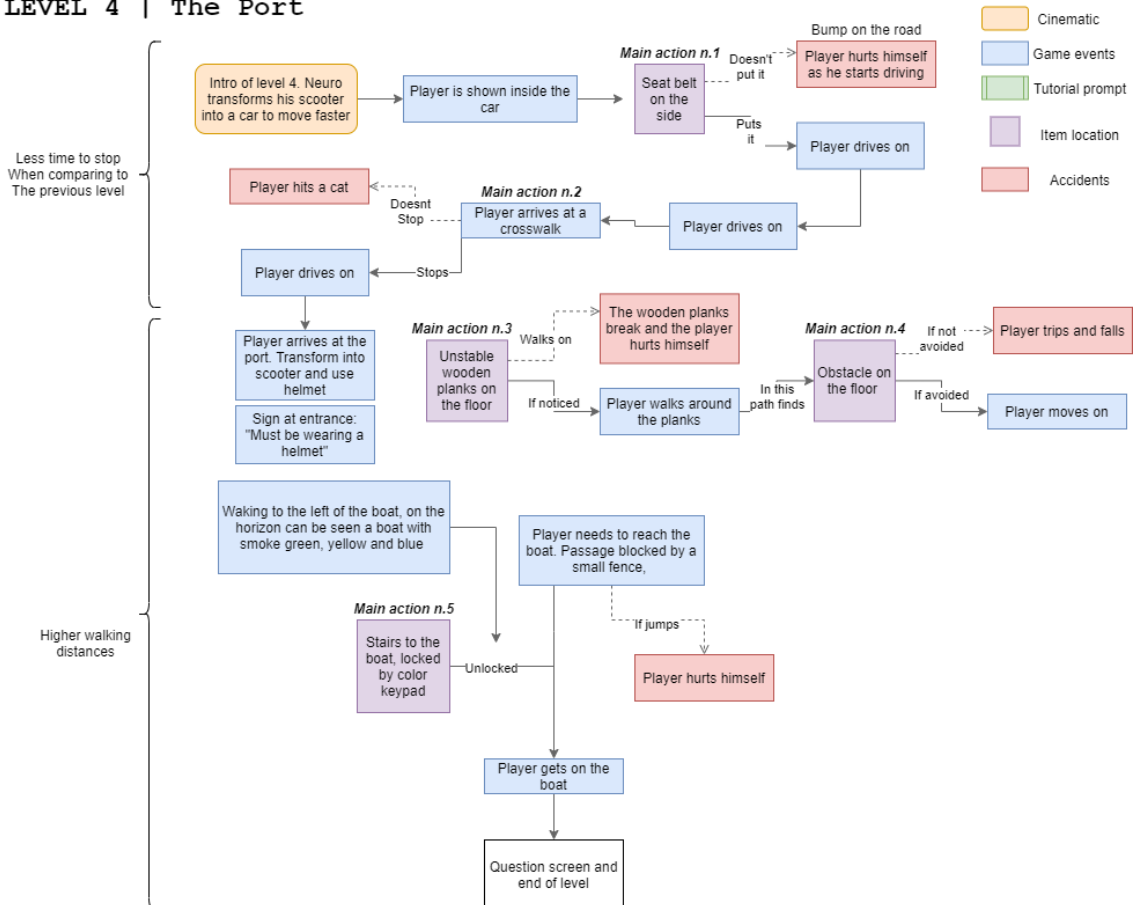


Figure A.4: Level four scheme

LEVEL 5 | The Voyage

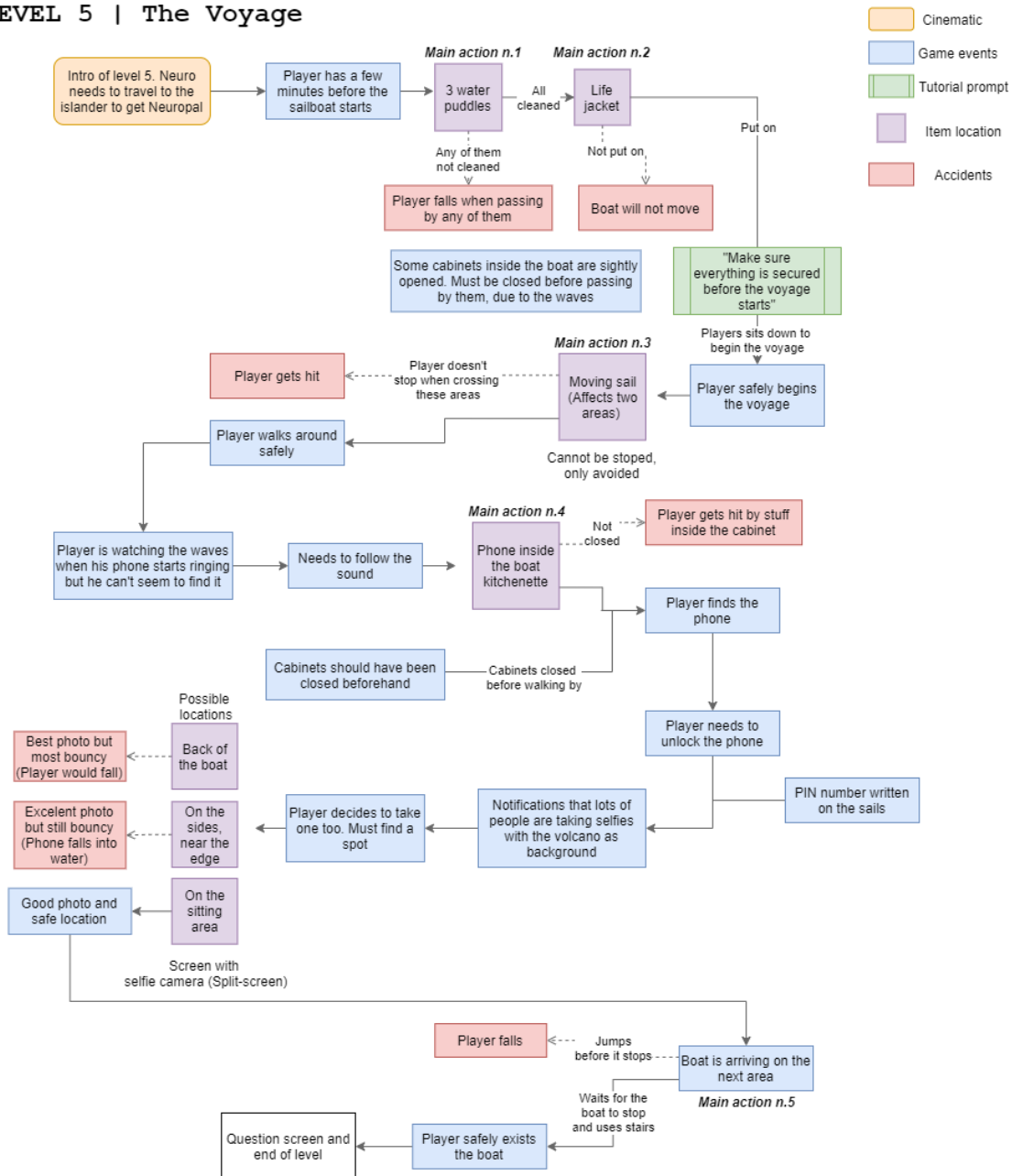


Figure A.5: Level five scheme

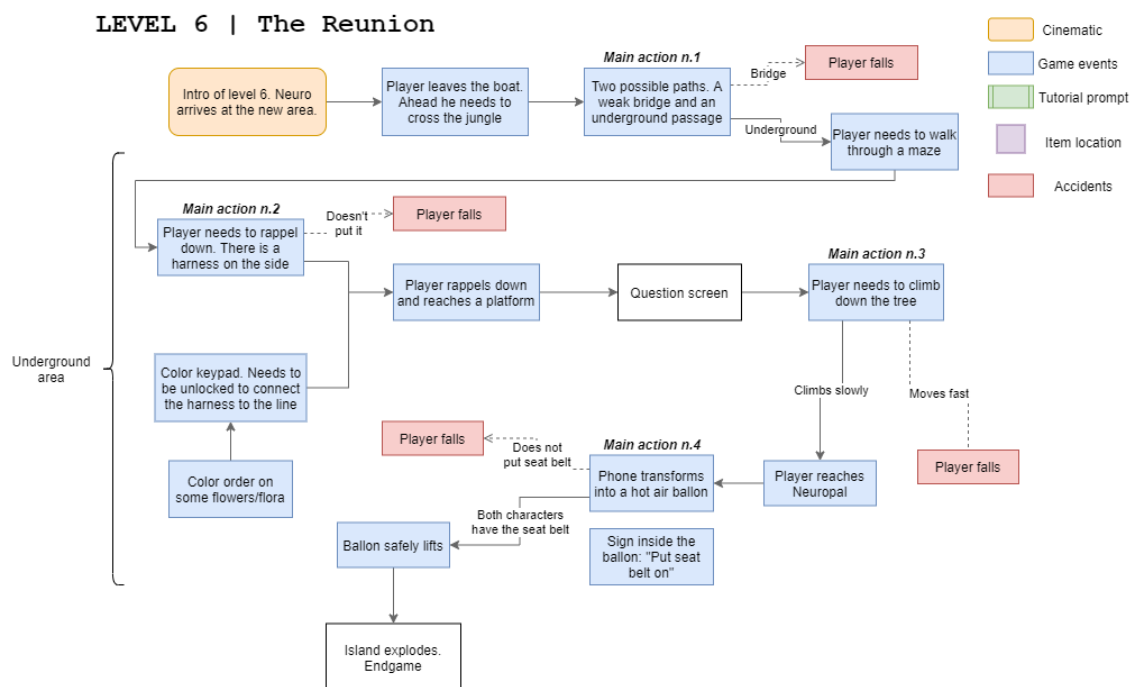


Figure A.6: Level six scheme

Appendix B

Kahoot questionnaire

This appendix includes the Kahoot questionnaire.



Neuropal

0 favorites

9 plays

77 players

A private kahoot

Questions (8)

1 - Quiz

Qual é a tua idade?

120 sec



7-8 anos



9-10 anos



11-12 anos



+12 anos



2 - Quiz

Uma cadeira é indicada para:

120 sec



Assistir às aulas



Chegar a um sítio alto



Jogar computador



Fazer uma sesta



3 - Quiz

Qual destes objectos é essencial para uma casa de banho segura?

120 sec

- | | | |
|--|-------------|---|
|  | Um capacete | ✗ |
|  | Um tapete | ✓ |
|  | Um rádio | ✗ |
|  | Uma toalha | ✗ |

4 - Quiz

Um capacete não te protege:

120 sec

- | | | |
|--|-------------------------------|---|
|  | Durante uma erupção vulcânica | ✗ |
|  | Numa corrida | ✓ |
|  | A andar de trotinete | ✗ |
|  | Numa escalada | ✗ |

5 - Quiz

Quando precisamos de chegar a um objecto num local alto devemos:

120 sec

- | | | |
|--|--|---|
|  | Usar um banco | ✗ |
|  | Construir uma pilha de almofadas | ✗ |
|  | Tentar saltar o mais alto que pudermos em cima do sofá | ✗ |
|  | Usar um escadote | ✓ |

6 - Quiz

Este contentor é para:

120 sec

- | | | |
|--|--------------|---|
|  | O lixo comum | ✗ |
|  | O vidro | ✗ |
|  | O papel | ✓ |
|  | O plástico | ✗ |

7 - Quiz

Quando um vulcão entra em erupção devo:

120 sec

- | | | |
|--|----------------------------|---|
|  | Ligar o rádio | ✓ |
|  | Fechar as portas e janelas | ✓ |
|  | Comer um gelado | ✗ |
|  | Ir dar um mergulho | ✗ |

8 - Quiz

Deixar lixo no chão:

120 sec

- | | | |
|--|---------------------------|---|
|  | Pode provocar um acidente | ✓ |
|  | É pouco higiénico | ✓ |
|  | Não incomoda ninguém | ✗ |
|  | Polui o ambiente | ✓ |

Appendix C

Used adaptation of the Game Experience Questionnaire

This appendix includes the questionnaire used, adapted from the GEQ.

Neuropal - Avaliação da experiência de jogo

Reitero, que todos os dados recolhidos são anónimos e confidenciais e serão usados apenas na presente dissertação.

Agradeço a sua colaboração.

***Obrigatório**

Idade *

- ☐ Menor que 8 anos
- ☐ 8 anos
- ☐ 9 anos
- ☐ 10 anos
- ☐ 11 anos
- ☐ 12 anos
- ☐ Maior que 12 anos

Género *

- ☐ Feminino
- ☐ Masculino
- ☐ Outro



Ano de escolaridade *

- ☐ 2º ano
- ☐ 3º ano
- ☐ 4º ano
- ☐ 5º ano
- ☐ 6º ano
- ☐ Outra:

Conseguiste completar as ações do jogo? *

- ☐ Com muita dificuldade
- ☐ Com alguma dificuldade
- ☐ Com facilidade
- ☐ Com muita facilidade

Gostaste do ambiente do jogo? *

- ☐ Não gostei nada
- ☐ Não gostei
- ☐ Foi-me indiferente
- ☐ Gostei
- ☐ Gostei muito



Achaste o jogo desafiante? *

- ☐ Muito pouco
- ☐ Pouco
- ☐ Indiferente
- ☐ Muito
- ☐ Demasiado

Quanto ao número de atividades, achas que o jogo tinha *

- ☐ Muito poucas
- ☐ Poucas
- ☐ Suficientes
- ☐ Muitas
- ☐ Demasiadas

O que achaste da experiência de jogo? *

- ☐ Muito aborrecida
- ☐ Aborrecida
- ☐ Indiferente
- ☐ Divertida
- ☐ Muito divertida

De que é que mais gostaste no jogo: *

A sua resposta



Se quiseres, deixa-nos os teus comentários:

A sua resposta

Página 1 de 1

Submeter

Nunca envie palavras-passe através dos Google Forms.

Este conteúdo não foi criado nem aprovado pela Google. [Denunciar abuso](#) - [Termos de Utilização](#) - [Política de privacidade](#)

Google Formulários



Annex A

FBM License

This annex includes the license for the use of the FBM graphic in the present work.

LICENSE FOR USE OF BJ FOGG'S GRAPHICS

Version 01.11.2020- Academic Work

By signing Exhibit A below, You agree to be bound by the terms of this License Agreement (this “**Agreement**”) for the use of certain graphic images owned by BJ Fogg LLC (“BJF”) (the “**Licensed Graphic(s)**”). The Licensed Graphic(s) are set forth on Exhibit A and Your use of the Licensed Graphic(s) is limited to the specific use set forth on Exhibit A (the “**Permitted Use**”). The effective date of this Agreement will be the date set forth on Exhibit A which is made part of this Agreement.

1. License Grant. Subject to the terms and conditions hereof, BJF grants You a non-exclusive, worldwide license to use the Licensed Graphic(s) solely for the Permitted Use. Unless otherwise set forth on Exhibit A, the foregoing license is for a single use of the Licensed Graphic(s). All other right, title and interest in the Licensed Graphic(s) are expressly reserved by BJF.
2. Restrictions.
 - a. You cannot modify, alter or create derivative works of the Licensed Graphics (other than to change the overall size of the Licensed Graphic(s) in order that the size is appropriate for the media on which it is displayed);
 - b. You cannot combine the Licensed Graphic(s) with any other graphics;
 - c. You cannot sublicense, resell, assign, or otherwise transfer or distribute Licensed Graphic(s); or
 - d. You cannot any use of the Licensed Graphic(s), or any BJF trademark, as part of a trademark, trade name, business name, service mark, or logo.
3. Legends and Watermarks and Updates. The Licensed Graphic(s) will be provided to You with a copyright notice and a watermark specifying the Permitted Use. The Licensed Graphic(s) may also contain a license number and Your name. You agree not to alter, obscure or diminish the visibility of these notices. In addition, if so indicated on Exhibit A, Your use of the Licensed Graphic(s) may be conditioned on a requirement that you update the Licensed Graphic(s) in the media in which it was approved for use (for example, your blog or website) upon receipt from BJF of an updated version of the Licensed Graphic(s).
4. DISCLAIMER. BJF EXPRESSLY DISCLAIMS ALL EXPRESS OR IMPLIED CONDITIONS, REPRESENTATIONS AND WARRANTIES INCLUDING, BUT NOT LIMITED TO, ANY WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT, EXCEPT TO THE EXTENT THAT SUCH DISCLAIMERS ARE HELD TO BE LEGALLY INVALID.
5. Termination. You can terminate this Agreement by destroying the Licensed Graphic(s) (including permanently deleting all electronic copies) and ceasing all use of the Licensed Graphic(s). BJF can terminate this Agreement without advanced notice if You fail to comply with any of its terms. Upon termination, You must immediately (i) cease using the Licensed Graphic(s) for any purpose; (ii) destroy or delete all copies and archives of the Licensed Graphic(s); and (iii) if requested, confirm to BJF in writing that You have complied with these requirements. Notwithstanding the foregoing, Sections 5, 6, and 7 survive termination or expiration of this Agreement.
6. Limitation of Liability. TO THE EXTENT NOT PROHIBITED BY APPLICABLE LAW, IN NO EVENT SHALL BJF BE LIABLE FOR: (A) ANY AMOUNT IN EXCESS OF ONE HUNDRED DOLLARS (\$100), OR (B) FOR ANY SPECIAL, INCIDENTAL, INDIRECT OR CONSEQUENTIAL DAMAGES (INCLUDING, WITHOUT LIMITATION, LOSS OF BUSINESS, REVENUE, PROFITS, GOODWILL, USE, DATA OR OTHER ECONOMIC ADVANTAGE) ARISING OUT OF OR RELATED TO THIS AGREEMENT, WHETHER IN BREACH OF CONTRACT, BREACH OF WARRANTY OR IN TORT, INCLUDING NEGLIGENCE, AND EVEN IF BJF HAS BEEN ADVISED IN ADVANCE OF THE POSSIBILITY OF SUCH DAMAGES.
7. General. Any action related to this Agreement will be governed by the laws of the State of California (except that body of law controlling conflict of laws). You exclusively and irrevocably submit to, and waive any objection against, the personal jurisdiction of the United States District Court for the Northern District of California, and the state courts of the State of California for the County of Sonoma. This Agreement constitutes the entire agreement and supersedes all prior or contemporaneous oral or written agreements regarding the subject matter hereof.

EXHIBIT A

The terms of this Exhibit A are made a part of and are incorporated into the License Agreement for the Permitted Use of Graphics between BJ Fogg LLC and You to which it is attached.

Effective Date: Jan 21, 2021

Term: one time use in academic work

Licensee Name: Luísa Maria Araújo Freire

Address: [REDACTED]

Email Address: [REDACTED]

Phone Number: [REDACTED]

Licensed Graphic(s): *Fogg Behavior Model*

After you complete this agreement, BJ Fogg will send the official graphic via email.

Permitted Use: *Use the graphic in an academic work (one time)*

Special Terms: *Do not modify the graphic in any way.*

Do not create derivative works.

If BJ Fogg requests, you agree to update to a newer graphic in the future.

Signed:  Luísa Maria Araújo Freire (Jan 21, 2021 18:50 GMT)
Printed: Luísa Maria Araújo Freire
Company Name (if applicable):
Title (if applicable):

Annex B

Original Game Experience Questionnaire

This annex includes the original GEQ.

2. Game Experience Questionnaire – Core Module

Please indicate how you felt while playing the game for each of the items,
on the following scale:

not at all	slightly	moderately	fairly	extremely
0	1	2	3	4
< >	< >	< >	< >	< >

- 1 I felt content
- 2 I felt skilful
- 3 I was interested in the game's story
- 4 I thought it was fun
- 5 I was fully occupied with the game
- 6 I felt happy
- 7 It gave me a bad mood
- 8 I thought about other things
- 9 I found it tiresome
- 10 I felt competent
- 11 I thought it was hard
- 12 It was aesthetically pleasing
- 13 I forgot everything around me
- 14 I felt good
- 15 I was good at it
- 16 I felt bored
- 17 I felt successful
- 18 I felt imaginative
- 19 I felt that I could explore things
- 20 I enjoyed it
- 21 I was fast at reaching the game's targets
- 22 I felt annoyed
- 23 I felt pressured
- 24 I felt irritable
- 25 I lost track of time
- 26 I felt challenged
- 27 I found it impressive
- 28 I was deeply concentrated in the game
- 29 I felt frustrated
- 30 It felt like a rich experience
- 31 I lost connection with the outside world
- 32 I felt time pressure

33 I had to put a lot of effort into it

3. In-game GEQ

Please indicate how you felt while playing the game for each of the items, on the following scale:

not at all	slightly	moderately	fairly	extremely
0	1	2	3	4
< >	< >	< >	< >	< >

1	I was interested in the game's story	GEQ Core – 3
2	I felt successful	GEQ Core – 17
3	I felt bored	GEQ Core – 16
4	I found it impressive	GEQ Core – 27
5	I forgot everything around me	GEQ Core – 13
6	I felt frustrated	GEQ Core – 29
7	I found it tiresome	GEQ Core – 9
8	I felt irritable	GEQ Core – 24
9	I felt skilful	GEQ Core – 2
10	I felt completely absorbed	GEQ Core – 5
11	I felt content	GEQ Core – 1
12	I felt challenged	GEQ Core – 26
13	I had to put a lot of effort into it	GEQ Core – 33
14	I felt good	GEQ Core – 14

4. GEQ - Social Presence Module

Please indicate how you felt while playing the game for each of the items, on the following scale:

not at all	slightly	moderately	fairly	extremely
0	1	2	3	4
< >	< >	< >	< >	< >

- 1 I empathized with the other(s)
- 2 My actions depended on the other(s) actions
- 3 The other's actions were dependent on my actions
- 4 I felt connected to the other(s)
- 5 The other(s) paid close attention to me
- 6 I paid close attention to the other(s)
- 7 I felt jealous about the other(s)
- 8 I found it enjoyable to be with the other(s)
- 9 When I was happy, the other(s) was(were) happy
- 10 When the other(s) was(were) happy, I was happy
- 11 I influenced the mood of the other(s)
- 12 I was influenced by the other(s) moods
- 13 I admired the other(s)
- 14 What the other(s) did affected what I did
- 15 What I did affected what the other(s) did
- 16 I felt revengeful
- 17 I felt schadenfreude (malicious delight)

5. GEQ – post-game module

Please indicate how you felt after you finished playing the game for each of the items, on the following scale:

not at all	slightly	moderately	fairly	Extremely
0	1	2	3	4
< >	< >	< >	< >	< >

- 1 I felt revived
- 2 I felt bad
- 3 I found it hard to get back to reality
- 4 I felt guilty
- 5 It felt like a victory
- 6 I found it a waste of time
- 7 I felt energised
- 8 I felt satisfied
- 9 I felt disoriented
- 10 I felt exhausted
- 11 I felt that I could have done more useful things
- 12 I felt powerful
- 13 I felt weary
- 14 I felt regret
- 15 I felt ashamed
- 16 I felt proud
- 17 I had a sense that I had returned from a journey