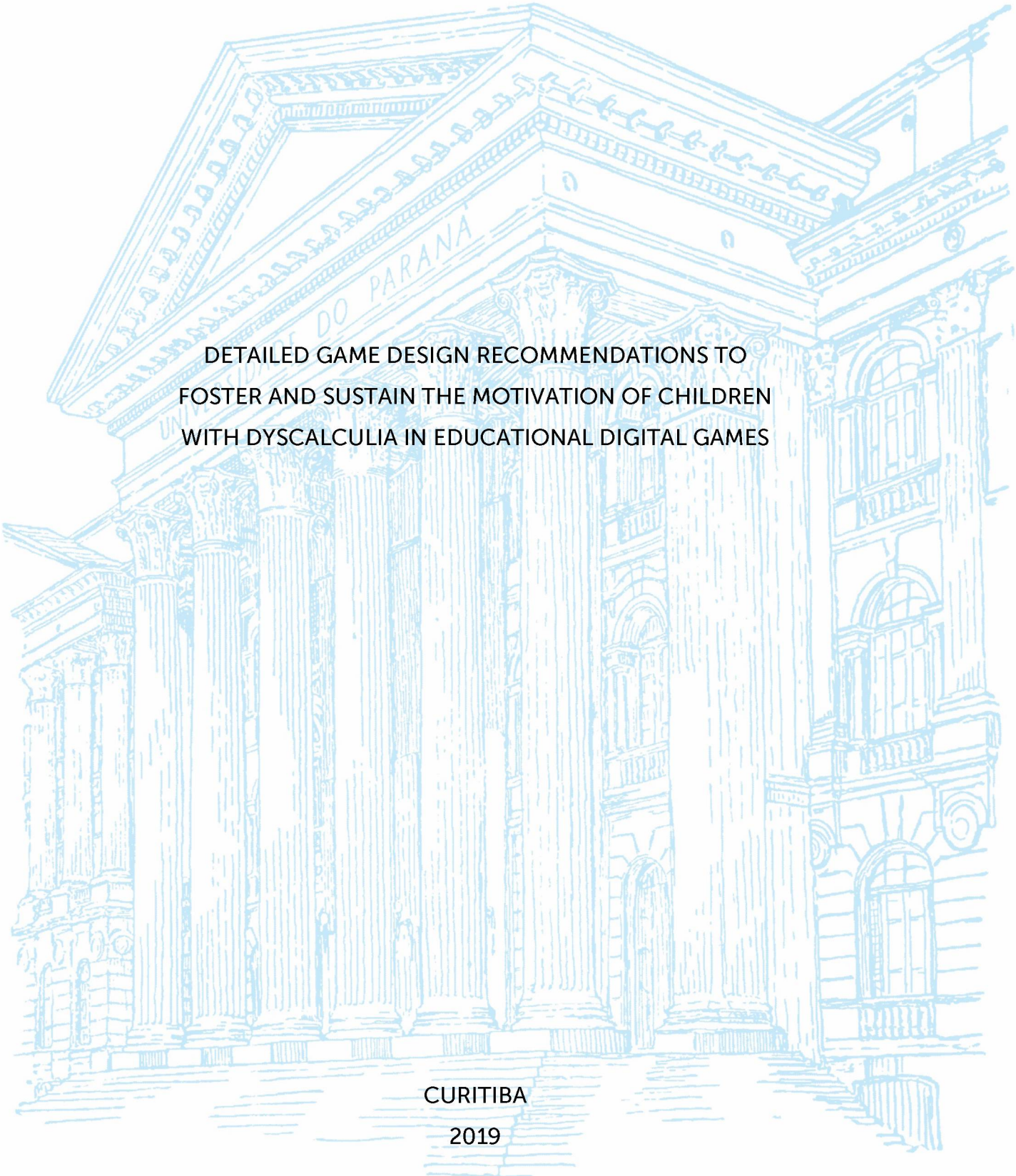
UNIVERSIDADE FEDERAL DO PARANÁ

MATHEUS ARAUJO CEZAROTTO



DETAILED GAME DESIGN RECOMMENDATIONS TO FOSTER AND SUSTAIN THE MOTIVATION OF CHILDREN WITH DYSCALCULIA IN EDUCATIONAL DIGITAL GAMES

CURITIBA

2019

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DETAILED GAME DESIGN RECOMMENDATIONS TO FOSTER AND SUSTAIN THE MOTIVATION OF CHILDREN WITH DYSCALCULIA IN EDUCATIONAL DIGITAL GAMES

Tese apresentada ao curso de Pós-Graduação em Design, Setor de Artes, Comunicação e Design, Universidade Federal do Paraná, como requisito parcial à obtenção do título de Doutor em Design.

Orientador: Prof. Dr. André Luiz Battaiola

Coorientadora: Prof. Dra. Barbara Chamberlin
(New Mexico State University)

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TERMO DE APROVAÇÃO

Os membros da Banca Examinadora designada pelo Colegiado do Programa de Pós-Graduação em DESIGN da Universidade Federal do Paraná foram convocados para realizar a arguição da Tese de Doutorado de **MATHEUS ARAUJO CEZAROTTO**, intitulada: **DETAILED GAME DESIGN RECOMMENDATIONS TO FOSTER AND SUSTAIN THE MOTIVATION OF CHILDREN WITH DYSCALCULIA IN EDUCATIONAL DIGITAL GAMES**, sob orientação do Prof. Dr. ANDRE LUIZ BATTAIOLA, após terem inquirido o aluno e realizado a avaliação do trabalho, são de parecer pela sua APROVAÇÃO no rito de defesa. COM DISTINÇÃO
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Curitiba, 25 de Setembro de 2019.

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I dedicate this work to my family, especially to my parents, who have always loved me, supported me, and believed in me.

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- This study also received financial support from CNPq as part of the research project "Design de jogos para crianças com discalculia do desenvolvimento", process number: 409770/2016-7.

RESUMO

Esta tese tem seu foco na motivação de crianças com discalculia no uso de jogos digitais educacionais. A discalculia do desenvolvimento é um transtorno de aprendizagem que afeta a aquisição dos conhecimentos matemáticos, o que traz como consequências prejuízos cognitivos, sociais e motivacionais nos aprendizes diagnosticados com tal transtorno. Assim, o objetivo dessa tese é detalhar recomendações de game design para promover e manter a motivação da criança com discalculia em jogos digitais educacionais, durante uma reabilitação neuropsicológica. A literatura indica que jogos digitais educacionais vêm sendo utilizados por pesquisadores e profissionais como uma alternativa de intervenção para crianças com discalculia. Além disso, apesar de existirem na literatura algumas pesquisas sobre os elementos dramáticos de jogo, os quais são os responsáveis por fomentar a conexão emocional entre o jogador e o jogo (durante a experiência do usuário), poucos estudos foram realizados sobre as preferencias do jogador acerca dos elementos de jogos educacionais. Em especial, sobre jogos desenvolvidos para crianças com discalculia no Brasil, onde existe uma demanda para novos jogos considerando as necessidades desse usuário. Assim, alicerçado no design centrado no usuário e considerando diferentes stakeholders (aprendizes, especialistas em reabilitação e desenvolvedores de jogo), esta tese pesquisa os elementos dramáticos de jogo, ademais as suas possíveis configurações para fomentar e manter a motivação desse usuário durante a reabilitação neuropsicológica. Para tanto, em uma abordagem interdisciplinar entre o game design e a neuropsicologia dos transtornos de aprendizagem escolar, esta tese se caracteriza como de natureza aplicada, objetivo descritivo e análise de dados qualitativa. Entre os procedimentos metodológicos foram utilizados: pesquisa bibliográfica sistemática, pesquisa de campo e experimental game design. A realização desta tese foi segmentada metodologicamente em cinco fases: (1) revisão sistemática de literatura sobre recomendações para jogos educacionais, (2) pesquisa de campo com desenvolvedores de jogos e especialistas em reabilitação, (3) geração inicial de recomendações de game design, (4) verificação com o usuário – crianças com discalculia, (5) detalhamento das recomendações. Durante a pesquisa foi realizado um estágio no exterior no Learning Games Lab, localizado na Universidade Estadual do Novo México – NMSU (Las Cruces – EUA), o que contribuiu com o desenvolvimento de algumas fases da pesquisa. Além disso, parte desta pesquisa for realizada no Laboratório de Neuropsicologia do Desenvolvimento (LND), localizado na Universidade Federal de Minas Gerais (UFMG). Como resultado, esta tese detalha recomendações de game design para promover e manter a motivação de crianças com discalculia em jogos educacionais. As recomendações estão centradas em três elementos dramáticas de jogo: personagem, mundo de jogo (narrativa) e recompensas. Ademais a tese contribui metodologicamente com informações sobre o processo de coleta de dados com crianças, no contexto dos jogos digitais educacionais.

Palavras-chave: Jogos educacionais. Game Design. Discalculia. Motivação.

ABSTRACT

This dissertation focusses on the motivation of children with dyscalculia while using math educational digital games. Developmental dyscalculia is a specific learning disability which affects the regular learning of arithmetical skills. Consequently, learners with this disability face cognitive, social, and motivational impairments. This study aims to make detailed game design recommendations on how to promote and sustain the motivation of children with dyscalculia in educational digital games, during neuropsychological rehabilitation. The literature shows that educational digital games have been used by researchers and professionals as an alternative intervention for children with dyscalculia. The literature also shows that although some research has been done on the dramatic game elements, which are the elements which provide the emotional connection between the player and the game (during the user experience), little is known about player preferences concerning the game elements in educational games. This is particularly the case in games designed for children with dyscalculia in Brazil, where there is a demand for new games for these users. Therefore, within a user-centered design framework encompassing different stakeholders (learners, specialists in rehabilitation, and game developers), this dissertation investigates what game elements can promote and sustain user motivation during the neuropsychological rehabilitation process, and how they do so. This dissertation has an interdisciplinary approach as it integrates aspects from the game design field with topics from the neuropsychology of learning disabilities to enhance user's motivation. It can be seen as an instance of applied research, with a descriptive goal, and a qualitative data analysis approach. The dissertation has made use of three main methods: systematic literature review, field research, and experimental game design. This dissertation includes five methodological phases: (1) systematic literature review concerning educational game recommendations, (2) field research with game developers and specialists in rehabilitation, (3) game design recommendations, (4) user verification with children with dyscalculia, and (5) detailed recommendations. Some of these phases had the support of the Learning Games Lab, at the New Mexico State University – NMSU (Las Cruces – USA). Part of this research was conducted at the Developmental Neuropsychology Laboratory (DNL) at the Federal University of Minas Gerais (UFMG-Brazil). As a result, this dissertation offers a set of detailed game design recommendations aiming to promote and sustain the motivation of children with dyscalculia. These recommendations include three dramatic game elements: character, world building and rewards. Additionally, this dissertation offers methodological information regarding the data gathering process with children, in the context of educational digital games.

Keywords: Educational Games. Game Design. Dyscalculia. Motivation.

LIST OF ABREVIATIONS

ADHD – Attention deficit hyperactivity disorder.

APA – American Psychological Association.

DD – Developmental dyscalculia.

DNL – Developmental Neuropsychology Laboratory.

DSM-IV – Diagnostic and Statistical Manual of Mental Disorders.

ICD- 10 – International Classification of Diseases.

NMSU – New Mexico State University.

SBGAMES – Brazilian Symposium on Computer Games and Digital Entertainment.

UFMG – Federal University of Minas Gerais.

WHO – The World Health Organization.

WISC IV – Wechsler Intelligence Scale for Children® – Fourth Edition.

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1 INTRODUCTION

1.1 Context

This dissertation[1] focuses on the design of educational digital games, more precisely on the design of digital games that are used by children with dyscalculia as a tool for helping them overcome their mathematical learning impairments. Developmental dyscalculia (DD) is a specific learning disability that affects the learner's normal acquisition of arithmetic skills (KAUFMANN and VON ASTER, 2012).

This dissertation addresses issues related to the Game Design field, a subarea of design concerned with creating and researching games (SALEN and ZIMMERMAN, 2004). As such, it is part of the research on Design of Information Systems carried out at the Design Postgraduate Program of UFPR[2].

The current investigation is a continuation of the research conducted during the master's degree of Cezarotto (2016). Through an exploratory approach, a set of game design recommendations was proposed. These recommendations referred to how to motivate children with dyscalculia in the context of educational digital games. Cezarotto's (2016) master's thesis received the game design innovation award from the SBGames 2017[3] (CEZAROTTO and BATTAIOLA, 2017b).

The current study takes an interdisciplinary approach to design (SVENSSON, 2003), combining knowledge and information from studies in the field of game design and studies from the field of neuropsychology of learning disabilities. In order to achieve this, a **partnership was established with the Developmental Neuropsychology Laboratory[4] (DNL)** at the Federal University of Minas Gerais (UFMG-BRAZIL). The laboratory research group conducts investigations on developmental dyscalculia, and provide assistance to children from local schools as part of a project. The researches carry out the evaluation, diagnosis and the neuropsychological rehabilitation of these children. The researchers use educational digital games with the children and have identified the need for new games.

As part of this doctoral research, the author/researcher spent six months (from August 2018 to January 2019) **at the New Mexico State University – NMSU (Las Cruces - USA)**, as an **affiliate scholar,** with a scholarship from CAPES (Brazilian Federal Agency for Support and Evaluation of Graduate Education). This dissertation, therefore, also benefits from the orientation of Professor Dr. Barbara Chamberlin, who is an expert in Innovative Media Research and Extension at the Learning Games Lab[5] at NMSU. The laboratory is well-

[1] This document uses American English and acknowledges: Thesis – preliminary research done to obtain a master's degree; Dissertation – original research done to obtain a doctoral degree.

[2] The Design Postgraduate Program of Federal University of Paraná (UFPR). Available at: <http://www.sacod.ufpr.br/portal/ppgdesign/en/apresentacao/linhas-de-pesquisa/> (Accessed on September 7, 2018).

[3] SBGames 2017 (Brazilian Symposium on Computer Games and Digital Entertainment) is the largest academic event on games and digital entertainment in Latin America. The Brazilian Computer Society has been responsible for organizing the event since 2004. The 2017 edition was held in Curitiba (at PUC). Available at: <http://www.sbgames.org/sbgames2017/> (Accessed on March 1, 2018).

[4] Developmental Neuropsychology Laboratory. Available at: <lndufmg.wordpress.com>. (Accessed on November 25, 2017).

[5] Learning Games Lab. Available at: <http://www.learninggameslab.org/>. (Accessed on December 26, 2017)

known for the quality of their educational digital games, user-testing approaches, and for their Learning Games Design Model, which is user-centered, collaborative and interdisciplinary (CHAMBERLIN, TRESPALACIOS and GALLAGHER, 2012). Some of the games from the project Math Snacks, developed by the Learning Games Lab, have won awards[6].

This dissertation also aligns **with the research project** "Design of games for children with developmental dyscalculia", sponsored by CNPq (Brazilian National Council for Scientific and Technological Development)[7]. The project is under the joint supervision of Professor Dr. André Battaiola (Design – UFPR) and Professor Dr. Vitor Haase (Psychology - UFMG).

Figure 1 shows the users, tasks, and artifacts that are part of the context of this dissertation.

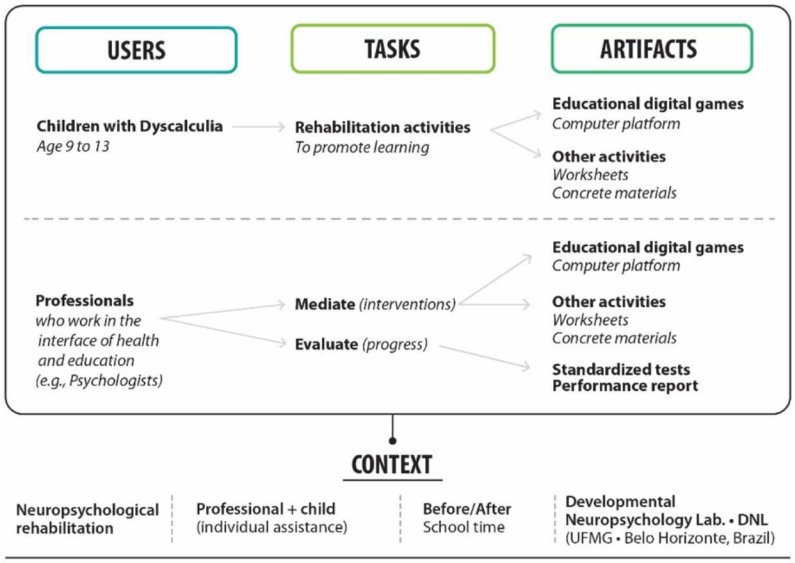


Figure 1: Visual representation of the dissertation context.
Source: the author.

1.2 Problematization

Digital games are highly expressive entertainment media, due to their capacity to engage and entertain the user in a multimedia environment (SITZMANN, 2011; PRENSKY, 2012; TOBIAS et al. 2014). The increasing use of digital games for entertainment purposes, and the need for effective educational training tools suggest that games can be used for purposes other than entertainment (De FREITAS and LIAROKAPIS, 2011). A number of authors have emphasized the motivational potential of these games and how they can be used in the teaching of more serious contents (MALONE 1980; ABT 1987; SITZMANN 2011; PRENSKY 2012; MAYER 2014).

Although the idea of using digital games for learning has gained increased attention, it remains an area in need of further research. Further investigation is needed in order to provide scientific orientations regarding how to develop educational games which can facilitate the learning of content and at the same time create a more motivating and enjoyable experience for the player (MAYER and JOHNSON, 2010; ECHEVERRÍA et al. 2011; FANG and STROBEL, 2011; De FREITAS et al. 2012; ROONEY 2012; CARVALHO et al. 2015).

[6] Math Snacks Project: Available at: <http://mathsnacks.com/>. (Accessed on December 26, 2017).
[7] Process number 409770/2016-7. The Project was carried out from 06/01/2017 to 05/31/2020.

Section 1.7 (State of the art and Originality) discusses the gaps in the educational digital game field.

Mattar (2010) highlights the existence of a chasm between educational games and games for pure entertainment. He explains that most educational games are considered boring when compared to entertainment games. Research on educational digital games is still in its early stages (DICKEY, 2015). The different graphic and conceptual aspects of these games, all essential for the player's experience, such as narrative, characters, and game environment, have not yet been fully investigated (ibid). This limitation is even more significant for educational digital games for children with dyscalculia, due to the cognitive profile of these users and the specific context in which they are used. Thus, although efforts have been made to improve this scenario (e.g. Wilson et al. 2006; Kucian et al. 2011; Butterworth, Varma, and Laurillard, 2011; Käser et al. 2013; De Castro et al. 2014; Waiyakoon, Khlaisang and Koraneeki, 2015; Ninaus et al. 2017), the design of games for this specific context and user is still in need of much research, primarily regarding player experience.

Thus, this dissertation focusses on the motivational aspects of children with dyscalculia when interacting with educational digital games, particularly during neuropsychological rehabilitation. The emphasis of the research is on the game design concepts and the elements of player experience, areas for which much research is still needed. Additionally, in Brazil there is demand for research on and the development of new educational games for children with dyscalculia (CEZAROTTO and BATTAIOLA, 2016; CEZAROTTO and BATTAIOLA, 2017a).

The current investigation therefore aims to offer scientific orientations to guide the design of educational digital games, primarily with regard to the motivational and conceptual elements of the game. This study also focuses on the use of these games as a neuropsychological intervention for children with dyscalculia. The following section discusses the scope of the research, its limitations and goals.

1.3 Scope of the Research

This is an interdisciplinary study. Its focus is on the design of educational digital games. It also considers aspects related to learner's motivation from the perspectives of neuropsychology, cognitive psychology, and game design. This study does not, however, consider game theory. Technical issues related to game development, such as game programming, are also beyond the scope of this study.

When investigating the use of educational games during neuropsychological rehabilitation, a triad is used. The components of the triad are: **theory, content and game design.** Winn (2008) proposes this triad to the study of educational games, based on Mishra and Koehler's (2006) Technological Pedagogical Content Knowledge. According to Winn, the relation between the triad components represent the heart of serious game design. In this study the model has been slightly reconfigured, as another element, namely the user, is also considered. This is because a user-centered approach to the design of educational games is assumed (see figure 2).

Wherefore, this dissertation has a human-centered design approach (ISO 9241-210). It aims to address the needs, requirements, and preferences of children with dyscalculia in

connection with the design of educational games. Moser (2000) clarifies that in the user-centered design of educational games there are two mains users: the player (learner) who interacts with the game, and the professional mediator who facilitates the interaction of the player (learner) with the game. These users have different needs and requirements that need to be taken into account in the design process of educational games.

Hence, this study will benefit developers of educational games, in that it will offer them a set of detailed game design recommendations. The final users of educational games, in this case Brazilian elementary school children diagnosed with dyscalculia, ages 9 to 13, and the specialists in rehabilitation will also benefit from this study. Finally it should be mentioned that this study focuses on digital games which are played on laptop devices.

Thus the aims of this study is to offer detailed game **design recommendations** which will foster and sustain the motivation of children with dyscalculia in educational games. Thus, the research unit of analysis is **children motivation**. Figure 2 summarizes the scope of this research.

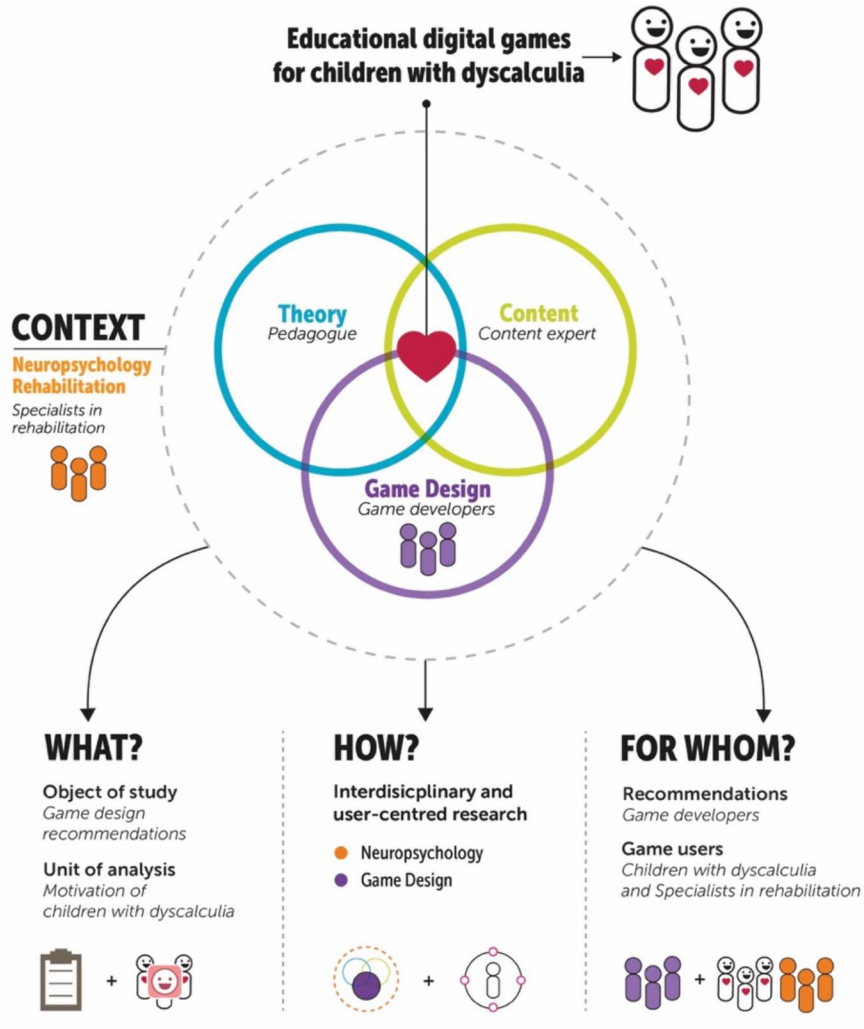


Figure 2: Research scope summary.
Source: The author.

1.4 Research question

This dissertation aims to answer the following research question:

How should developers design motivational elements of the educational digital game to best promote and sustain motivation of children with dyscalculia in neuropsychological rehabilitation?

1.5 Main goal

The main goal of this study is: **to make detailed game design recommendations on how to promote and sustain the motivation of children with dyscalculia in educational digital games, during neuropsychological rehabilitation.**

It should be noted that the recommendations made here are centered on the user motivational preferences, which will be explained in the methodology (chapter 4). Such recommendations are more significant for the design field, mainly due to its qualitative and user-centered approach.

1.6 Specific goals

1. **To identify** recommendations, guidelines, and principles for the design of educational games which apply to the neuropsychological rehabilitation of children with dyscalculia.

2. **To investigate**, from the perspective of specialists in rehabilitation, what the requirements to develop educational digital games for children with dyscalculia in neuropsychological rehabilitation are.

3. **To investigate** what motivational game elements are used by game developers to promote player motivation, and how these elements are set up during an educational game project. Also, to contrast this information with the literature data.

4. **To propose** a set of game design recommendations for educational games capable of fostering and sustaining motivation in dyscalculic children during neuropsychological rehabilitation.

5. **To verify,** with children with dyscalculia, the game design recommendations made by this research, and explore how these recommendations contribute to increasing the motivational element in educational digital games.

1.7 State of the art and Originality

This section examines the originality of the contribution made by this dissertation. The information presented here summarizes the **systematic literature** review conducted[8], which covered two categories of publications: journal and conference papers; theses and dissertations. Other relevant materials such as suggestions by academics, new materials from references from papers, are also alluded to in the review.

The systematic review of journals and conference papers accessed the following databases: **ScienceDirect, Scopus, and IEEE Xplore Digital Library**. For each database two search cycles were conducted using the strings "game design" and "recommendations"; "games" and "guidelines". From these searches, based on their titles and the information provided in the abstracts, 66 papers were selected for more detailed reading (introduction, methods and conclusions). Finally, out of the 66 papers, 28 were selected based on their relevance to this research and to the field of educational games.

Much research has been conducted on educational games. In the literature, the terms "serious games" and "educational games" are used interchangeably to refer to games that aim to promote learning about specific content. The 66 studies selected are from a variety of fields. Most of the studies (29) are from computer science, and some (12) are from the education field. Only a few studies (8) are from the design field.

It was observed that there is a consensus among the researchers from the various fields, that educational digital games are a significant tool for fostering motivation for learning. An interest in formally describing how to develop these games was also observed by De Freitas et al. (2012); Carvalho et al. (2015); Echeverría et al. (2011); Fang and Strobel (2011). Farrel and Moffat (2014), for instance, warn that the lack of formalization during the design of educational games, will result in an uninformed and limited development of games.

The literature review also showed that one of the most researched topics concerns the proposal of frameworks, conceptual models, and game design models for the development and study of games. A number of models specific for the design of educational games were identified: Winn (2008); Echeverría et al. (2011); Kiili et al. (2012); Chamberlin, Trespalacios, and Gallagher (2012); Kiili et al. (2014); Waiyakoon, Khlaisang and Koraneekij (2015); Carvalho et al. (2015). The models proposed by Winn (2008) and by Chamberlin, Trespalacios, and Gallagher (2012) stand out due to their quality. Both models are from educational game labs at American universities.

Regarding motivation and player experience, several studies on the players' flow state are available, for instance, Kiili et al. (2012); Kiili et al. (2014). These studies are based on the flow theory (CSIKSZENTMIHALY, 1990). However, not much research has been done on how to promote this flow experience based on the elements of educational games and how these elements are arranged. Moreover, very little has been researched on the act of aligning these motivational game elements with instructional principles in educational games. Bjorner and Hansen (2010); Mayer and Johnson, (2010); Mayer (2014), and Rooney (2012) all stress the importance of finding the right balance between the game elements (entertainment and instructional) and how difficult this can be.

On the subject of games for dyscalculia or mathematics learning difficulties, the literature review identified the studies by Kucian et al. (2011); Käser et al. (2013), Wilson et al. (2006); Kadosh et al. (2013); De Castro et al. (2014). Despite their contributions to the

[8] A full description of the systematic literature review can be seen in the appendices, p.240.

efficacy of these games as an intervention, these studies have a strictly quantitative approach. Consequently, none or little qualitative information, such as player experience and motivation while using educational games as an intervention, is provided in these studies. This may be because most of these studies are from Neuropsychology, an international journal devoted to contributions that advance understanding of human cognition and behavior from a neuroscience perspective.

For the systematic review of theses and dissertations the following databases were accessed: ***Biblioteca digital brasileira de teses e dissertações***[9]**; *Catálogo de Teses e dissertações* (CAPES)**[10]**; OpenThesis.** In these searches, the main strings used were: *"jogos educacionais"*; *"jogos educativos"*; "game design"; "educational games"; "game-based learning". In this category of the literature review, 43 studies were selected (23 theses and 20 dissertations).

Both the dissertations and the theses selected are **from a wide range of fields.** The theses are mainly from the fields of design (9) and computer science (7). In contrast, the dissertations are mostly from the field of engineering (6), although a few come from the field of design (4). This shows that a number of fields have an interest in and produce research on games.

Most of the theses and dissertations have an **exploratory goal**. It is assumed that the educational game field has already outlined a set of variables and information, which allows further research with descriptive or explanatory goals. Additionally, many of these studies seem to combine different types of research goals (e.g. descriptive-exploratory; explanatory-descriptive; explanatory-descriptive-exploratory).

The literature review also shows that studies about games and children with dyscalculia, such as the dissertation by Käser (2014) and that of De Castro (2011), focus on the technical aspects of the game, such as game programming, algorithm construction or artificial intelligence. According to the literature review, Chamberlin's (2003) dissertation was the only work whose aim was to investigate the player's preferences in educational digital games. Thus, further research on the experience of children with dyscalculia when interacting with these games is needed. In other words, more needs to be known about qualitative aspects of the use of these games. According to Chamberlin (2003), it is necessary to investigate "how" and "why" the game is fun from the children's perspective, rather than only whether the game is fun or not. Chamberlin (2003) highlights that this lack of qualitative information is recurrent in educational digital games research in general. For her further studies on children's preferences about educational games are necessary. For her, it is this lack of information about the player's preferences in educational digital games that distinguishes these games from entertainment ones. Although educational games are not the focus of her study, Barendregt's (2006) dissertation also offers some insights into how to evaluate the fun and usability aspects in digital games.

Vargas (2014), whose study focus on game design models, briefly discusses the importance of finding the balance between entertainment game elements and learning elements. Vargas draws attention to the complex models available in the literature which can help in the design of educational digital games. Some of these complex models have been proposed by Jappus (2014), Savi (2011), as well as Vargas (2014) himself.

[9] A Brazilian database of thesis and dissertations organized by Ibict (Brazilian Institute of Information in Science and Technology).
[10] A Brazilian database of thesis and dissertations organized by CAPES (Brazilian Federal Agency for Support and Evaluation of Graduate Education).

To sum up, the literature review (Journals + Theses and dissertations) has identified the need for further research on the following aspects:

- Formal orientation for educational digital games, primarily qualitative information regarding the game elements and how these affect players' preferences;
- How to find the right balance between the entertainment elements and the learning elements of the game;
- In the context of games for children with dyscalculia, qualitative research regarding user motivation and experience when playing the games. This requires interdisciplinary research which will bring together aspects from the game design field and the neuropsychology field.

The aim of the present study is therefore to address some of these gaps in the literature, and its originality rests on the following:

- The scope of the research. It proposes to investigate educational digital games for children with dyscalculia in a neuropsychological context. Additionally, due to its interdisciplinary approach, it investigates aspects of educational digital games from both the design and neuropsychology perspectives;
- The findings. Based on qualitative information, it offers detailed game design recommendations to promote and sustain the motivation of children with dyscalculia in a neuropsychological intervention;
- The research method. Research in the game field lacks scientific rigor, especially with regard to how to evaluate information about the user of educational games. This study adheres to a rigorous research process which can be seen both in the data collection and data verification with users.

1.8 Justification

This dissertation makes a significant **academic contribution to the design field**. Its results and findings also **contribute to the development of society** through four lenses, namely: educational, social, economic and technological. These contributions are described in detail below.

Academic relevance to the design field

This research makes a significant contribution to the field of design. According to Frankel and Racine (2010), research "for design" is clinical, as it focuses on a specific design problem, and therefore demands information about a particular situation (e.g. information about users, context data, artifacts analysis). Through an interdisciplinary approach, this research study seeks to make a significant contribution to the field of design by offering detailed game design recommendations which can help development teams to create educational digital games which fulfill the needs of children with dyscalculia. The specialists in rehabilitation that use games as part of their interventions will also benefit from these recommendations.

Following a user-centered design approach, this research has identified effective techniques for user data collection. This is an important contribution to the game design field in general, as the development of games is still to a certain extent guided by the developer's intuitions (FARRELL and MOFFAT, 2014). Game development through intuition is one of the main drawbacks of educational game development (CHAMBERLIN, 2003). Users are different, children are different, and developers should consider these differences during the game design process (ibid).

While the participatory design approach is acknowledged in areas such as human-computer interaction, this approach is seldom used in educational digital games (KHALED and VASALOU, 2014; KHALED et al. 2014). Thus, researches have emphasized the importance of the participation of the user in the design process of digital educational games[11]. For instance, Farrel and Moffat (2014) discuss the limitations of the trustful technique in the design of educational digital games. However, for them, there is a set of established techniques from other fields (e.g. human-computer interaction) that can be applied in an attempt to fulfill the demands of educational game design.

Battaiola and Cezarotto (2017), through a systematic review of the Art & Design track of SBGames[12], identified that although more research on games is now available, better research methods are still necessary to fulfill the demands of the field. Lankoski and Björk (2015) have addressed this gap. Their book, *Game Research Methods: an overview*, introduces different methods of thinking, specifically in the context of research on games.

It is important to make it clear that the aim of this dissertation is not to suppress the creative process or the development of team autonomy during the design of educational games. Its goal is to offer orientations, recommendations, methods and flexible techniques, mainly with regard to players' motivation, which will help the design teams during the design process. Therefore, by addressing a gap in the existing literature, this research makes a significant contribution to the field of game design.

Relevance to society

This dissertation's contributions to society as a whole are threefold:

Educational lens

This research, although to a lesser extent, also contributes to the discussion about cyberculture and the use of new information and communication technologies. According to Pérez Gómez (2015), the digital era has brought a wide range of possibilities and challenges to educational practices. Nevertheless, the use of design in teaching-learning contexts allows for the discovery of new methods and approaches (PORTUGAL, 2009).

According to Lemos and Cunha (2003) cyberculture is a sociocultural expression that emerges from the relation between society, culture, and the new digital technologies. For these authors, cyberculture is primarily defined by the digital technologies. These technologies continuously update and foster reconfiguration in many of society's activities (e.g. online actives, use of mobile devices, instant messaging). This study focuses on

[11] This is discussed in detail in the theoretical chapter of this dissertation.
[12] SBGames (Brazilian Symposium on Computer Games and Digital Entertainment).

educational digital games, and argues that it is an important tool for fostering and maintaining motivation in children with dyscalculia during the learning process.

Social lens

According to Kucian and von Aster (2015), society underestimates the relevance of numerical comprehension in the daily life of children. For these authors, mathematical abilities are essential for the realization of everyday tasks. Similarly, Bastos (2008) and Bellos (2011) argue that learning, reasoning, and knowing mathematics should not be considered a privilege. For instance, the British Parliament considers mathematical knowledge as part of the mental capital concept, i.e. the concept that represents the intellectual development of the population and their contribution to the economy (COOPER et al. 2010). Haase et al. (2012) consider learning disabilities such as dyscalculia one of the main impairments of the mental capital of a community. Yet in Brazil around 6% of the children from 2nd to 6th grade of elementary school have developmental dyscalculia (FORTES et al. 2016).

For Käser et al. (2013) the use of educational digital games for remediation of dyscalculia can bring positive results. For these authors, educational games offer an intense, stimulating and accessible environment for practicing math skills. However, in several countries, noticeably in Brazil, digital games for dyscalculic children are not easily available. Despite the contribution of some researchers (e.g. Käser et al. 2013; Wilson et al. 2006; De Castro et al. 2014), further research on these games is still required, especially from the game design perspective. More needs to be known about the player experience, playability and usability so that these games can be fully utilized (CEZAROTTO and BATTAIOLA, 2016). Thus, research on educational games for children with dyscalculia through the game design perspective and player experience will also benefit society.

Economic and technological lens

A further contribution of this study to society is that it strengthens the existing connections and create new links between scholars and practitioners (academia and industry) in the field of educational digital games. Essentially, game developers, companies, laboratories will all benefit from the detailed game design recommendations made here.

Data from market research reveal that digital games are now the most prominent artifact of the digital entertainment field. The digital game industry is growing fast and is now ahead of the motion picture and digital music industries (IHS TECHNOLOGY AND APP ANNIE, 2014). However, according to Almeida and Silva (2013), there is a lack of formal techniques during the design process of this kind of media. Neil (2012) also discusses this limitation and calls attention to the fact that this is even more expressive in the educational game field, due to resources being less representative in this media, and due to the complexity of these games, that is the fact that they combine entertainment and learning aspects. Vargas (2014) explains that in the educational game field, the interdisciplinary development team should have practical tools and the vocabulary to optimize the design process.

Data from the 1st Census of the Brazilian Digital Games Industry (FLEURY, SAKUDA, and CORDEIRO, 2014) show that from a sample of 149 research game companies, 34 do not use any developmental methodology, which represents 25,6% of the sample. This reveals the lack of professionalism in the Brazilian game industry.

In that context, academia plays a critical role in the growth of the game industry, particularly the industry of digital games for learning. Academia can provide the industry with expert staff, appropriate settings, and motivation to foster consistent innovation. One obstacle faced by academia, however, is the frequent lack of funding. Also, whereas companies in the game industry avoid taking risks, as a single mistake could lead a company to bankruptcy, taking risks and making mistakes are part of the academic process. For example, academia can take on a high-risk project or experiment and test new ideas purely for the sake of learning. This does not mean that academic projects do not need to offer value and provide results to the funders and partners. Those results (value), however, may be in the form of products or knowledge/learning. (KLOPFER, OSTERWEIL and SALEN, 2009)

1.9 Research methodology overview

The research methodology of this study comprises **five main phases**. Each one of these phases is related to a specific research goal. Together, these phases can be seen as the path followed during the research process (see figure 3). An overview of each phase is given below. A full description of the methodology is provided in chapter 4 (methodology, p. 63)

Phase 1 comprised a systematic literature review. In this phase, orientations for the design of educational digital games, primarily applicable information related to neuropsychological rehabilitation for children with dyscalculia, were identified.

Phase 2 consisted of field research. This phase consisted of two parts and addressed two specific goals of this study. In the first part, in collaboration with professionals involved in neuropsychological rehabilitation, the requirements to develop educational digital games focusing on children with dyscalculia were established. The second part of the field research investigated what game elements are used by game developers to foster motivation in educational games and how these elements are organized.

Phase 3, in this phase the data collected so far were analyzed. Through data triangulation (literature review + filed research) a set of game design recommendations focusing on children with dyscalculia was proposed. Some further recommendations in connection with a user-centered approach were also made.

Phase 4 was the user-verification phase. In this phase, through an experimental game design, the recommendations made were verified with children with dyscalculia. This took place during a neuropsychological rehabilitation, with the support of researchers from DNL (UFMG). This phase of the study also had the support of the researchers at the Learning games lab (NMSU) who provided both practical and theoretical information.

Phase 5 comprised the final data analysis. This phase detailed the game design recommendations using data triangulation. This phase was the final step towards achieving the main goal of this study.

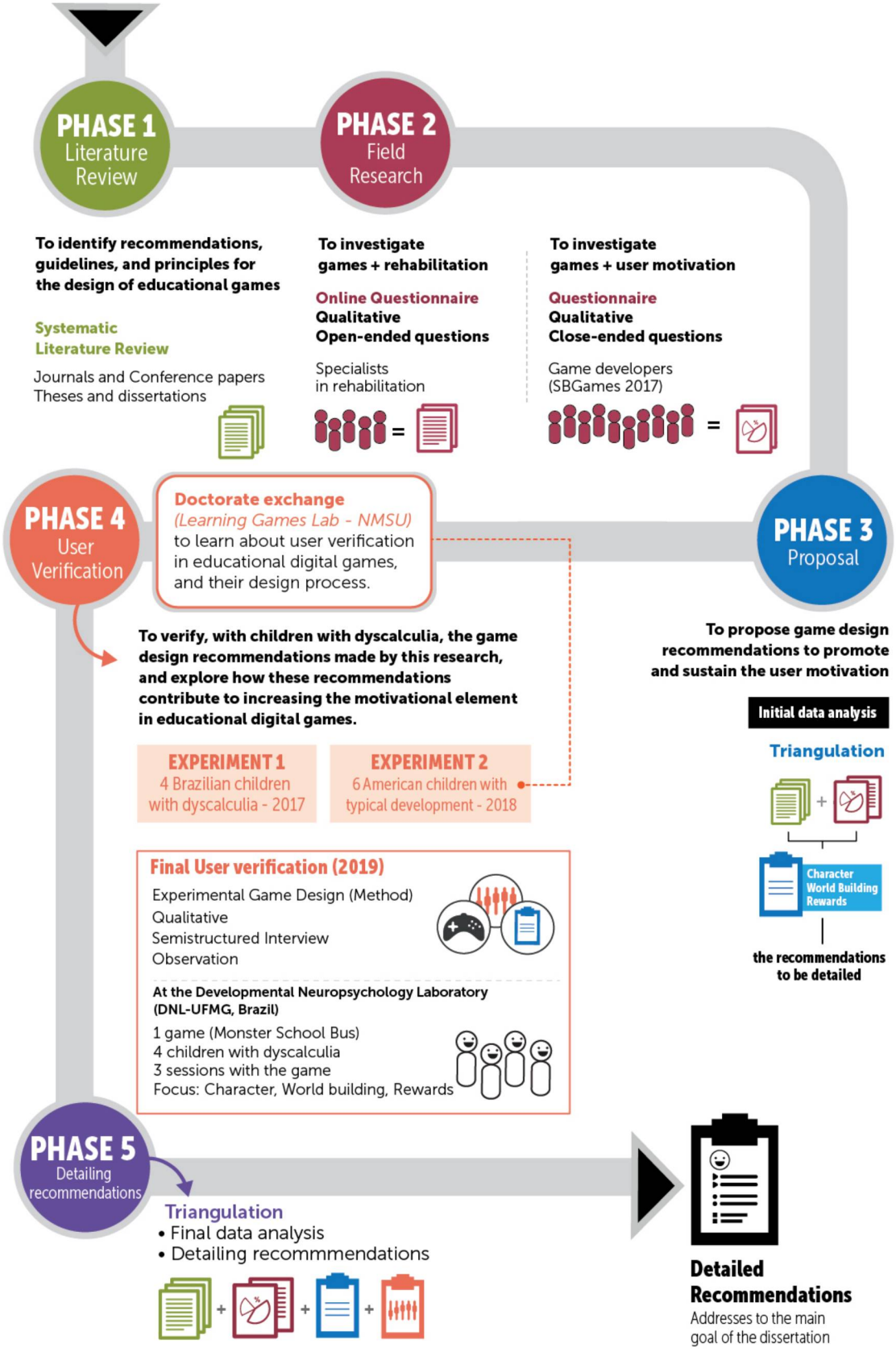


Figure 3: Research methodology overview.
Source: the author.

1.10 Dissertation structure

This dissertation has nine chapters. The content of each chapter is described below, and table 1 summarizes the dissertation structure.

- **Chapter 1. Introduction:** This chapter provides an overview of the research - i.e. its context, scope, aims, structure.
- **Chapter 2. Learners motivation in educational digital games:** This chapter provides information on the theoretical bases of this dissertation. It discusses the current state of the design of educational games and how it deals with learner's motivation.
- **Chapter 3. Developmental dyscalculia:** This chapter provides further information on the theoretical bases of the dissertation. It focuses on children with developmental dyscalculia and their rehabilitation using games.
- **Chapter 4. Methodology:** This chapter describes in detail the research methods used in this dissertation.
- **Chapter 5. Field research:** This chapter presents the results of the field research with game developers and specialists in rehabilitation.
- **Chapter 6. Game design recommendations proposal:** This chapter describes the qualitative analysis and proposes a set of game design recommendations.
- **Chapter 7. User verification:** This chapter describes the verification of the game design recommendations made with children with dyscalculia, through an experimental game design.
- **Chapter 8. Detailing recommendations:** This chapter details the game design recommendations based on data triangulation (literature review + field research + user verification).
- **Chapter 9. Conclusions:** This chapter discusses the findings of this study. It also offers a reflection on the research question, method and goals of this study.

Table 1: The relation between the goals, phases and chapters of this dissertation.
Source: the author.

Specific Goal	Research phase	Technical procedure	Dissertation chapter
			Chapter 1. Introduction
To identify recommendations, guidelines, and principles for the design of educational games which apply to the neuropsychological rehabilitation of children with dyscalculia.	**Phase 1** Literature review	**Systematic literature review** Journals, theses, dissertations	**Chapter 2** Learners motivation in educational digital games **Chapter 3** Developmental dyscalculia
			Chapter 4. Methodology
To investigate, from the perspective of specialists in rehabilitation, what the requirements to develop educational digital games for children with dyscalculia in neuropsychological rehabilitation are.	**Phase 2** Field research	**Online questionnaire** Specialists in rehabilitation	**Chapter 5** Field research
To investigate what motivational game elements are used by game developers to promote player motivation, and how these elements are set up during an educational game project. Also, to contrast this information with the literature data.		**Questionnaire** Game developers	
To propose a set of game design recommendations for educational games capable of fostering and sustaining motivation in dyscalculic children during neuropsychological rehabilitation.	**Phase 3** Proposal	**Triangulation** Data analysis strategy	**Chapter 6** Proposal recommendations
To verify, with children with dyscalculia, the game design recommendations made by this research, and explore how these recommendations contribute to increasing the motivational element in educational digital games.	**Phase 4** User verification	**Semi-structured interview** **Observation** Children with dyscalculia	**Chapter 7** User verification
Main goal: To make detailed game design recommendations on how to promote and sustain motivation in children with dyscalculia in educational digital games, during a neuropsychological rehabilitation.	**Phase 5** Detailing recommendations	**Triangulation** Data analysis strategy	**Chapter 8** Detailing recommendations
			Chapter 9. Conclusions

2 LEARNERS' MOTIVATION IN EDUCATIONAL DIGITAL GAMES

This chapter focuses on learners' motivation in educational digital games. In this chapter the following will be discussed: (1) definition of educational digital games; (2) game elements; (3) motivation as an element of learners' experience; (4) game design orientations for learners' motivation.

2.1 Defining educational digital games

It is not easy to define what a game is and there is no consensus in the literature about what the definition of game should be. This can be due to two factors. First, technology is constantly evolving, which makes it difficult to establish what a game can be (CHAMBERLIN, 2003). Second, as identified by Salen and Zimmerman (2004), different authors define the artifact game according to different contexts and approaches. Thus, the definition of game, or more precisely educational digital game, presented in this chapter is not a universal one, but the one that best suits the purposes of this study.

This study considers a game to be *"a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome"* (SALEN and ZIMMERMAN, 2004 p.83). Additionally, this study considers that based on a set of primary characteristics a game can be defined as an interactive digital system, capable of promoting emotions and experiences for the player (KAPP, 2012; MAYER and JOHNSON, 2010). These characteristics and the experiences they create are listed below:

1. **Rule-based:** Players interact in a rule-based environment, where they understand how things work. Games provide the experience of understanding;
2. **Responsive:** Players interact and perform actions in the game environment, and they receive immediate feedback on their performance. Games provide an experience of power or control;
3. **Challenging:** Players face challenges according to their abilities, and this improves their skills. Games provide an experience of self-efficacy;
4. **Cumulative:** Players achieve progressive goals in the game environment, based on their skills development. Games provide an experience of goal-directedness.

As for the term *digital*, it refers to games developed for digital devices (e.g. computers, mobile devices, consoles). This study focuses on educational games used in a computer platform, such as desktops and laptops. Digital games are also referred to in the literature as electronic games, computer games, video-games or simply games (CHAGAS, 2009). Educational digital games are also referred to as *computer games for learning* (MAYER, 2014); *digital game-based learning* (PRENSKY, 2012). The popular term *serious Games* (ABT, 1987) is also used.

Following Mayer (2014) and Clua and Bittencourt (2004), this study considers that educational digital games are developed to promote the learning of specific content

through a ludic approach. This means that educational digital games have a clear educational goal oriented by a pedagogical proposal, as well as characteristics of entertainment games (see figure 4).

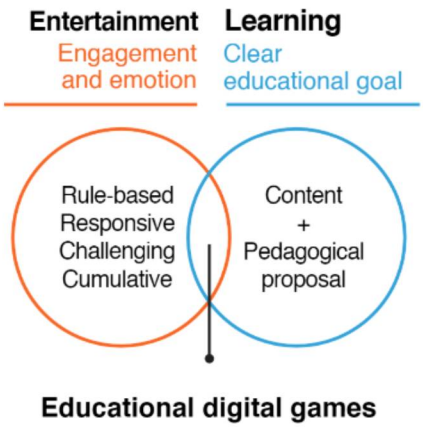
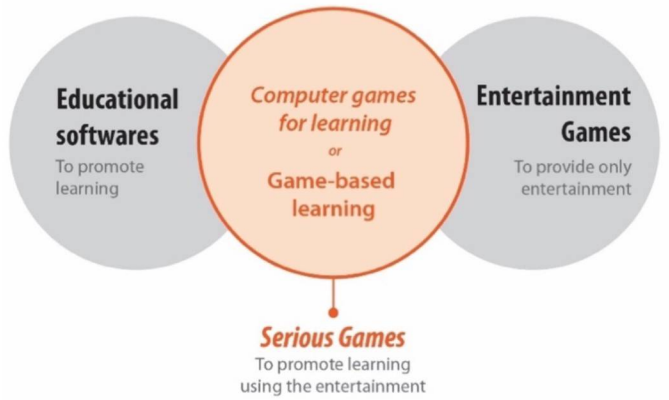


Figure 4: Graphic synthesis of the basic principles of educational digital games.
Source: The author based on Mayer (2014); Kapp (2014); Clua and Bittencourt (2004).

Moras (2015) calls attention to the fact that educational games, or serious games, are in an intersection between educational software and entertainment games. Similarly to educational software, educational games make use of learning strategies based on "edutainment". Edutainment (education + entertainment) refers to the use of multimedia learning materials to educate through entertainment, therefore providing a learning experience which is fun and pleasant. On the other hand, educational games, like entertainment games, make use of an interactive fictional world in a multimedia environment composed by a narrative and rules. Figure 5 provides the different definitions of educational games and the different terms used to refer to this type of game.



5: Educational digital games: the overlap between educational software and entertainment games.
Source: Adapted from Moras (2015 p.70).

Every game, even those without an explicit learning goal and whose purpose is solely to entertain, can develop players' cognitive skills, such as creativity, problem solving, logical thinking (CLUA and BITTENCOURT, 2004). The focus of this study, however, is on educational digital games, in other words, games that are developed with clear education goals, such as to teach a specific content (e.g. arithmetic).

Not all games, however, not even educational ones, should by themselves be considered as artifacts that can provide and foster a more fun and meaningful learning experience (ARNSETH, 2006). Similarly, educational digital games should not be seen as artifacts capable of meeting all educational needs, or as the only technology for developing learners' skills, as some studies seem to suggest (CLUA and BITTENCOURT, 2004).

Finally, Tobias et al. (2014) observe that most digital games represent a multimedia environment, since they make use of graphical images combined with text, sound effects and oral communication. Rieber (1996) explains that **educational digital games as a multimedia environment focus on the player experience.** This means that the learning occurs through the player interaction with the dynamic elements of the game. This player experience results from either the player's interaction with elements of the game or with other players, according to Mattar (2010). In the educational context, this experience is also relevant to foster players' motivation for the pedagogical content. In order for this to be achieved, it is necessary to find the right balance between the entertainment elements of the game and the pedagogical elements, which has been considered a demanding task. In the following section, the elements that make up educational digital games will be described.

2.2 Game Elements

This section discusses the elements which are considered to make up educational digital games. As mentioned earlier, in this study a game is considered as *"a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome"* (SALEN and ZIMMERMAN, 2004 p.83). Based on this definition, some authors (e.g. Winn, 2008; Chamberlin, Trespalacios and Gallagher, 2012) categorize the game elements into two types, namely those related to entertainment aspects and those associated with learning and educational aspects. This study also recognizes two categories of educational game elements: **entertainment elements** and **educational elements.** Although they can be separated into two classes, these elements are interconnected. These two game categories are discussed below. The technical aspects of these game elements (e.g. programming), however, are beyond the scope of this study.

2.2.1 Entertainment Elements

Based on Fullerton, Swain, and Hoffman (2004) it can be said that educational digital games are a form of entertainment. It is through this experience of entertainment that the game provides that the player learns about a specific content. Hence, similar to other sources of entertainment, educational digital games should stimulate the player, both emotionally and intellectually.

This study is based on the premise that educational digital games are systems, and as such they are made up of parts that interconnect to make up a complex whole (SALEN and ZIMMERMAN, 2004). In educational digital games, these parts are the game elements, with which players interact in a specific context. As regards the game system, Järvinen (2008) describes it as being composed of nine elements. These elements are summarized in table 2.

Table 2: The nine elements of digital games.
Source: based on Järvinen (2008).

Element	Common Example
Component: the objects (physically or virtually) that players can manipulate, modify and play with during the game.	Physical or virtual objects. For instance, tokens, characters, vehicles, etc.
Environment: The space or setting for play (physical or virtual).	Boards, worlds, levels, mazes, etc.
Rule set: the procedures used by the game system to regulate players' actions in the game.	Achieve a goal within a set time frame, only use a specific object to complete a task, etc.
Game mechanics: the actions that players perform when playing in order to fulfill the game goals.	Move characters or vehicles, shoot, throw objects, etc.
Theme: the topic of the game, which works as a metaphor for the game system and as its rule set. Although the theme and the narrative can be aligned, they are not the same.	War theme in chess, licensed games (e.g. Lord of the rings).
Information: what players need to know while playing. What the game system collects and presents to the player as game states and which will affect the player's actions.	Rewards, points earned, clues, tasks, amount of time remaining/used, etc.
Interface: a tool that allows players to play the game. This element refers to both virtual interfaces and physical devices.	Physical interface (e.g. joystick, controllers); virtual interface (e.g. graphical user interface- GUIs, menus, heads-up displays – HUDs).
Players: the human aspect of the game, it refers to those who play the game.	Players' behavior, humor, relation with the game preferences, motivations, etc.
Context: The physical environment where the playing takes place. It also refers to the reasons why players play the game and when they play it.	Educational context, for instance at school, or at home; with or without a mediator; in rehabilitation, etc.

Järvinen (2008) emphasizes that for each game element there are many possibilities of implementation, and that these vary according to the game. Thus the game system is dynamic rather than static (JÄRVINEN, 2008; FULLERTON, SWAIN, and HOFFMAN, 2004). Game elements connect with one another in a complex way. These connections develop during the play, when they interact with the players' behavioral aspects. It is this connection between game elements and player(s) that creates the game experience in the mind of the player(s).

Fullerton, Swain, and Hoffman (2004) also propose a set of elements for the game system. These can be seen as complementary to the one proposed by Järvinen (2008). According to Fullerton, Swain, and Hoffman, the game elements can be divided into two categories, namely: formal elements and dramatic elements. According to these authors, there are eight **formal elements,** and these usually represent the functional and elementary structure of the game system. These elements are shown in table 3.

Table 3: Formal elements of the game.
Source: based on Fullerton, Swain and Hoffman (2004).

Formal Elements
Players: an essential element of the game, independent of the interaction mode (e.g. single player, cooperative, multiplayer, etc.). The player is invited to play, then voluntary he/she accepts the game rules and enters the "Magic cycle" (HUIZINGA, 2000).
Objectives: represent what the players pursue in the game. The game objective can be short or partial - i.e. guides the player gradually to the primary game objective.
Procedures: refer to the way of playing and the actions that players can perform in order to achieve the game objectives. In digital games, players do these procedures using controllers or other types of physical device.
Rules: define the game objectives and establish the actions that players can or cannot perform during the game. In digital games, the rules can be explained through tutorials or instructions, or can be implicit in the game system interface.
Resources: can be seen as the game assets - i.e. the resources required to achieve the goal of the game. Weapons, potions, magical objects, coins, lives, actions and time are examples of resources.
Conflict: emerges when players attempt to fulfill the game objectives. The game conflict, the rules and the procedures are designed to prevent players from achieving the game objectives too easily. Obstacles, opponents, and dilemmas are examples of conflict.
Boundaries: separate players from all things outside the game - that is, ordinary life outside the "magic circle." Boundaries can be physical (e.g. the game arena), or conceptual (e.g. a social agreement between players).
Outcome: a quantifiable game result. An outcome can relate to a phase of the game, a level of the game, or the final game result (e.g. points earned, rewards, losing or winning). The game outcome is set based on the game objectives and challenges.

According to Fullerton, Swain, and Hoffman (2004), these formal elements can be combined in a number of ways and represent a simple game structure. However, for a game to be meaningful for the players, in the sense of allowing their imagination to flourish and providing them with a motivational and emotional experience, it is necessary to make use of the **dramatic elements.**

This motivational and emotional experience constitute the primary focus of this study. Table 4 summarizes the dramatic elements identified by Fullerton, Swain, and Hoffman (2004). For these authors, these elements can provide an emotional connection between players and game, and as a result, they create a unique experience of entertainment.

Table 4: Dramatic game elements.
Source: based on Fullerton, Swain, and Hoffman (2004).

Dramatic Elements
Challenge: the activities of the game which players need to complete. Players' feeling of satisfaction comes from overcoming the challenges. A challenge demands an exact amount of effort so as to provide a fun feeling. A challenge is entirely individual and dynamic, and it depends on the player's skills and progress during the game.

Dramatic Elements
Play: an activity with a broad range of possibilities; it provides freedom of action in a rigid structure or environment. In games, the rule-set represent this rigid structure, and when the player interacts with it, they explore freedom through the game "magic circle." This interaction provides emergent and individual personal expression. The play offered by games is an essential element to engage players emotionally in the game.
Premise: represents the exposition of the game story (e.g. time, place, characters, relationships) or the metaphor for the game system. For instance, the premise of the classic game Space Invaders is: the game takes place on planet earth when it is being attacked by aliens. Thus, players are the unknown heroes, responsible for protecting the planet from these invaders.
Character: the acting agency from the game narrative. In the game, characters have two primary functions: (1) be the agency of the game by representing the player in the game environment; (2) stimulate the players' empathy, that is, to flourish the players' emotional connection with the character and consequently with the goals of the game.
Story: told through a narrative and has an unexpected outcome, whose aim is to catch the players' attention. Very often in games, the story is reduced to a backstory, which can be seen as a more elaborate version of the premise. This backstory includes the time, the setting and the game conflict, all of which are responsible for fostering the game character motivation. Some games use a more elaborate story, which allows players to choose and change the linear game story.
World Building: represents the universe created for the game, which usually includes maps, stories, cultural aspects, languages, etc. For instance, the whole universe created for the Star Wars franchise.
The Dramatic Arc: represents the conflict in the game, and is responsible for creating a good drama. It can be seen as the amount of tension in the game story. The dramatic arc connects players with the game story emotionally by creating a sense of tension, thus providing them with an experience of entertainment.

Table 5 below sums up and contrasts all the game elements identified so far. A set of game elements have been selected for this study. These elements are usually seen as part of the entertainment layer of this media. Following Fullerton, Swain, and Hoffman (2004), the selected elements are categorized as **formal** or **dramatic.** This study is mostly concerned with the dramatic elements, due to their importance in stimulating players' motivation during the play experience.

Table 5: Entertainment elements.
Source: the author based on Fullerton, Swain, and Hoffman (2004); Järvinen (2008).

Järvinen (2008)	Fullerton, Swain, and Hoffman (2004)	Identified elements
Component	/	Component
Environment	World Building	World Building
Rule set	Rules	Rules
Players	Players	Players
/	Resources	Resources
/	Objectives	Objectives
/	Procedures	Procedures
Game mechanics	/	Mechanics
	Outcome	Outcome
Information	/	Information
Theme	/	Theme
/	Story	Narrative (story)
/	Conflict	Conflict
Interface	/	Interface
/	Boundaries	Boundaries
Context	/	Context
/	Challenge	Challenge
/	Play	Play
/	Premise	Premise
/	Character	Character
/	Dramatic Arc	Dramatic Arc

Categorization of the identified elements

Formal Elements	Dramatic Elements
Component	World Building
Rules	Narrative (story)
Players	Conflict
Resources	Challenge
Objectives	Play
Procedures	Premise
Mechanics	Character
Outcome	Dramatic Arc
Information	*Rewards
Theme	
Interface	
Boundaries	
Context	

Fullerton, Swain, and Hoffman (2004) and Järvinen (2008) consider the game rewards as part of the formal elements "information" or "outcomes." However, when focusing on players' motivations, it should be possible to infer what element should receive more attention. This study will argue that the element reward fits better in the dramatic category

It should be highlighted that these elements represent one approach, among many, to the study of games. For the purposes of this study, however, these elements represent the best alternative. In the following section the educational game elements associated with learning will be described.

2.2.2 Educational Elements

In this study, educational digital games are considered as complex and interactive systems, whose goal is entertain the player, but which have at the same time specific learning outcomes. This section presents an overview of the learning elements of educational digital games. In contrast with the entertainment elements, the game elements related to learning are more abstract. The educational elements of the game draw on educational resources and instructional approaches to foster learning through the game activities.

Winn (2008), the author of the well-known DPE framework (Design, Play, and Experience), established **learning** as a sub-component of his framework. It is while considering this sub-component that the development team defines the game content and pedagogy. It means that these educational elements are created based on the learning content to be taught through the game interaction. Thus, according to Winn (2008), for

this task, the development team uses many learning theories to set up the learning goals, and also to identify the best way to configure these goals into the educational game.

The Learning Games Design Model (CHAMBERLIN, TRESPALACIOS and GALLAGHER, 2012), another renowned model, also emphasizes the relevance of defining the game learning goals and content proposal. In order to do so, the authors propose a set of guiding questions (see table 6). According to the authors, these questions should be answered by a multidisciplinary team, as a collaborative process. Professionals with different backgrounds should see this as an opportunity to share their knowledge, teaching methods, ways of identifying learners' difficulties, and ways of creating a motivating learning environment through the gameplay.

Table 6: Guide questions for learning aspects in the educational digital games process. Source: adapted from Chamberlin, Trespalacios and Gallagher (2012, p.93-95).

Audience
Who is the specific audience?
What is their existing knowledge of the content?
Environment of Use
Where will the game be played, and how?
Will students be playing in a controlled environment?
Will they play alone or collaboratively?
On which platforms or environments will the game be accessed?
Guiding Questions Shaping refinement of educational objectives
How is this content currently being taught?
Why is that not working?
What common mistakes do learners make?
How do we know if the learner fully understands this? What can they do, say or demonstrate? What will they do or say if they do not fully understand this?
What should the learner know, do, and understand to be able to learn this content?
What does our learner already know or believe about this content?

Both Winn (2008) and Chamberlin, Trespalacios and Gallagher (2012) affirm that the **educational objectives** and the **game pedagogy** should be defined at the beginning of the design process. The reason for this is that, for these authors, the **educational objectives** and the **game pedagogy** represent the foundation of educational games, and provide information which will help create the game story, mechanics, interface, among other game elements.

Thus, in summary, the educational elements of games are: **content definitions, pedagogy approach and educational objective**. These definitions, however, rather than referring to specific elements, serve as guidelines for the configuration of all game elements (e.g. mechanics, rules, story, theme, character).

Several authors have used **the Revised Bloom's Taxonomy** (ANDERSON et al. 2001) when setting the educational objectives of a game (e.g. MAYER, 2002; WINN, 2008; ECHEVERRÍE et al. 2011; JAPPUR, 2014; CARVALHO et al. 2015). Learning theories, however, are beyond the scope of this study. This study does not discuss learning theories, nor does it make suggestions as regards which theory is the most suitable for designing educational games.

The Revised Blooms Taxonomy (ANDERSON et al. 2001) serves as an instructional approach during the educational game design process. Carvalho et al. (2015) explain that

while the educational objective represents the player's perspective of what will be learned, the instructional aspects are concerned with what strategies the developers will use to facilitate that learning for the players.

The literature suggests that it is the interaction between the entertainment and the educational game elements that creates a fun play experience, at the same time enabling the learning of a specific content. The following section-discusses players motivation and experience.

2.3 Motivation as a component of player experience

As stated earlier, the main focus of this study is the motivation of children with dyscalculia in educational digital games, more specifically, during neuropsychological rehabilitation. Motivation is an important part of players experience in the educational game interaction. In this section it will be made clear what motivation means in this study, and what the main motivation features for children are.

According to Reeve (2009), the concept of motivation is usually related to why people perform a specific activity, that is, what their reasons are. Bandura (1994) states that motivation represents a stimulus for action. Thus, motivation can be measured based on personal choices of action, and how intense or persistent these actions are, or how much effort they involve. **In this study motivation is understood as what triggers a person's behavior, that is, what leads them to perform a specific activity.**

Reeve (2009) also highlights that the factors responsible for energizing and directing one's behavior towards an activity can be Internal Motives (relate to the individual) or External Events (relate to the environment). Thus, Reeve's recognizes two types of motivation: Intrinsic Motivation and Extrinsic Motivation.

According to Reeve (2009), **intrinsic motivation** emerges spontaneously in people as an innate striving for growth. This type of motivation comes from psychological needs and personal interests. Malone and Lepper (1987) argue that people are intrinsically motivated when they act out of interest. That is to say, they do not seek external reasons, stimuli or rewards. For these authors, an intrinsically motivated person sees the activity as fun, entertaining, engaging and pleasant.

On the other hand, Reeve (2009) explains that **extrinsic motivation** arises from external incentives and from the environment, for instance, attention, money, badges, scholarships, candy, awards. These incentives represent external reasons for people to start and to continue to do an activity, it is a way to attract them and foster their motivation. Hence, extrinsic motivation emerges from external factors that are not part of the activity itself. Thereby, whereas through intrinsic motivation the person engages in the activity for the pleasure of doing it, those with extrinsic motivation will do the activity based on external reasons and incentives. Table 7 sums up and contrasts the different types of motivation.

Table 7: Types of motivation.
Source: the author based on Reeve (2009).

Type of Motivation	Approach	Source of behavior	Stimuli (for a reason)
Intrinsic	Spontaneous behavior. The person considers the activity interesting, fun and enjoyable.	This motivation originates from the person's psychological satisfaction in doing an activity.	Internal (individual, psychological needs, cognition, and emotions).
Extrinsic	Conditioned behavior Someone or a social environment conditions the person: "Do this in order to get that." "Do this, and you will get that."	This motivation arises from external incentives or conditioned consequences which initiate and sustain a specific behavior.	External (social and cultural environment).

Therefore, when looking at motivation in educational digital games, the focus should be on intrinsic motivation. According to Alves and Battaiola (2011), this is because intrinsic motivation is the real motivation. It is intrinsic motivation that bolsters and maintains the person motivated, even without or after external incentives. The authors emphasize that the challenge does not lie in initiating the person's motivation, but rather in sustaining their initial intrinsic motivation throughout the activity. Thus some game incentives (e.g. types of feedback, rewards) may be used as external stimulus, as these will help to sustain players motivation in educational game activities. Habgoob and Ainsworth (2011) stress that educational digital game systems automatically allow the use of rewards and other external incentives, which may help energize players intrinsic motivation for educational game activities.

2.3.1 Motivation through a ludic perspective

This section discusses how motivation occurs, particularly in children. Motivation is considered here through a ludic perspective, taking into account the connection between play and child development. This is a broad topic, and only those aspects relevant to the present study will be discussed.

Pereira, Amparo and Almeida (2006) explain that the play contributes to the personal and social development of a child. The authors consider playing as an essential element for child development. According to Vygostsky (2001), children are ludic, and for that reason, they are always playing. Child play, however, has a meaningful purpose, which corresponds to the child's age, interests, habits and developmental skills. Huizinga (2000) explains that the Latin word *ludus* refers to all types of games, ranging from children's games to gambling games. Moreover, most games are identified especially for their non-seriousness. Therefore, since children are ludic by nature, they will identify themselves with and be attracted to ludic activities, and ultimately to games.

Macedo, Petty and Passos (2005) identify five indicators or qualities which show the ludic dimension of an activity. These indicators are applicable to the investigation of children's motivation in educational digital games interactions. They are summarized below.

- **Functional pleasure:** Children do not play to learn some content, to become wiser, or to become successful adults. Children play for the ludic and functional pleasure that the activity itself provides them with. For children playing is fun and challenging. Thereby, children's interest in playing is intrinsically motivated. The

functional pleasure of an activity refers to the fact that children do the activity solely for the pleasure of doing and repeating it (e.g. to read for the pleasure of reading), rather than as a means to an end (e.g. to read to gather information);

- **Challenge and Surprise:** Challenges here refer to the obstacles in an activity or a play to be faced by the child based on their cognitive skills. To overcome these challenges the child must learn something and make some effort, this represents the ludic aspect (e.g. thinking more, building strategies, trying new ideas). So that the child does not have total control when dealing with these challenges, and also to foster their curiosity, there should be some surprises;
- **Possibilities:** It should be possible for the child to overcome the challenges in an activity based on the child's internal resources (e.g. skills, competence, knowledge) and external resources (e.g. required tools, time, space). Moreover, the activities should be meaningful that is, they should be seen by the child as necessary for some situation or context. Challenges which are impossible to overcome, or activities which are meaningless for the child will be seen as unattractive and uninteresting;
- **Symbolic dimensions:** These refer to the connection between the child, who performs the activity, and what is done or thought during the activity. The child gives meaning to the elements of the activity, based on their life experiences. This symbolic meaning represents the child's desires, values and feelings, in other words, it is how the child understands and interacts with the world;
- **Constructive expression:** It refers to the different possibilities that the activity offers the child, in the sense of achieving an objective, the different perspectives in which the child can do the activity. The focus is on the activity, and during the process the child can image strategies, try alternatives, among other things, to achieve the objective.

Thus, the connection between ludic play and child development is evident. Children need to play, and the play represents an opportunity for them to explore the world.

2.3.2 Expression of the child's motivation

According to Reeve (2009), although motivation is an unobservable experience, a person's motivation can be inferred through some aspects. The aspects relevant to the present study are **behavior expression, level of engagement and self-report**. These aspects are described below, following Reeve's (2009).

- **Behavior expression:** refers to the observation of the child's behavior during an activity. Through the behavior expression it is possible to infer the presence, intensity, and quality of motivation;
- **Level of engagement:** refers to the child's behavioral intensity, emotional quality, and personal effort during an activity. These engagement factors can be observed in the child's behavior (e.g. attention, persistence), positive emotion (e.g. enjoyment), cognition (e.g. use of well-strategies) and voice (e.g. expression of needs, preferences, desires);
- **Self-report**: refers to the information gathered with the child through interviews or questionnaires about his/her motivation. Although the use of self-reports is a useful approach, Reeve (2009) stresses the importance of using more than one

method to measure motivation, for instance, an interview and a behavior observation.

These three aspects are used in this study to investigate children's motivation in games. The following section offers a discussion of motivational theories so as to better understand the process of motivation in games.

2.3.3 Motivation theories that are consistent with the ludic perspective

In order to measure children's motivation in educational games, the following four theories are used in this study: (1) Flow theory (CSIKSZENTMIHALYI, 1990); (2) Self-efficacy (BANDURA, 1994, 2016); Taxonomy of intrinsic motivation for learning (MALONE and LEPPER, 1987); (4) ARCS model (KELLER, 2010). These theories will be described below.

A. Flow theory

Csikszentmihalyi's (1990) Flow theory proposes ways to achieve an optimal experience during an activity. As shown in figure 6, the flow channel varies according to the challenges presented in the game and the skills required to overcome these challenges. The flow channel also varies according to the level of anxiety and boredom of the player. Hence, the flow experience occurs when there is a progressive balance between the challenges provided by the activity and the player's skills.

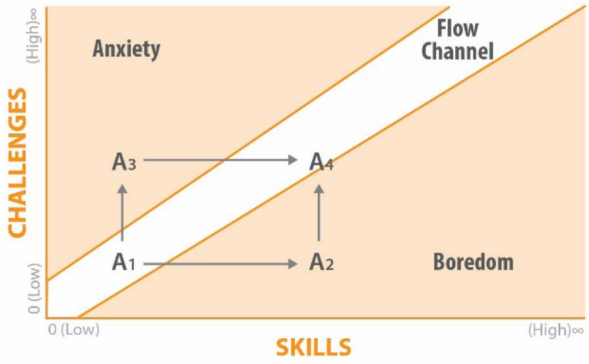


Figure 6: Flow theory.
Source: Adapted from Csikszentmihalyi (1990 p. 74).

The flow theory is well accepted in the game design field because playing a game supposedly takes the player into a flow state, also known as immersion in the game context (MATTAR, 2010). The flow theory makes it possible to plan game tasks which provide challenges according to the player's skills, offering an intermediate level of difficulty (not too easy nor too hard), and by doing so providing a motivational experience.

According to Csikszentmihalyi (1990), eight elements lead to the flow experience. He refers to them as the elements of enjoyment. These elements make individuals intrinsically motivated, that is, they perform the activity for personal interests rather than external gains. These elements are:

- Challenging activities which take into account the person's skills, and which are therefore achievable;
- Full concentration through the merging of action and awareness;

- Clear goals and feedback;
- Concentration on the activity, making it possible to forget other aspects of life;
- Feeling of control over the activity;
- Loss of self-consciousness;
- A new understanding of the concept of time and how it passes;
- Flow state based on the combination of the previous elements. This will provide the person with a pleasant feeling during the activity.

For Csikszentmihalyi (1990) the flow experience is autotelic. Put differently, the person does the activity for intrinsical reasons without expecting external rewards. For the person, simply doing the activity already provides an internal reward. Hence the flow experience represents an intrinsic motivation.

Csikszentmihalyi (1990) also elucidates that although the flow experience is autotelic, not all of the activity is. For him, many situations require external incentives to encourage people to begin a specific activity, specially those with a low rate of adherence (due to the most varied reasons). External stimuli can be seen as a way to both encourage people to begin a required activity, and to continue one for which they have not yet developed intrinsic motivation. The use of educational digital games by children with dyscalculia in rehabilitation is an example of such external stimuli. The vast majority of the children in neuropsychological rehabilitation present difficulties in learning math. Many of these children develop mathematical anxiety, due to their difficulties with this subject (RUBINSTEN and TANNOCK, 2010). As a result, these children are not intrinsically motivated by games or other activities which involve the use of math. They do not only dislike these activities but develop a feeling of repulsion for them. Thus, the use of an external stimulus can help these children to develop intrinsic motivation for these activities, and eventually overcome their difficulties in math.

B. Self-Efficacy

According to Bzuneck (2009), the self-efficacy construct is one of the psychological mechanisms of motivation, thus its relevance to this study. Specialists in neuropsychological rehabilitation often use this construct when looking into learning disabilities interventions (see Antunes et al. 2013).

Bzuneck (2009) defines self-efficacy as a person's perception of their own capabilities, such as intelligence, skills, and knowledge. Bzuneck also explains that this construct is not about actually having or not having these capacities, but about how good the person believes their ability to do some activity is. For Bandura (2016), self-efficacy is the basis of a person's motivation. For him, it is through their sense of self-efficacy, that is, it is based on what they believe as possible to do, that a person directs their actions. Thus, in an activity, a person's sense of self-efficacy influences players' actions, engagement level, amount of effort, as well as their persistence in the face of challenges. Bzuneck (2009) stresses that in the academic context, learners are motivated by an activity when they believe that by using their capabilities (e.g. knowledge, abilities) they will succeed in learning new things and will enhance their skills. Hence, learners will select action

strategies that they consider themselves capable of doing. On the other hand, learners will reject action strategies that they perceive to be impossible to implement.

Bandura (1994) and Bzuneck (2009) identify what they consider to be the sources of self-efficacy. Of these sources, two are relevant for this study and they are described below:

- **Mastery experiences:** The learner's progressive success during an activity makes them believe that it is possible to successfully perform other activities. Positive feedback during an activity strengthens the learner's sense of self-efficacy, based on their efforts during the activity;
- **Social persuasion:** Verbal encouragement helps learners overcome self-doubt and increases self-efficacy. The use of statements such as "Let's go, you can do it!" is an example of verbal persuasion.

To sum up, the self-efficacy construct may be used as a mechanics to flourish and sustain player motivation in educational digital games. The game system can provide players with mastery experience during the gameplay, through levels of difficulty which correspond to the skills of the players. The game system can also offer positive feedback on the players' performance, and persuade them to believe that they have the capabilities to succeed using graphic elements or verbal encouragement.

C. Taxonomy of intrinsic motivation for learning

Malone and Lepper (1987) propose a taxonomy which focuses on building learning environments capable of stimulating fun and learning for learners through intrinsic motivation. Their taxonomy includes two categories of intrinsic motivation, namely individual and interpersonal. Only the individual motivations are relevant for this study and these are: challenge, curiosity, control and fantasy.

- **Challenge:** according to the authors, learners tend to feel intrinsically motivated by an activity when they are instigated to solve challenges at an optimal level, according to their skills. The authors consider the following as challenges: Goals, Uncertain outcomes, Performance feedback, Self-esteem;
- **Curiosity:** the authors consider this factor as the most directly connected with the learning. They allude to two types of curiosity: sensory curiosity and cognitive curiosity. Sensory curiosity catches the learners' attention through sensorial variation in visual effects or audio. For instance, remarkable characters, backgrounds. Cognitive curiosity is stimulated through instructional techniques to surprise and intrigue learners. For example, presenting the learner with a content they already know but in a different or simplified approach;
- **Control:** according to the authors learners tend to feel motivated when the educational activity provides contingency (responsive environment), choice (in various aspects and levels – personalization), power (allow the learner to have the dominant effect in the activity).
- **Fantasy:** according to the authors, fantasy provides learners with a mental image of unreal physical or social situations. Through fantasy the educational environment can: involve the learner emotionally (e.g. through the use of characters); provide cognitive aspects (e.g. through the use of metaphors to

present a content); offer endogeneity (e.g. through the endogenous connection between the content and the fantasy).

Malone and Lepper's taxonomy is therefore a useful framework for the development of educational digital games. Also, this taxonomy provides theoretical information that can be helpful when measuring players' motivation in these games.

D. ARCS Model

The ARCS Model was created by Keller (1984) and it focuses on the motivational aspects of the learning environment. According to Keller's model, there are four key components for promoting and sustaining learners' motivation - Attention, Relevance, Confidence and Satisfaction - thus the acronym ARCS (KELLER, 2010). These components are described below.

- **Attention:** This component of the model refers to the elements that can create and sustain learners' interest and curiosity in the activity. According to Keller, in the learning environment attention is what guides learners to the learning objective;
- **Relevance:** This component relates to the learners' beliefs about the relevance of an activity to their learning. According to Keller, learners will be motivated to learn something if they judge the task or instruction as necessary and related to their objectives;
- **Confidence:** This component refers to learners' level of confidence in their ability to succeed. Keller explains that, even if the learner has attention and considers the activity relevant, in order to be motivated, they need to feel confident. Learners need to believe that they can succeed, that they can achieve the objectives of the activity.
- **Satisfaction:** This fourth and last component of the model refers to the elements which can sustain learners' motivation during the activity. In order to stay motivated, learners should be satisfied of what they achieved during the learning process. According to Keller, there is a direct link between satisfaction and level of motivation, either intrinsic (e.g. self-esteem, personal goals in learning something, information from notices, interactions with people) or extrinsic (e.g. grades and other rewards);

To conclude, the ARCS model (KELLER, 2010) is complementary to the other motivational theories presented in this section. What distinguishes this model from the other theories, however, is that the ARCS model is particularly concerned with how to maintain learners motivation throughout the activity.

The theoretical aspects aforementioned will be the basis of this research study into the factors affecting learners' motivation. Table 8 offers a summary of these frameworks and highlights their main features. All these theories share the same overall purpose, that is to promote and sustain intrinsic motivation in an activity. Moreover, this theoretical basis can also be used to plan ways to evaluate learners' motivation during educational digital games (see Cezarotto and Alves, 2019).

Table 8: Overview of the motivational theories used in this dissertation
Source: the author based on Csikszentmihalyi (1990); Bandura (1994, 2016); Malone and Lepper (1987); Keller (2010).

Flow theory *Csikszentmihalyi (1990)*	**Self-efficacy** *Bandura (1994, 2016)*	**Taxonomy of intrinsic motivation** *Malone and Lepper (1987)*	**ARCS model** *Keller (2010)*
- Challenging and achievable activities **- Clear goals** **- Immediate feedback** **- Concentration** (making possible to forget other aspects of life) **- The transformation of how time goes by** **- The loss of self-consciousness** **- Full concentration** (merging of action and awareness) **- The feeling of control over or during the activity**	**- Success experience** Positive Feedback Effort during the activity (challenge) **- Social Persuasion** Communication Visual or sound stimuli	**- Challenge** Goal Uncertain outcomes Performance Feedback Self-esteem **- Fantasy** Emotion Cognition **- Curiosity** Sensory Cognitive **- Control** Contingency Choice Power	**- Attention** **- Relevance** **- Confidence** **- Satisfaction**
The flow state represents an intrinsic motivation.	It represents a component to foster the learners' intrinsic motivation in an activity.	It aims to promote learners' intrinsic motivation in the activity.	It identifies the 4 key components to promote learners' intrinsic motivation for an activity.

2.4 Heuristics, design guidelines, and recommendations to promote and sustain learners' motivation in games

This section presents a set of heuristics, design guidelines, and recommendations which focus on promoting and sustaining learners' motivation in games. It is important to clarify that it is not the aim of this section to describe all the existent game orientations. The orientations selected are associated with the dramatic elements of games, which in turn are associated with players' motivation. Firstly, it is important to explain what is understood by heuristics, guidelines, and recommendations from a design perspective:

- **Heuristics:** Principles already identified that can help in designing an artifact or evaluate its qualities (FEDEROFF, 2003). When design principles are put into practice, they are usually referred to as heuristics. This term also implies that something needs to be done according to certain principles, especially when problems occur (PREECE, ROGERS and SHARP, 2013);
- **Design guidelines:** General prescriptive orientations that can be used at different stages of the development of an artifact. These guidelines come from experts' experience or empirical evidence. These orientations aim to achieve a successful solution for a project, considering its requirements (FU, YANG, and WOOD, 2015; KIM, 2010);
- **Recommendations:** In game design, recommendations are orientations provided at the initial stages of the development of a game, and which define the genre (learning, and/or entertainment) of the game. Recommendations can be used throughout the design process (CHAMBERLIN, 2003). In contrast with the orientations described above, recommendations are specific to a context or problem, and as such they allow for a more detailed elaboration.

Eight studies that provide game design orientations are discussed below (table 9). These studies cover many aspects of game development (e.g. accessibility, technical

aspects), however, only the orientations associated with dramatic elements and motivation are considered.

Table 9: Orientations from the literature
Source: the author

#	Authors	Orientation type	Objective
A	*Malone and Lepper (1987)*	Heuristics	Educational digital games
B	*Federoff (2002)*	Heuristics	Digital games
C	*Chamberlin (2003)*	Recommendations	Educational digital games
D	*Desurvire and Wiberg (2009)*	Heuristics	Digital games
E	*Leite and Mendonça (2013)*	Guidelines	Educational digital games
F	*Alfadhli and Alsumait (2015)*	Guidelines	Educational digital games
G	*Dickey (2015)*	Heuristics	Educational digital games
H	*Cezarotto and Battaiola (2016)*	Recommendations	Educational digital games

A. Malone and Lepper (1987): Heuristics for intrinsic motivation

Malone and Lepper (1987) propose a set of heuristics to enhance learners' intrinsic motivation. Table 10 summarizes the heuristics which are relevant for this study.

Table 10: Selected Heuristics from Malone and Lepper (1987).
Fonte: adapted from Malone and Lepper (1987).

Category	Heuristic
Challenge	**Self-esteem:** the activity should have different levels of difficulty. Learners should be provided with positive feedback based on their performance. This increases learners' self-esteem.
Curiosity	**Sensory curiosity:** the activity should promote sensory curiosity through visual effects and sounds.
	Cognitive curiosity: the activity should offer, through instructional techniques, surprises to incite learners.
Control	**Power:** the activity should allow learners to make choices and changes in the learning environment, that is, the activity should give them some level of power.
Fantasy	**Emotional aspects:** the activity should offer fantasy as an emotional appeal for the learners. This allows learners to identify themselves with characters and use their imagination in a fictional context.

B. Federoff (2002): Game design heuristics

Based on a literature review and a case study with experts, Federoff (2002) proposes a set of 40 game design heuristics. Those relevant to this study are listed in the table 11.

Table 11: Selected heuristics from Federoff (2002).
Source: adapted from Federoff (2002).

Heuristics
The game should have an unexpected outcome.
The game should offer rewards.
The game should allow players to create content in the game world, to give a customized experience.
The game should use visual and sound effects to stimulate the player's curiosity in the game world.
One type of game reward should be the acquisition of knowledge.
A game world that works with or without the character should be created, based on an interesting storyline.

C. Chamberlin (2003): Game design recommendations

Based on a literature review and a case study with players (children), Chamberlin (2003) proposes a set of game design recommendations focusing on player's engagement. The recommendations considered in this study are listed below (table 12).

Table 12: Recommendations selected from Chamberlin (2003).
Source: Adapted from Chamberlin (2003).

Games should provide feedback during the game experience: This feedback (e.g. scores, rewards) helps players to progress in the game, and is a stimulus for facing the challenges. In educational games, feedback can reflect players' learning strategies.
Game environment and characters are relevant: In the game world elements such as characters, sounds, humor, surprise, and fantasy are relevant for player experience. Formative tests and user participation are needed to create an appropriate game environment and characters.
Games should give players some control over the activities: Players enjoy exercising control and taking part in creative activities, such as designing or customizing the characters. Control helps to increase users' level of engagement and offers them a customized experience of play.
Build a game based on players' familiarity with other games, characters, and content: Using elements which are familiar to players makes them comfortable. Games should use familiar elements based on players' experiences, but also surprise them with new things.

D. Desurvire and Wiberg (2009): Heuristics for evaluating playability

Based on a literature review and a game expert evaluation, Desurvire and Wiberg (2009) propose some Heuristics for Evaluating Playability (HEP). Table 13 presents the heuristics which are relevant to this study.

Table 13: Heuristics selected from Desurvire and Wiberg (2009).
Source: adapted from Desurvire and Wiberg (2009).

Heuristics
Players have fun in the game when there are no boring or repetitive tasks.
The game should have rewards to stimulate the player's immersion in the game while enhancing their skills.
The game should provide players with a sense of control inside the game world.
The game should provide an emotional connection between players, the game world and their avatar.
The game should use humor to create the game elements.
The game should make use of a narrative and of a fictional world to encourage the player's immersion in the game

E. Leite and Mendonça (2013): Guidelines for the design of educational digital games

Leite and Mendonça (2013), based on a literature review, propose a set of guidelines for the design of educational digital games. Only the guidelines related to player experience are of relevance to this study and these are presented in the table 14.

Table 14: Educational digital games guidelines.
Source: adapted from Leite and Mendonça (2013).

Players' experience and motivation
Characters: Provide players with a new identity experience.
Rewards: Represent respect for the player. Players put effort into a task and deserve to be rewarded.
Fantasy: Provides players with the experience of a new reality.
Progressive development: Allows players to check their progress. It also allows them to play without feeling pressure for a while.

F. Alfadhli and Alsumait (2015): Guidelines for the design of educational digital games

The guidelines proposed by Alfadhli and Alsumait's (2015) focus on educational games for mobile devices. These guidelines are based on a literature review and an expert evaluation. The guidelines which are of relevance to this study are listed in table 15 below.

Table 15: Educational digital games guidelines.
Source: adapted from Alfadhli and Alsumait (2015).

Characters
Create ethic and relevant characters for players.
Involve players emotionally during the game.
Progressively allow players'characters to become more powerful.
Stimulate players' sympathy for the game characters.
Storyline
Reveals the game characters using a storyline.
Creates a clear, fast and engaging storyline.
Associates the game story with players' experience in the real world.
Logically presents the game setting (the local and fictional time of the game story).
Provides a clear connection between the game setting and the learning goals.
Challenges
Develop achievable challenges and goals, with exciting rewards.
Develop challenges that can provide a positive experience for the players and which can encourage them to keep playing.
Provide rewards that increase the players' skills and enhance their engagement in the game.

G. Dickey (2015): Characters design and game narrative heuristics

Dickey (2015) has conducted research on how the game graphic elements influence player experience in educational digital games. Her research offers important insights into the educational game design field. She proposes a set of useful heuristics, two of which are of

great relevance to this study and will be discussed in some detail below. These are the orientations which relate to game narrative and to game characters.

Narrative

Dickey (2015) explains that in a game, the narrative and the story allow players to explore new places, situations, and meet people. Moreover, the narrative brings about the player's emotions and feelings, which make the play a pleasant experience. According to Adams (2009), the narrative can stimulate and sustain the player's interest in a game. For him, this is because the narrative provides a broader emotional identification between the player and the game characters, which makes the players more eager to complete the game tasks.

Every narrative has a structure. According to Dickey (2015), the three-act structure is one of the most classic and widely used narrative structure in many media (e.g. movies, books, games). **The first act** represents the beginning of the story and it is when the player or spectator is given fundamental information about the story (e.g. character, setting, conflict). **The second act** corresponds to the middle of the story, and it is usually the longest part. It is in the second act that characters face the obstacles they need to overcome to solve the problems, conflicts, and challenges presented in the first act. **The third and final act** represents the end of the story, when the characters overcome the challenges and solve the main problems and conflicts.

In addition to her own orientations, Dickey (2015) also recommends Vogler's the Writer's Journey (1998). Vogler proposes a structure for writers, based on Carl Jung's archetypes, and Joseph Campbell's mythic study, Hero's Journey. The Hero's Journey is composed of 12 stages which can be correlated with the three-act structure (see figure 7).

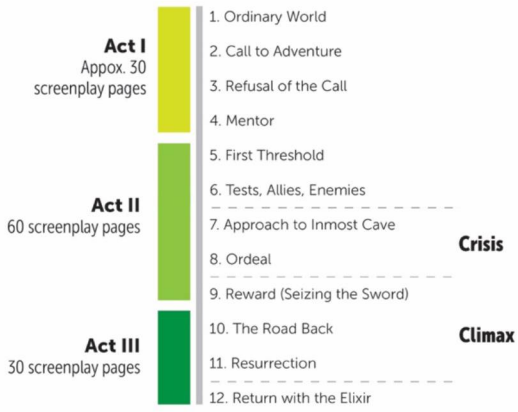


Figure 7: The correlation between the Hero's Journey and the three-act structure.
Fonte: the author based on Vogler (2007 p.8).

Dickey's (2015) orientations about how to create an attractive game narrative are based on three aspects: **Function, Type and Quest.** These orientations are summarized below.

- **Function:** Refers to the role of the narrative in the game. It relates to the fantasy aspect of the game, and can be exogenous or endogenous. According to Rieber (1996), exogenous fantasy (narrative) is external to the gameplay. He uses the expression 'sugarcoating' to stress that this narrative is superficial and not essential to the game. In contrast, endogenous fantasy (narrative) is integrated with the game content, in other words, the narrative fantasy and the activities in

gameplay are closely connected. Both Rieber (1996) and Malone and Lepper (1987) consider endogenous fantasy (narrative) more adequate for educational digital games, as they believe it to be better at motivating learners compared to exogenous fantasy (narrative). However, until now no studies that analyze this distinction have been identified in the literature review;

- **Type:** Refers to how the narrative will be presented to the player in the educational digital game activities, in other words, whether it will be linear or non-linear. According to Adams (2009), in a linear game story, the player cannot change the plot or the end of the story. On the other hand, a game with a non-linear story (e.g. emergent narrative or fold back stories) allows players to contribute to the future events in the story, or to change the direction of the story;
- **Quest (journey):** Refers to the development of a narrative. Dickey (2015) explains that after the narrative type and function have been defined, a plot needs to be created. This will involve creating a setting, characters, and conflicts. At this stage of the game development, the three-act structure can be used, as well as the Hero's Journey (see figure 7).

Additionally, Dickey (2015) proposes a set of heuristics for implementing a linear narrative in educational digital games. These heuristics are summarized in table 16.

Table 16: Heuristics for using a linear narrative in educational digital games. Source: adapted from Dickey (2015).

Setting: refers to where the narrative will take place. It covers the physical, temporal, environmental, and ethical aspects of the place.
Characters and their roles: refers to the identification of the game characters and what they do in the story. It involves the player's character and other characters from the gameplay.
Conflict: refers to the challenges, objectives or initial tasks in the narrative. Defining the conflict is central to the creation of the narrative plot.
Obstacles: refers to the small challenges in the game narrative. Before facing the main challenge in the story, the character needs to overcome small obstacles. In educational games, obstacles can be used to fulfill a specific learning content or to practice specific skills.
Backstory: refers to the identification of the environment of the game, and of the ethical, physical, emotional and temporal dimensions of the game story (which includes the protagonist(s)' profile). The backstory is responsible for introducing the call for adventure/action.
Plot integration: refers to the creation of the game cut scenes (small scenes from the narrative that are revealed through the gameplay), characters and other elements that support the narrative storyline.

Character

According to Dickey (2015), in educational games a well-developed character can promote learner's engagement in the task through an emotional connection. For her, this emotional connection comes from the learner's identification with the game character. Dickey points out that although there is evidence that the character plays a role in promoting learners' motivation in educational games, few studies in the design field focus on this aspect.

Through a literature review, Dickey (2015) observes that in educational digital games, character design typically includes the following: **roles and functions; visual representations; dialogue.** Considering these categories, she proposes a set of heuristics. These are summarized in table 17 below.

Table 17: Character design heuristics for educational digital games.
Source: adapted from Dickey (2015).

Identify the role of the character in the game. The roles of the characters in the gameplay represent what they will do regarding the action and the narrative of the game. Dickey (2015) recommends using the following character archetypes from Vogler (1998): Hero, Mentor, Threshold Guardian, Herald, Shapeshifter, Shadow, Trickster.
Identify the relationship between character, conflict, environment, and other characters in the game.
Create a backstory for each game character. For this to happen it is necessary to identify the goal (motivation) of each character and the obstacles that prevent the character from achieving the goal.
Detail the appearance and movements of the characters. The visual aspects of the characters and the way they move provide players with information about them (e.g. personality, mood, feelings).
Develop a dialog capable of accomplishing the characters' role in the game. How the character communicates/speaks can help learners engage emotionally with the activity and achieve their goals.

H. Cezarotto and Battaiola (2016): Game design recommendations

Cezarotto and Battaiola (2016) propose a set of game design recommendations to promote the motivation of children with dyscalculia in games. These recommendations are based on a literature review, a case study with users, and an expert evaluation. These recommendations are presented in Cezarotto's (2016) master's dissertation in Design. Table 18 lists the recommendations which are relevant for this study.

Table 18: Game design recommendations focusing on motivation in children with dyscalculia.
Source: Adapted from Cezarotto and Battaiola (2016 p. 471-472).

Use characters as a visual stimulus in order to attract the player's attention to the activity.
Use the scenery as part of a ludic game context, acting as a background for the game activities. Through graphical expression, the scenery can create an emotional appeal and attract user's attention.
Use graphical elements based on a narrative, for instance, character, mechanics, activities, rewards.
Use graphical elements to provide immediate feedback and self-perception, so that players can assess their performance during the intervention activities. For instance, scores, badges, leaderboard, missions, achievement, progress, levels.
Offer positive feedback to players according to the number of right actions performed. This will increase their engagement in the activity. Use different types of rewards systematically designed to keep the player in the flow.

To conclude, with regard to the orientations presented in this chapter, it can be said that they tend to complement each other. Moreover, most of these orientations are based on literature reviews and on expert evaluations (Federoff, 2002; Desurvire and Wiberg, 2009; Leite and Mendonça, 2013; Alfadhli and Alsumait, 2015), which indicates that these studies are not user-centered. Malone and Lepper (1987), Chamberlin (2003), and Cezarotto and Battaiola (2016) seem to be the only studies to take the user into consideration when elaborating their orientations. Finally, it should also be mentioned that Dickey's (2015) study is the only one to focus specifically on character and narrative as part of player experience in educational games.

Despite their contributions, many of the orientations are rather general, lacking in detailed information about the users. Therefore, recommendations focusing on the user and on specific, rather than general, contexts should be proposed. The present study, with its focus on the use of educational games as an intervention by children with dyscalculia is an instance of such recommendations.

2.5 Summing up

This chapter focused on players' motivation in educational digital games. In this study, game is understood as a system (SALEN and ZIMMERMAN, 2004). As for educational digital games, these are seen here as games which are developed to promote the learning of a specific content, through a ludic approach. These games have a clear educational goal oriented by a pedagogical proposal (CLUA and BITTENCOURT, 2004), presenting at the same time characteristics of entertainment games (MAYER, 2014; MAYER and JOHNSON, 2011; KAPP, 2011). Educational digital games make use of a digital platform and can be classified as a multimedia learning environment (RIEBER, 1996; TOBIAS et al. 2014). It should be made clear at this point that the definitions adopted in this study should not be seen as the only possible definitions, but rather as alternatives.

In this chapter, the elements which make up educational digital games have been identified and classified as being of two types: entertainment elements and educational elements.

The entertainment elements relate to the players' fun experience and can be divided into two categories, formal elements and dramatic elements, according to Järvinen (2008) and Fullerton, Swain, and Hoffman (2004). The formal elements are technical, and usually represent the functional and elementary structure of the game system. In contrast, the dramatic elements are conceptual, being capable of providing an emotional connection between players and game.

As for the educational elements of the game, these include content definitions, pedagogy approaches, and educational objectives, according to Chamberlin, Trespalacios and Gallagher (2012); Winn (2008); Anderson et al. (2001).

Regarding motivation as part of player experience in educational games, this chapter has presented **the definition of motivation** adopted in this study, and has established from what perspective the concept of motivation will be explored, namely **through children's ludic perspective.** Based on Reeve (2009) and Malone and Lepper (1987), two types of motivation are recognized in this study: **intrinsic and extrinsic motivation.** Moreover, four theoretical studies on motivation were presented and compared: (1) Flow (CSIKSZENTMIHALYI, 1990), (2) Self-efficacy (BANDURA, 1994, 2016), Taxonomy of intrinsic motivation for learning (MALONE and LEPPER, 1987), (4) ARCS model (KELLER,2010).

Finally, nine studies that propose a set of game design orientations (e.g. heuristics, guidelines, recommendations) focusing on learners' motivation in games have been discussed.

The following chapter discusses the basic theoretical fundamentals of developmental dyscalculia. This discussion is key to this study since it focuses on the use of educational digital games in the neuropsychological rehabilitation of children with this learning disability.

3 DEVELOPMENTAL DYSCALCULIA

This chapter also provides the theoretical basis of this dissertation. It focuses on the learning disability known as developmental dyscalculia and is divided into three sections: (1) definition; (2) neuropsychological rehabilitation, and (3) intervention with digital artifacts.

3.1 Definition of developmental dyscalculia

This section will explain what is understood by the learning disability known as developmental dyscalculia. It focuses on dyscalculia in elementary-school children, and will discuss the main characteristics and causes of this disability, its prevalence, and how it affects children's learning.

According to the American Psychological Association (APA, 2002), a learning disorder or learning disability is the inadequate development of specific academic skills such as reading, writing and mathematical skills, which is not related to intellectual impairments, lack of opportunity or inadequate schooling. These disorders can be diagnosed through standardized tests which assess the individual's performance based on what is expected for their age, their level of schooling, and their intelligence level.

Developmental dyscalculia (DD) is a specific learning disability which affects the learning of arithmetic facts (KAUFMANN and VON ASTER, 2012). Children with dyscalculia have a severe and persistent difficulty in learning basic arithmetic facts despite presenting an adequate intellectual capacity for their age and having proper schooling. Also, according to the World Health Organization (WHO, 2007) a person with developmental dyscalculia has a deficit that affects the learning of basic arithmetic skills such as addition, subtraction, multiplication and division. Hence dyscalculia is also known as a Mathematics disorder in the ICD-10[13] and DSM-IV[14].

It is important to clarify that a range of factors can lead to children presenting difficulties in dealing with numbers. These difficulties can have characteristics similar to developmental dyscalculia, but they do not constitute a specific learning disability (BRAVO, 2011). Capovilla (2009) explains that when learning problems occur due to environmental reasons (e.g. poor teaching methods, inadequate instructional approach, family issues), this constitutes a learning difficulty. In contrast, when learning problems are caused by a neurological variable (e.g. dyslexia, dyscalculia), it constitutes a learning disability. In summary, what distinguishes a learning disability, such as developmental dyscalculia, from a learning difficulty is its level of persistence and severity.

For a number of authors, dyscalculia results from a specific impairment of brain function. 3% to 6% of school-aged children in the USA, Europe, and Israel have this learning disorder (SHALEV and GROSS-TSUR, 2001; WILSON and DEHAENE, 2007). In Brazil, a study

[13] **ICD- 10:** International Classification of Diseases. Published by the World Health Organization (WHO, 2007).
[14] **DSM-IV:** Diagnostic and Statistical Manual of Mental Disorders: descriptions, symptoms and standard criteria for the correct diagnosis of mental disorders. Produced by the American Psychiatric Association (APA, 2002).

with 1,600 elementary-school children, from 2nd and 6th grades, and from four different cities, showed that 6.0% of the sample has developmental dyscalculia (Fortes et al. 2016).

According to Argollo (2008) three aspects define development dyscalculia as a specific learning disability:

- The learner has a specific deficit in mathematical skills which does not affect their general cognitive skills;
- There is a discrepancy in the learner's mathematical skills when compared with other learners' in his/her age group;
- The hereditary or congenital cause damages the normal function of the brain areas related to mathematical skills.

3.1.1 Theoretical models of number acquisition

Many authors have presented theoretical models which aim to explain numerical representation and how it is acquired during the math learning process. In this section, two very well-known theoretical models are described, namely the Triple-code model (DEHAENE and COHEN 1995) and the Four-step developmental model of number acquisition (von ASTER and SHALEV, 2007).

In the **triple-code model,** Dehaene and Cohen (1995) maintain that the numerical process and the arithmetic operations are accomplished based on three mental representations: (1) Analog magnitude representation (e.g. "●●●"); (2) Verbal representation (e.g. "three"); (3) Arabic representation (e.g. "3"). This is illustrated in figure 8 below.

According to Dehaene (2001), the analog magnitude representation is related to the concept of number sense. For him, number sense is the innate mental ability to recognize, compare, estimate, sum and subtract quantities without using the counting resource, which occurs in a mental number line. Hence, number sense ability is what allows a person to recognize and manipulate numerical quantities quickly. In contrast, the verbal and arabic representations depend on the cultural context and the learning environment of the learner. Thus, according to Silva and Santos (2009), number sense works as a central number system connected to both the verbal and arabic representations. This means that this connection must be strengthened in order to consolidate the development of advanced arithmetic knowledge. Dehaene (2001) points out that for the proper development and learning of mathematical knowledge to occur, the three numerical representations need to be correlated.

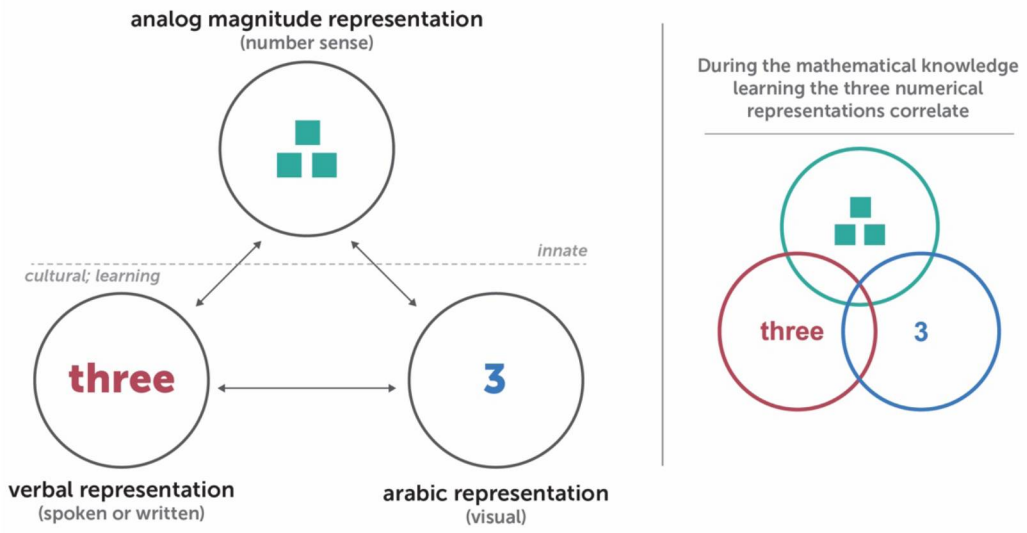


Figure 8: Triple-code model.
Source: Cezarotto and Battaiola (2017b, p. 82) based on Dehaene and Cohen (1995); Kaufmann and von Aster (2012).

The **four-step developmental model of number acquisition** was proposed by von ASTER and SHALEV (2007). According to this model, it is possible to predict neurological dysfunctions related to developmental dyscalculia through four steps. These steps are described below and also shown in figure 9. Notice that in figure 9, the grey area with a dashed line represents how the numerical abilities increase as the work memory of the learner increases over the years.

- **Step 1 (infancy):** it represents the core system of the cardinal numerical representation and the accompanying functions, for instance, approximating and subitizing. It is an automatic process which allows to determine the magnitude of a small set of items.
- **Step 2 (Preschool):** It represents a linguistic process. In this step the learner learns how to associate a number of objects or events with sounds or written words (verbal representations);
- **Step 3 (School):** It also represents a linguist process. In this step, however, the learner learns how to associate a number of objects or events to an Arabic number (visual representation);
- **Step 4 (School):** In this step, the learner develops the mental line and the sense of ordinality, which become his/her second core system of numerical representation. Thus, the learner develops abilities such as approximate calculation and arithmetic thinking.

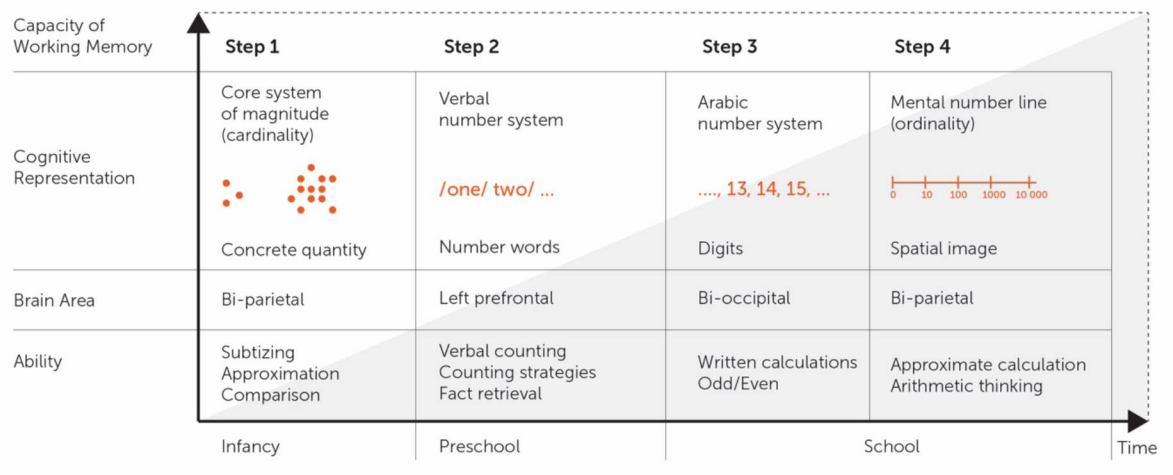


Figure 9: A Four-step developmental model of number acquisition.
Source: adapted from von Aster and Shalev (2007, p.870).

Von Aster and Shalev (2007) explain that step 1 (infancy), in which the child acquires basic number understanding, is a precondition for step 2, when the child learns to associate a number of objects or events with speech, and then with writing (verbal representations). Step 1 is also a precondition for step 3, when the child learns to associate a number of objects or events with arabic number symbols (visual representations). For Dehaene (2001), number sense contributes directly to step 1. Steps 2 and 3, in turn, are preconditions for the development of the learner's mental number line in step 4. Thus, it is possible to infer that if limitations occur during any of these steps, this will negatively affect the learning of mathematical skills.

In conclusion, the triple-code model and the four-step developmental model of number acquisition complement each other. By discussing these models, this section has offered an overview of how a child develops numerical abilities. A number of neuropsychological studies on learning disabilities are available in the literature, but these are beyond the scope of this dissertation.

3.1.2 Learning difficulties presented by children with dyscalculia

Santos, Kikuche and Ribeiro (2009) call attention to the fact that learners with developmental dyscalculia have a persistent impairment in their academic performance in mathematics, and in other daily life activities that require this type of ability. The authors stress that the impairment is more prominent in academic activities.

Argollo (2008), and Ardila and Rosselli (2002), following Strang and Rourke (1985), describe the mathematical errors most regularly made by children with dyscalculia. These errors have been classified into seven categories, as shown in table 19.

Table 19: The mathematical errors most regularly found in children with dyscalculia.
Source: Adapted from Ardila and Rosselli (2002, p. 191); Argollo (2009, p.116).

Categories	Error	Characteristics
Errors in spatial organization of quantities	Spatial	Difficulty in placing numbers in columns, following appropriate directionality of the procedure
Errors in visual attention	Visual	Difficulty in reading arithmetic signs, and in remembering the points of the units of thousand, etc.
Errors in arithmetical procedures	Procedural	Omission or addition of a step in arithmetical procedures, and application of a learned rule for a procedure to a different one. For instance, in the expression 75 + 8 = 163, the multiplication rule is applied rather than the sum rule
Errors in graphic motor when writing quantities	Graphomotor	Difficulty in forming the appropriate number during the writing of quantities
Errors in numerical judgment and reasoning	Judgment	Errors that lead to impossible results. For instance, when the result of a subtraction is bigger than the number being subtracted (e.g. 5 - 4 = 6)
Errors in memory for quantities	Memory	Problems to recall multiplication tables or arithmetical procedures
Errors in the perseveration to solve arithmetical operations and numerical problems	Perseveration	Difficulty in changing from one task to another, repetition of the same number.

In addition to those listed in table 19, another area in which learners with dyscalculia frequently have difficulty with is the learning and retrieving of arithmetic facts, due to memory limitations (GOMIDES, 2016; BUTTERWORTH, VARMA, and LAURILLARD, 2011). This study is concerned with the learning of arithmetical facts, which will be discussed in detail in the next section.

A number of authors, such as von Aster and Shalev (2007); Argollo (2008); Kaufmann and von Aster (2012), point out that children with developmental dyscalculia commonly have other types of learning disability, which is known in the literature as **comorbidity**[15]. For instance, individuals with dyscalculia frequently also have dyslexia or ADHD (attention deficit hyperactivity disorder). Comorbidities should be taken into consideration during the diagnosis, and during the neuropsychological rehabilitation process of the child. This topic, however, falls outside the scope of this study.

3.1.3 Neuropsychological diagnostic evaluation

Professionals who work in the interface of health and education (e.g. doctors, psychologists, psych pedagogues) are responsible for conducting a neuropsychological evaluation so as to diagnose developmental dyscalculia. These professionals evaluate the

[15] **Comorbidity:** the presence or association of one or more additional condition with a primary condition in the same patient. This study is only concerned with conditions which are themselves learning disabilities (HAASE et al. 2012).

mathematical skills of the learner through standardized tests. The tests reveal the learner's score and allow comparison based on the level expected for the learner's age group and intelligence (APA, 2002; HAASE et al. 2011). Conforming to Haase, Wood and Willmes (2010), the evaluation of numerical learning disabilities is guided by theoretical models, such as the triple-code model presented in the previous section (figure 8, triple-code model).

Due to the comorbidities and the heterogeneity of learning disabilities, Haase and Santos (2014) maintain that the cognitive mechanics subjacent to the difficulty evaluated should also be considered. In consonance with that, Argollo (2008) states that during the neuropsychological evaluation all the cognitive domains must be considered. This means that the evaluation will not be restricted to the learner's weak cognitive domains, but it will also consider the learner's preserved cognitive domains, which can be used to enhance the rehabilitation. Haase, Pinheiro-Chagas, and Andrade (2012) recommend an ecological diagnosis. In other words, the neuropsychological evaluation should take into account the impact the learning disability has on all aspects of the learner's life, such as daily activities, well-being, family relationships, leisure activities, and academic performance.

A number of battery tests for the neuropsychological evaluation of children with dyscalculia are available in the literature, for instance, NEPSY II (Developmental NeuroPSYchological Assessment) used by Argollo (2008), and the German ZAREKI-R (Neuropsychological Test Battery for Number Processing and Calculation in Children, revised) used by Silva and Santos (2009). This study will consider the battery of tests used by the DNL-UFMG (Developmental Neuropsychology Laboratory) to diagnoses dyscalculia in children.

The neuropsychological evaluation conducted by the lab team comprises of two-steps, namely **evaluation of general domains and evaluation of math-specific domains**. The first step evaluates the learner's **general cognitive domains** (e.g. intelligence, working memory, executive function, phonology processing, motor skills, somatosensory and visuoconstructive abilities). These are the domains which are relevant and required for the learning of all subjects, for instance, mathematics, literature, history, etc. (CIRINO et al. 2015; COWAN and POWELL, 2014). The DNL-UFMG uses a specific battery test for evaluating the general domains. Antunes et al. (2013) have described this test in a study as part of the lab research. The second step of the evaluation evaluates the math-specific domains. The DNL-UFMG uses their own battery test, which is composed of three tasks: **numerosity, transcoding and arithmetic.**

The neuropsychological evaluation process is a dynamic process. Cowan and Powell (2014) point out that the specific domains vary according to the knowledge field investigated. Moreover, at the DNL-UFMG, different scripts are used in the neuropsychological evaluations, based on the cognitive profile of the child being evaluated.

3.2 Neuropsychological Rehabilitation

Based on the results of the neuropsychological evaluation of the learner, a neuropsychological rehabilitation program is devised. According to Wilson (2008), the aim of the neuropsychological rehabilitation is to help the person to overcome the cognitive, emotional, psychosocial, and behavioral deficits caused by some brain impairment. Thus, the main goal of this treatment is to enable the person to regain the skills required to aptly

perform his/her normal functional, social, and academic activities (HAASE, PINHEIRO-CHAGAS and ANDRADE, 2012). For this to occur, the authors claim that it is necessary to use psychological, cognitive and behavioral techniques. The neuropsychological rehabilitation of children with dyscalculia aims to enhance their functionality and improve their quality of life. The rehabilitation fosters the learning of math-specific domains in which the child has some limitations.

According to Antunes et al. (2013), two main approaches can be used in neuropsychological rehabilitation (or intervention), namely restitution and compensation. The **restitution** approach is grounded in the neuroplasticity concept, and proposes a functional restoration of the cognitive functions of the patient (HAASE, PINHEIRO-CHAGAS, and ANDRADE, 2012). The authors point out, however, that despite its applicability, studies reveal that this approach is not adequate for most of the cognitive functions. In contrast, the **compensation** approach aims to compensate the patient's deficits. In this approach the strategies used are centered on the preserved cognitive functions of the patient, as reported by Wilson (2008). Hence, Wilson affirms that the compensatory approach is the most indicated for the vast majority of neuropsychological treatments.

For the reasons provided above, the compensatory approach is the one used by the DNL-UFMG team to develop research and extension projects with the schools of Belo Horizonte (Minas Gerais State - Brazil). These projects consist of the evaluation, diagnosis, and neuropsychological rehabilitation of children and teenagers with developmental dyscalculia and other learning disabilities. Furthermore, the lab offers behavioral interventions to the parents of those children. These activities are carried out by the lab team in ambulatory *Número*, which is part of the DNL-UFMG.

In **the ambulatory,** the neuropsychological rehabilitation for mathematics learning difficulties is usually conducted individually. A psychologist works with one child at a time, after or before their school activities. In this intervention the lab team uses materials whose efficacy has already been scientifically tested, for instance, specific cognitive exercises developed at the lab (e.g. worksheets), as well as other concrete materials available (e.g. addition domino, *kit material dourado*).

The team also frequently uses digital tools, such as educational digital games. For the rehabilitation of children with dyscalculia, The DNL-UFMG team uses seven hierarchical modules of content, which are applied separately. The modules have orientations regarding the goals and activities of each session of the rehabilitation. These modules follow the hierarchal structure of the numerical and arithmetical abilities: **Number sense; Counting; Transcoding; Addition; Subtraction; Mathematical problems; Multiplication (arithmetic facts).**

The patient (child with dyscalculia) will only do the module (or modules) related to the impairment that they present, and which was measured through a neuropsychological evaluation. Also, after the rehabilitation, further tests are carried out to measure the patient's progress in the ability dealt with during the treatment.

Auerbach et al. (2008) highlight that due to the impairments in their learning mathematical abilities, children with dyscalculia are also at a disadvantage in the social and emotional aspects of their lives. Thus, the lab team considers three main interconnected concepts during the rehabilitation process. These are: Motivation; Errorless learning; Self-efficacy.

According to Gomides et al. (2017), **motivation** is essential for the rehabilitation of any person. This is because **motivation** is responsible for directing the person's behavior

towards the activities. With that in mind, the DNL-UFMG team creates a ludic environment in the intervention sessions for children. Also, they set up the objective of the activity at an optimal level, that is, at an intermediate level based on the child's cognitive profile. By doing so, tasks which are too challenging or not challenging enough are avoided. Thus, the child sees the tasks' objectives as achievable, worthwhile and, at the same time motivating.

Pinheiro et al. (2006), also explain that behavioral techniques are used to foster child motivation during rehabilitation. They mention the "*Economia de Fichas* (Cards economy)", where the child is given a little card as an immediate reinforcement after a desirable behavior. The child collects these cards during the sessions, and afterwards he/she can swap them for more valuable reinforcements (e.g. rewards - gifts). The authors state that this technique is an initial and temporary extrinsic motivation, in that it helps the child to develop an intrinsic motivation for the activity.

The second concept, **errorless learning,** also relates to child motivation**.** According to Middleton and Schwartz (2012), this approach has been increasingly used during cognitive interventions. When the errorless learning concept is used in rehabilitation, the activities are planned in a way so as to prevent patients from making mistakes during the treatment, especially while learning a new ability. Thus, by using this approach in the rehabilitation of children with dyscalculia, the math tasks can be adapted according to the patient's cognitive profile. This will result in a reduction in patient's errors rate, offering more successful experiences, and consequently, an increase in the self-efficacy of the child for the activity. Melo, Hanna and Carmo (2014) state that assimilating the incorrect content requires a great deal of work from the child. This is because forgetting the mistake and relearning the correct way is a complex process, especially for children with a learning disability such as developmental dyscalculia.

The third construct, **self-efficacy,** refers to the individual's belief in their ability (i.e. knowledge and skills) to do an activity (BANDURA, 1994). Self-efficacy is very important for learner motivation. Therefore, during the rehabilitation, the DNL-UFMG team uses visual representations to show the child his/her performance in the activity. This allows the patient to see how they are progressing and how they can improve further. Moreover, the experience of success provided by the errorless learning approach increases the patient's motivation and their engagement in the tasks (ANTUNES et al. 2013).

This section looked at neuropsychological rehabilitation for children with developmental dyscalculia. Special attention was given to the work done by the DNL-UFMG team. The following section looks at **the multiplication module. This module is particularly relevant for this study, since this research aims to investigate** the motivation of children with dyscalculia when playing educational digital games during **the intervention for the multiplication module** (arithmetic facts).

3.2.1 Multiplication (arithmetic facts)

This study is particularly concerned with the **multiplication module (arithmetic facts).** This is because one of the most frequent difficulties faced by children with dyscalculia is the learning and the retrieving of arithmetic facts (GOMIDES, 2016; BUTTERWORTH, VARMA, and LAURILLARD, 2011). Moreover, according to the team of researchers at the DNL-UFGM, a large number of children with dyscalculia present an impairment in the acquisition of arithmetic facts.

According to Domahs and Delazer (2005) many daily activities involve solving simple arithmetic problems such as 6+3, 4x5 or 9-3. The authors explain that solving such problems does not require computational processes or strategies, because the answer can be retrieved directly from long-term memory. The authors refer to this type of problem as arithmetic facts. Similarly, Gomides (2016) define arithmetic facts as simple calculus, which is solved and stored in long-term memory without the use of procedural strategies. For her, arithmetic facts are essential for learning advanced mathematical abilities.

Based on the above understanding of arithmetic facts, the multiplication module administered by the DNL-UFMG team focuses on the practicing of the arithmetic facts of tables 1 to 10. These multiplication tables are practiced during the rehabilitation sessions[16]. The number of rehabilitation sessions varies. However, each child takes a pre and post-test to measure the progress of the treatment. The module's objectives are to provide the following: (1) conceptual comprehension of multiplication; (2) the use of stimulus semi-concerts, and association with the addition module; (3) comprehension of the multiplication principles, such as proportionality and Pythagoras table.

The lab researchers believe that learners with dyscalculia are at an advantage when the teaching of multiplication facts follow a different instructional strategy. In other words, these children are more likely to do well when a non-conventional approach is used, that is, one that does not follow an ascending order – tables 0 to 10 (ANTUNES et al. 2013, GOMIDES, 2016). Table 20 summarizes how the different instructional strategies for teaching and practicing arithmetic facts (0-10) are carried out, which tend to be according to the level of difficulty of each fact.

Table 20: An instructional strategy to teach and practice multiplication arithmetic facts.
Source: based on Antunes et al. (2013).

Facts table (multiplication)	Teaching strategy
0, 1 and 10	Based on the rules
2	Based on the "double" strategy
5	Based on the "five effect" strategy
9	Using fingers as a representation – somatosensory strategy
3, 4, 5, 6, 7 and 8	In that order

Through the above instructional strategy, the lab team provides the learners with an understanding of the three main types of arithmetic knowledge: conceptual knowledge, procedural knowledge and arithmetic facts knowledge (Domahs and Delazer, 2005).

Conceptual knowledge supports the understanding of arithmetic operations and principles. According to Domahs and Delazer (2005), this knowledge stands as a pre-requirement for making inferences and making connections between different arithmetic information. In other words, it is related to "why to do". **Procedural knowledge** guides the execution of algorithms, and as such it is related to "how to do". **Arithmetic facts knowledge** represents the knowledge stored in and retrieved directly from long-term memory. This type of knowledge develops from the two previous types of knowledge. Therefore, the multiplication module aims to provide learners with an overall comprehension of the principles and strategies for the execution of algorithms and arithmetic operations.

[16] This information was collected from the multiplication module, which was made available by the lab team, for this dissertation.

This section presented a brief description of how the multiplication module is used by the DNL- UFMG, in the rehabilitation of children with dyscalculia. The main purpose was to provide an understanding of how the module is applied and to draw attention to its importance. It is necessary to become familiar with this module before considering using games or other digital artifacts as part of the intervention. The following section reviews some interventions for dyscalculia which make use of digital artifacts.

3.3 Intervention with digital artifacts

This section looks at what digital artifacts are used during interventions for learning disabilities, such as mathematical learning difficulties and developmental dyscalculia.

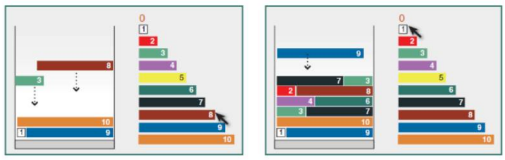
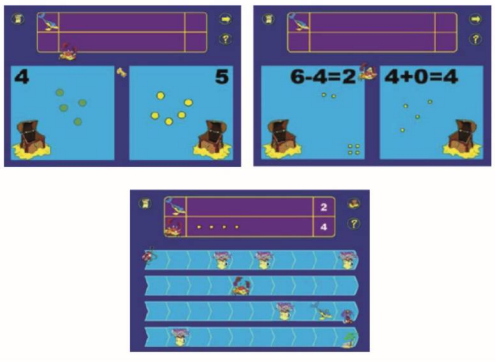
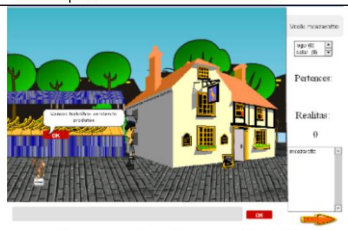
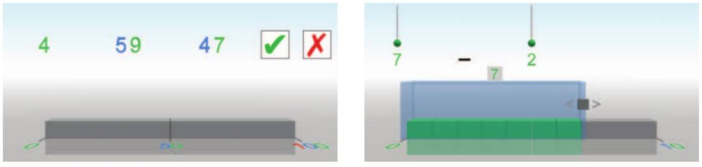
Research conducted by Swanson and Sachse-Lee (2000); Kroesbergen and Van Luit (2003); Wilson et al. (2006); Fuchs et al. (2008); Käser et al. (2013) confirm the efficacy of digital interventions for mathematical learning difficulties and disabilities. The first benefit is individualization. The authors stress the importance of considering the learner's cognitive profile during the rehabilitation. Second, the use of hierarchical training, which should be mediated by a qualified professional. A further benefit is increased motivation. The motivational aspect of learners needs to be considered during the interventions, and this type of learner usually lacks motivation for math activities due to their disability or difficulty.

Kadosh et al. (2013) point out that digital interventions, such as educational digital games, have been receiving much attention by researchers in the neuropsychological field. As reported by Moeller et al. (2012), these games are a promising alternative as they can offer learners a ludic environment during the intervention training. Wilson et al. (2006) list a number of cognitive advantages that learners can attain when using these artifacts in rehabilitation. They are:

- Digital interventions allow keeping the activities in the learner's "Zone of Proximal Development" – ZPD (VYGOTSKY, 1998). According to Vygotsky, ZPD represents the difference between the real level of development of the child (ability to solve problems independently) and their potential development level (their need for help to solve some problems).
- Digital interventions can reduce the learner's errors rate as the system can set up an adequate level of difficulty (based on the learner's cognitive profile). This balance between learner's abilities and level of challenges promotes the required stimulation for progress. This is in agreement with the errorless learning approach, commonly used in rehabilitation, as mentioned previously.
- The use of a computer or other digital media draws on the attraction that most children, teenagers and also adults have for digital entertainment games. This inclination towards digital language makes learners more interested in the intensive training, which could be considered tedious if other artifacts were used.

Through a literature review, it has been possible to identify the digital games that researches have been using as interventions for mathematical abilities, either for learning difficulties or disabilities. Notice that this literature review starts with Cezarotto's (2016), which also described this type of games, see table 21.

Table 21: Games used as interventions for math learning disabilities or difficulties.
Source: based on Cezarotto (2016).

Game	Figure
Number bonds (Butterworth, Varma and Laurillard, 2011)	 Source: Butterworth, Varma, and Laurillard (2011 p.1052)
The Number Race (Wilson et al. 2006)	 Source: Wilson et al. (2006, p.4)
The Number Catcher (Researchers from INSERM-CEA Cognitive Neuroimaging Unit[17])	 Source: <http://www.thenumbercatcher.com>
O Resgate de Tom (De Castro, 2011)	 Source: De Castro (2011)
Rescue Calcularis (Käser et al. 2013)	 Source: Käser et al. (2013)

Despite the relevant contributions made by these authors (table 21), their research does not give sufficient attention to game design concepts. This lack of awareness reduces the game possibilities, as it ignores or pays little attention to player experience (considered a secondary element) (CEZAROTTO and BATTAIOLA, 2016).

In addition to the games in table 21, the game *Meister Cody* and the project *Math Snacks* were also identified in the literature review. The game Meister Cody[18] is an online app for mobile devices, and is composed of several games that together constitute an intervention for dyscalculia. The app activities provide the rehabiliatator with helpful

[17] An international institute that researches mathematical cognition.
[18] Meister Cody, available to purchase online in <https://www.meistercody.com/en/talasia>

information for the diagnoses, as well as for the training of math skills impairment. The app and its games follow an adventure theme guided by wisdom and a magical mentor. This Project is part of the research conducted by Professor Dr. Jörg-Tobias Kuhn from Dortmund University, in Germany. Figure 10 shows some screenshots from the Meister Cody app.

Figure 10: Screenshots from some of the games in the Meister Cody app.
Source: meistercody.com.

The Math Snacks project[19] is composed of animations, games, and apps designed to help elementary school children understand math concepts. The project is part of the research conducted by the Learning Games Lab team, from the media productions at New Mexico State University. This project is not intended for children with dyscalculia, and therefore it is not directly related to this study. However, the project can be said to be relevant to the current investigation for two reasons. First, the high quality of the project. Experimental research has showed that children using the games and animations from Math Snacks showed significant improvements in their understanding of mathematics concepts. Second, the Learning Games Lab is well-known in the literature for the high quality of their products, as well as for their creative design process. The lab team has developed as well as applied a collaborative, interdisciplinary, and user-centered design model, as described in Chamberlin, Trespalacios, Gallagher (2012). Moreover, as part of this investigation, the researcher has spent six months at the Learning Games Lab, as an affiliate scholar, during which time he has learned about their user testing techniques and the learning games design model. Also, this study uses the games developed by the lab during the user's data collection. Figure 11 shows two educational games from the Math Snacks project: (A) Gate – works with numbers and place value; (b) Monster School bus – works with base 10.

[19] Math Snacks, available online at <http://mathsnacks.com/>

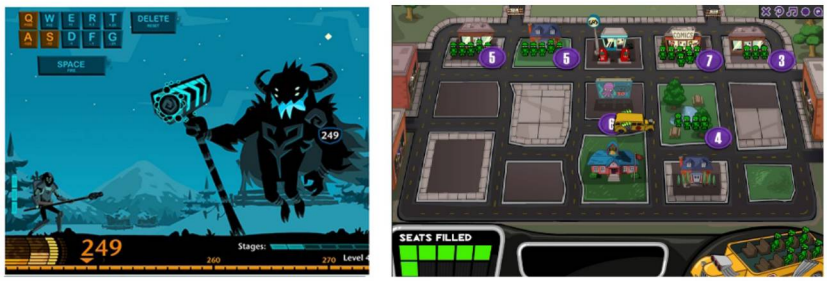


Figure 11: Two games from Math Snacks - (A) Gate; (B) Monster school bus.
Source: mathsnacks.com.

3.4 Summing up

This chapter discussed the main characteristics of developmental dyscalculia and the impact this learning disability has on the learning of mathematical skills by elementary school children. The following three topics were considered:

- Developmental dyscalculia as a learning disability;
- Neuropsychological rehabilitation based on DNL-UFMG practices;
- Interventions based on digital artifacts.

In the first section of the chapter it was claimed that **developmental dyscalculia** is a specific learning disability which severely affects the learning of basic arithmetic abilities, in learners with a standard intellectual capacity and adequate schooling. This section also discussed the possible causes of this disability and its prevalence. In addition, two theoretical models which can help understand the impairments caused by dyscalculia during the development of numerical abilities were described in this section. Although **developmental dyscalculia** affects the normal acquisition of several mathematical abilities, in accordance with Gomides (2016); Butterworth, Varma, and Laurillard (2011), it was argued that the learning and retrieving of arithmetical facts is the most common impairment in learners with dyscalculia.

The second section of this chapter looked at the **neuropsychological rehabilitation** of children with dyscalculia. It described the diagnoses and the intervention/rehabilitation processes. Most of the information in this section was provided by the ambulatory *Número* (DNL-UFMG) team. It was shown that their rehabilitation process follows seven modules of content, which in turn follow the hierarchical structure of math. Moreover, the team lab uses three concepts during the rehabilitation, namely Motivation, Errorless learning and Self-efficacy. Moreover, this section discussed the multiplication module (arithmetic fact) developed and applied by researchers at the DNL-UFMG lab. It was shown that this module recognizes three types of arithmetic knowledge: concepts, procedures, and facts.

The last section, based on a literature review, looked at studies on digital artifacts, primarily games, used as a tool during mathematical learning disability interventions. It was argued that these games consider user motivation as secondary, and are primarily interested in the effectivity of the intervention. However, it has been shown that learner motivation is also an important factor for the efficacy of the intervention.

4 METHODOLOGY

This chapter describes this dissertation methodology, and is divided into 5 parts: (1) research classification, (2) research phases, (3) methods, (4) data collection techniques, and (5) data analysis strategy.

4.1 Research classification

This study is **applied research**, and as such it aims to determine whether its findings have a practical application with regard to the problem investigated (PADRONAV and FREITAS, 2013). In other words, in detailing game design recommendations, this dissertation offers development teams guidelines to be followed during the creation of educational digital games for children with dyscalculia.

This dissertation uses a **qualitative approach** to data analysis. This method of data analysis is the most appropriate to understand the existing dynamics between the subject, the context, and their meaning, which cannot be translated or measured in numbers (SILVA and MENEZES, 2005).

This dissertation is also a descriptive study (GIL, 2002) as it describes and details the necessary elements to promote and sustain the motivation of children with developmental dyscalculia in games. Also, a vast number of exploratory research concerning educational digital games are available in the literature and some are discussed here.

This dissertation also adopts an **interdisciplinary design approach.** According to Svensson (2003), this approach aims to connect ideas, artifacts, and experiences from different research fields. For the author, researchers in the educational digital game field are naturally multidisciplinary, as this field uses knowledge from many academic fields, and industries. However, Svensson explains that, due to technological advances and digital society demands, the need for interdisciplinary teams, with multiple competences and knowledge, is increasing. Thus, this dissertation uses an interdisciplinary approach so as to bring together knowledge from both the game design field and the neuropsychology field.

Within the design field research, this dissertation research is **for design**, as it investigates a specific practical design problem (FRANKEL and RACINE, 2010), namely the motivation of children with dyscalculia in educational digital games.

Finally, the methods used in this research are: **systematic literature review, field research, and experimental game design.** These will be discussed in 4.2 below. Table 22 offers a summary of how this research can be classified.

Table 22: Research classification
Source: the author based on the mentioned references

RESEARCH	DATA APPROACH	GOAL	DESIGN APPROACH	DESIGN RESEARCH	PROCEDURES	
Basic	**Qualitative**	Exploratory	Multidisciplinary	*Into Design* Basic (theoretical)	**Literature Review**	**Experimental Game Design**
Applied	Quantitative	**Descriptive**	**Interdisciplinary**	*Through Design* Applied (practical - general)	**Field Research**	
		Explanatory	Transdisciplinary	***For Design*** **Clinical (practical - specific)**		
Prodanov and Freitas (2013)	Silva and Menezes (2005)	Gil (2002)	Svensson (2003)	Frankel and Racine (2010)	Prodanov and Freitas (2013)	Waern and Back (2015)

4.2 Phases and steps

This section describes the phases and steps of this dissertation methodology. Five interconnected phases comprise the research methodology. These phases follow a linear path and help to understand the dissertation process. Each phase will be described below, including: (1) which dissertation goal it addresses; (2) the technical procedure for data collection; (3) criteria for the selection of participants; (4) data analysis strategy. A graphic representation of the research methodology is presented in section 1.9 (figure 3, p. 24).

4.2.1 Phase 1 | Literature review

The first phase comprised a systematic literature review on the development of educational games (PRODANOV and FREITAS, 2013). The literature review was not restricted to educational games, but also considered studies on digital games in general. This provided a broader overview of the studies on digital games. In addition, this literature review helped in the elaboration of the theoretical base of this dissertation

Phase 1 aimed to fulfill specific goal 1 of this dissertation: To identify recommendations, guidelines, and principles for the design of educational games which apply to the neuropsychological rehabilitation of children with dyscalculia.

As a result, this phase delineated what is considered to be state-of-the art in the design of educational digital games and provided relevant information regarding the use of these games in the rehabilitation of children with dyscalculia. A summary of the latest in educational digital games is presented in section 1.7 (State of the art and Originality, p. 18).

Technical procedure for data collection

A literature review is a scientific method inherent to any academic research, since through considering previous research, the researcher can build a useful basis for the advancement of knowledge. A literature review allows researchers to identify gaps and opportunities for further research (WEBSTER and WATSON, 2002). Also, a literature review is preponderant for advanced research, for instance, a doctoral dissertation, whose contribution should be original. Therefore, in a literature review systematization and traceability are key (COMFORTO, AMARAL, and SILVA, 2011).

The literature review of this dissertation is organized into two categories: **(1) Journal and conference papers; (2) Theses and dissertations.** Other relevant materials such as

suggestions by academics, new materials from references from papers, are also alluded to in the review.

For the systematic literature review, two protocols (one for each material category) were created. These protocols refer to the procedures, the required steps, and the process of revision. According to Yin (2001), the use of protocol is an effective strategy to increase reliability in a case study. The use of protocol also helps with the planning and execution of a literature review, allowing other researchers to fully understand the review and to replicate it based on the protocol used.

The first protocol relates to the systematic literature review of **journals and conference papers,** whereas the second protocol relates to **theses and dissertations.** Both protocols are grounded in the orientations of Conforto, Amaral, and Silva (2011); Kitchenham et al. (2009).

The systematic literature review of this study was conducted between 2016 and 2017 (see figure 12). It used two search cycles for each protocol, and different strings of search. The first strings came from a narrative literature review and were updated after the first research cycle. As a result, the systematic literature review presents what is considered to be state-of-the-art in the design of educational digital games, taking into account the scope of this dissertation, temporal delimitations, and the database consulted. The protocols and its respective final reports are presented in the appendix of this document, see page 240.

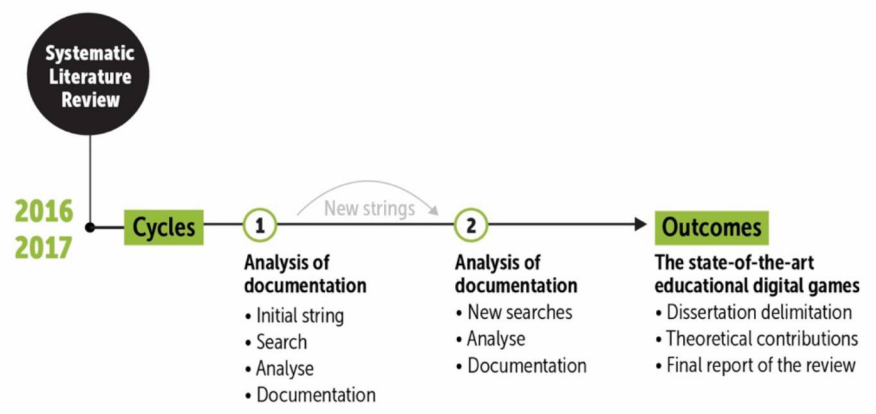


Figure 12: Systematic literature review used in this dissertation.
Source: the author.

4.2.2 Phase 2 | Field research

Phase 2 is the field research. Marconi and Lakatos (2011) explain that the purpose of a field research is to collect information relevant to a specific problem or phenomenon. Also, Prodanov and Freitas (2013) highlight that this method of research can be used both in qualitative studies and in quantitative studies.

This study has used field research to gather information from game developers about the motivational elements in educational digital games. Field research has also been used to gather information from specialists in neuropsychology rehabilitation regarding the use

of these games with children with dyscalculia. Both groups of informants are stakeholders in this research.

The field research phase aimed to fulfill two of this dissertation's goals, and has accordingly, been divided into two stages, one for each goal: **(A) stage with specialists in rehabilitation; (B) stage with game developers.** In both stages, a questionnaire was used for data collection. Each questionnaire was designed according to its stakeholder and goal. Each questionnaire is described below.

Technical procedure for data collection

In both stages of the field research a questionnaire was used for data collection. Marconi and Lakatos (2010) define a questionnaire as a data collection instrument, consisting of a series of questions for the purpose of gathering information from respondents. However, Gil (2008) states that it is possible to use a questionnaire orally, similarly to a script of an interview. He calls this type of questionnaire 'applied questionnaire'.

A. Stage with specialists in rehabilitation

This stage aims to fulfill the second specific goal of this dissertation: To investigate, from the perspective of specialists in rehabilitation, what the requirements to develop educational digital games for children with dyscalculia in neuropsychological rehabilitation are.

This investigation is particularly relevant because this dissertation focuses on the use of educational digital games in a specific context (rehabilitation of children with dyscalculia). According to Haase, Pinheiro-Chagas, and Andrade (2012), the purpose of this rehabilitation is to promote learning through cognitive and behavioral techniques. Moreover, this rehabilitation is mediated by a professional who works in the interface of health and education. Hence, it is essential to investigate with these mediators, what characteristics educational games need to have in order to be effectively used in that context.

The use of a questionnaire in this phase proved to be an easy and efficient way of gathering data from the mediators. It also proved to be a more flexible tool in terms of time. The questionnaire was selected, based on its facility to gather the data with mediators. Also, because this technique gives the participants time flexibility, which is not possible in an interview, for example.

Questionnaire construction and implementation strategy

The questionnaire to be used with the mediators was designed using the online platform google forms. The questionnaire consisted of 12 questions. Gil (2008) supports the use of short questionnaires as these contain strictly the necessary questions. Thus a short questionnaire is used in this phase so as to keep the data gathering process simple, and the participants focused.

The questionnaire used primarily open-ended questions. According to Gil (2008), this type of question gives participants the freedom to provide their own responses. Also, since

this study is of a qualitative and exploratory nature, open-ended questions were more suitable. Moreover, little is available in the literature on the subject matter of this dissertation and the use of closed-end questions could limit the scope of the data.

Information from the theoretical base of this dissertation was used in the design of the questionnaire. The questions were organized in three categories, namely: Questions about the mediators' profile; Questions about children rehabilitation and educational games in general; Questions focusing on games and rehabilitation of children with dyscalculia.

A text containing information about the research and a consent form were also designed. The consent form informs potential participants that they are not obligated to take part in the research, and that when the results are published their names will be omitted.

Before making the questionnaire available to participants, an experienced member of the DNL (UFMG), a neuropsychology doctorate student, performs a final check of the questionnaire (e.g. vocabulary, understandability, size). After some adjustments the questionnaire was finally made available on google forms. The questionnaire, the informative text, and the consent form are available in the appendix of this dissertation (see p. 240.)

Criteria for selecting participants

The questionnaire was to be used with specialists in rehabilitation and was qualitative in its approach. The purpose of the questionnaire was not to generalize data, but rather to gather in-depth information on the perceptions and demands of the speciliasts, when using games with children with dyscalculia. In order to attract potential participants, the team of DNL (UFMG) made the questionnaires available in the lab, and to their academic network. Participants were then selected according to the inclusion and exclusion criteria below. 12 specialists in rehabilitation fulfilled the criteria and were invited to complete the questionnaire.

Inclusion criteria:

- Be a professional mediator working in the interface between education and health (e.g. psychologists, psycho-pedagogues);
- Have conducted at least one neuropsychological rehabilitation in children with learning disabilities;
- Both undergraduate and graduate students (e.g. psychology) qualify as mediators, provided that they have conducted or assisted in rehabilitation of children with learning disabilities.

Exclusion criteria:

- Professional mediators with no experience in neuropsychological rehabilitation of children.

Data analysis strategy

The analysis of the data collected through field research, both from specialists in rehabilitation and from game developers, is based on Miles and Huberman (1994); Gil (2002); Cote and Raz (2015). This process of analysis has four steps. In the first step, **Data Organization,** the collected data is organized into excel sheets. In the second step, Data Reduction, visual representations are created using a small percentage of the data collected from game developers. Also, in this step, the organized data from the specialists' in rehabilitation are highlighted (e.g. sentences, keywords) and patterns and relevant information are identified. In the third step, **Qualitative Discussion,** participants' responses as well as the trends in the full sample responses are interpreted qualitatively. This provides the main ideas gathered from the questions. These ideas are cross-examined and contrasted with information gathered through the literature review. In the fourth and final step, **Drawing conclusions,** the information gathered is correlated with the specific goal that the questionnaire aims to satisfy. Figure 13 below offers a summary of this analysis process.

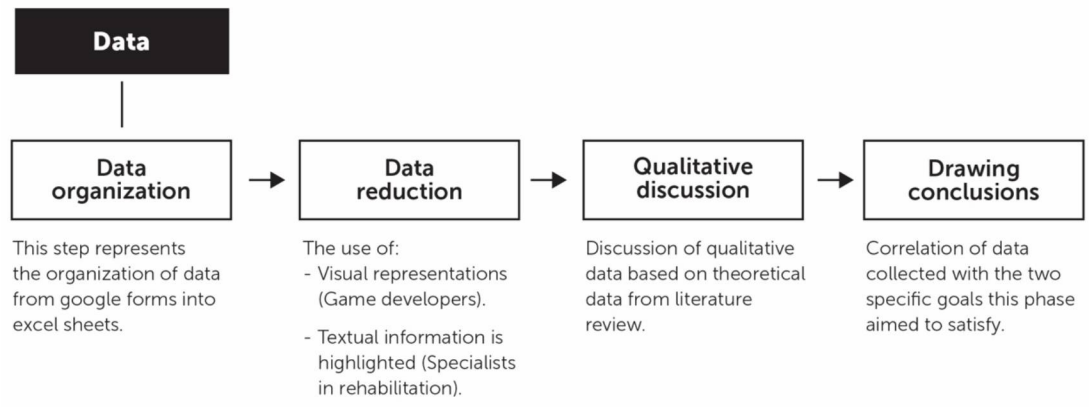


Figure 13: Steps from the analysis process used in this dissertation.
Source: the author based on Gil (2002); Miles and Huberman (1994); Cote and Raz (2015).

B. Stage with game developers

The second stage of the field research aims to satisfy the third specific goal of this dissertation: To investigate what motivational game elements are used by game developers to promote player motivation, and how these elements are set up during an educational game project. Also, to contrast this information with data from the literature.

This stage is particularly relevant as it takes into account the perspective of one of the stakeholders of this research, namely game developers with experience in educational digital games. To reach this target participant, the data was collected during the SBGames 2017[20], since many game developers attend this symposium. The data was gathered through a questionnaire, which is described below.

Questionnaire design and application

[20] SBGames (Brazilian Symposium on Computer Games and Digital Entertainment) is the largest academic event in games and digital entertainment in Latin America. The Brazilian Computer Society has been organizing the event since 2004. The 2017 edition was held in Curitiba (at PUC). Available at: <http://www.sbgames.org/sbgames2017/> (Accessed on March 1, 2018).

The questionnaire used with developers was administered in person, in digital format (google forms) on a tablet. The questionnaire was short and contained mostly closed-ended questions, to allow respondents to complete it quickly. This type of questions requires respondents to select an answer from a predefined list of alternatives (GIL, 2008).

Before creating the questions and predefining the alternatives, an exploratory questionnaire was administered with educational game developers early in 2017, prior to the SBGames. This questionnaire focusses on the game design elements of educational games and how these elements are set up. The exploratory questionnaire also used google forms, however, this time the questions were open-ended. This questionnaire was administered during a forum of the IGDA Curitiba[21], and five respondents completed the questionnaire. The information gathered through this exploratory questionnaire was taken into account when creating the closed-ended questions for the actual research questionnaire. In addition, theoretical information from the literature review regarding game elements and user motivation was also considered when designing the questionnaire (e.g. JÄRVINEN, 2008; ALVES and BATTAIOLA, 2011; CEZAROTTO and BATTAIOLA, 2015). Prior to completing the exploratory questionnaire, participants were asked to sign a consent form (see appendix p. 240).

Criteria for selecting participants

Before presenting the criteria for selecting participants, it is important to briefly discuss the composition of the team involved in the development of educational digital games.

According to Svensson (2003), the development team of a digital game is interdisciplinary. The roles of the different members of the team usually vary according to the scope of the project and its variables, as well as the company size. However, Chandler (2012) highlights five professional categories which constitute the educational game development team, namely: administrative, production, engineering, design, and testing. In the educational digital game context, other professionals may also be required, for instance, content experts, instructional designers, etc. (CHAMBERLIN, TRESPALACIOS and GALLAGHE, 2012). Mattar (2010) points out that most educational game companies have a small number of professionals, resulting in one professional being responsible for several areas of the game development.

Therefore, this study's research field considers a variety of professionals provided that they have experience in developing educational digital games. These are professionals who have experience with conceptual game decisions, game project management, game technical decisions, or with learning aspects of the game. Thus, the designed questionnaire considers professionals such as programmers, game designers, education experts, and project managers. This avoids restricting the data, which would be limited if only one type of professional was considered.

Thus, in order to fulfil the **inclusion criteria** the professional needs to have participated in at least one development project of an educational digital game. Developers with no previous experience in education digital games development were not considered.

[21] The International Game Developers Association (IGDA) is a non-profit professional association and a global network of collaborative projects by professionals involved in the game development process (e.g., programmers, artists, game designers) (IGDA, 2016). The IGDA in Curitiba, Brazil (IGDA-CWB) aims to bring together local communities, the game industry, the academy, and society in general (IGDA-CWB, 2016).

Questionnaire implementation strategy

The application strategy for the questionnaire to be used with game developers can be summarized in three stages: **invitation; consent form presentation; participation.**

Firstly, potential participants were invited to take part in the research. At this initial stage, they were provided with an overview of the study and the researcher checked whether they met the criteria for inclusion. Further research details (e.g. estimate duration, goal) were then provided. Once they had agreed to take part in the study, he/she would receive a tablet (Samsung model – android system) in order to complete the questionnaire. Before answering the questions, participants were asked to read and sign the consent form. The researcher was available to answer any questions they had regarding the study. Participants were then given some privacy to complete the questionnaire. Again the researcher was available to answer any questions. 37 individuals took part in this phase of the study. Some participants recommended other members of their teams for the study. The researcher would then take note of their e-mails so as to later send them the link to the questionnaire. This resulted in another 4 individuals taking part in the study, bringing the total number of participants to 41.

4.2.3 Phase 3 | Proposal

The proposal phase aims to fulfil the fourth specific goal of this dissertation: to propose a set of game design recommendations for educational games capable of fostering and sustaining motivation in dyscalculic children during neuropsychological rehabilitation.

It is in this phase that the data collected so far, both through literature review and field research, is analyzed for the first time. The aim is, through data triangulation, to propose a set of game design recommendations and then select those recommendations related to user's motivation for a more detailed examination within a user-centered approach.

Triangulation as a data analysis strategy

Triangulation has been chosen as the data analysis strategy for this phase because, at this point in the research process, sets of data from different sources (literature review + field research with specialists in rehabilitation + game developers) have been collected. According to Yin (2001), triangulation is an appropriate method of data analysis, when the researcher needs to analyze data from different sources. Moreover, Azevedo et al. (2013) state that triangulation allows the researcher to examine and understand the phenomenon or artifact being investigated from multiple perspectives.

Based on Minayo (2005), the proposal phase has three steps: data organization; data categorization; proposing process (triangulation) (see table 23).

Table 23: Data analysis strategy.
Source: the author of this dissertation based on Minayo (2005).

Step	Description	Result
1. Data Organization	Each set of data is individually organized.	**Chapter 2:** Theoretical data from game design literature **Chapter 5:** Data from field research with game developers and specialists in rehabilitation.
2. Data Categorization	Categories are identified, based on theoretical information. The focus is on the relation between the dramatic game elements and the learners' motivation categories.	**Dramatic elements** Challenge; Character; Play; Premise Story; World Building; The Dramatic Arc; Rewards.
3. Proposing process	Triangulation of the data collected so far, in order to propose the game design recommendations.	**Chapter 6:** Game design recommendations focusing on players' motivation.

To start the triangulation process, **the already organized** data from the previous phases of this study was selected. With all the data selected and organized, **the information was then categorized.** Finally, with the data categorized, the last step was to analyze it. To do that, a question guide was used (see table 24). The data from different sources are used so as to achieve a better understanding of the topic, and the recommendations were proposed in a single report, what Minayo (2005) calls data exchange.

Table 24: Question to guide the data triangulation.
Source: the author.

Question	Source of information	Answer (initial)
How to promote and sustain the motivation of children with dyscalculia in games?	From the literature review	Game design recommendations to be verified and detail with the users (children with DD)
	From the Specialists in rehabilitation	
	From the Game developers	

Recommendations selection

The dramatic game elements (FULLERTON, SWAIN, and HOFFMAN, 2004) were used as a category for the game design recommendations proposal. However, this study focuses on only three dramatic game elements: **Character; World building; Rewards.** These elements have been chosen due to the contribution that a better understanding of these elements will make to the design field. Moreover, due to the scope and limitations (e.g. time, materials) of this study, only a few elements could be considered.

This dissertation is primarily concerned with the conceptual aspects of the educational game elements, rather than the technical elements (e.g. interface, controls). Other dramatic elements, such as *Challenge* and *Play,* are not investigated here, and can be the topic for further investigations. It is also important to clarify that some dramatic game

elements were grouped together based on their similarities and shared properties. For instance, the element World Building will encompass the elements of Story, Premise, and Dramatic Arc. These game elements have been investigated here as ways to provide and sustain player motivation during the play. Additionally, these elements correlate with most of the players' motivation categories discussed in the theoretical phase of this document, such as: (1) Optimal level of challenge; (2) Clear goal; (3) Performance feedback; (4) Emotional aspects; (5) Cognitive Aspects; (6) Sensory curiosity; (7) Level of control; (8) State of immersion (satisfaction); (9) Self-efficacy (confidence and self-esteem); (10) Activity's relevance. Also, these categories are described in-depth in the study of Cezarotto and Alves (2019).

4.2.4 Phase 4 | User verification

This phase aims to fulfil the fifth specific goal of this dissertation: To verify, with children with dyscalculia, the game design recommendations made by this research, and explore how these recommendations contribute to increasing the motivational element in educational digital games. This user verification was approved by the Federal University of Paraná ethics committee.

Experimental game design (WAERN and BACK, 2015) is the research method used in this dissertation to carry out user verification. According to Waern and Back (2015), experimental game design is a scientific method of inquiry which involves the target players and considers how they see the game design. This method makes use of a game or a prototype to investigate with players some abstract qualities of their play experience and preferences, in order to develop innovative ideas. The method investigates with players how design choices affect player experience, what the authors refer to as an evocative experiment.

The experimental game design method is a relatively new method and little has been said about it in the literature. With that in mind, table 25, based on Waern and Back (2015), offers a comparison of this method with two other methods, namely playtest and classical experiment.

Table 25: comparison between playtesting, experimental game design, and classical experiment. Source: the author based on Waern e Back (2015).

Playtest	Experimental game design	Classical experiment
Usually used by the development team during the iterative game design process. The goal is to refine and enhance a specific game.	It aims to understand a more fundamental aspect of game design, rather than enhancing one type of game in particular. This method does not require a control variable.	In the game context, it investigates the characteristics of the game. The research sets up a game, that the player plays with or without a specific feature. This method requires all the control variables.
It does not necessarily involve the target game player. It can be restricted to the game development team.	It invariably involves the targeted players (qualitative approach).	It requires a representative sampling of the target player to allow generalization (quantitative approach).
Scientific rigor is not required.	Requires scientific rigor	Requires scientific rigor

Notice that in table 25 experimental game design was placed in the middle. This is because, on the one hand, experimental game design is a more elaborated method compared to playtest, based on scientific rigor and contributions from the game field. On the other hand, in the experimental game design the player sample is small, and not all the variables are controlled. These characteristics are present in classic experiments, which allows generalizations, according to Gil's (2002) definition of experimental research.

According to Waern and Back (2015), experimental game design is a more flexible experiment to explore and develop an innovative game solution. The authors stress, however, that this flexibility should not be interpreted as lack of scientific rigor. It simply means that it is a method in which it is not possible for the researcher to control all the variables or select a representative player's sample.

This study does not use classical experiment since this method would make the process of selecting and diagnosing children with dyscalculia in a quantitative approach a very complex process, requiring an infrastructure and a support team. Additionally, to group together children with this learning disability would not be possible in neuropsychological rehabilitation. Also, the control of all the variables in an educational digital game, may affect the real player experience in the game, which includes the motivation of children with dyscalculia.

This dissertation uses experimental game design due to its flexibility. This method also seems to better attend to the demands of the gaming area. Thus, this method was used to verify the motivational preferences of children with dyscalculia in educational games. A pre-existing game developed by the Learning Games lab (NMSU) was used as a tool to elicit the preferences of the user and to verify their motivational aspects for the game elements.

Waern and Back (2015) highlight the importance of scientific rigor in experimental game design. They do not, however, discuss how to achieve this rigor when using the method.

As part of this dissertation, a set of formal steps related to the methodology have been established. These steps are incorporated in the structure of the experimental game design. This formalization helps to understand the methodological path of this dissertation. It also fosters scientific rigor, and allows other researchers to apply the structure in other research contexts. Thus, it represents one of the contributions of this dissertation. Table 26 below presents the formal steps to be followed when using the experimental game design method. These steps can be seen as a research protocol.

Table 26: A formalization proposal to use the experimental game design method.
Source: the author based on Gil (2002) and Yin (2001) notes regarding case study.

Research question formulation: this step represents the formulation of the research question/problem. The research will aim to answer this question through the research method. The formulation of the research question is based on information gathered through the literature review. The question also considers the possibilities that the experimental game design method can offer.
Defining the unit of analysis: the goal of this step is to identify the unit of analysis of the study, the primary unit to be analyzed during the research. For instance, the player's motivation, assessment in a game, the preferences of a specific players group, etc. The selection of the unit of analysis is related to the research question and goal.

Defining the number of design experiments: the aim of this step is to determine if the study needs to be conducted as a single experiment or multiple experiments. The decision is based on the research problem and goal.
Criteria for selecting participants: in this step the inclusion and exclusion criteria for the selection of participants are defined.
Material elaboration: in this step the game (final or prototype) is selected and prepared to be used in the research. This is in keeping with the research goal and problem.
Data collection strategy: in this step the dynamic planned for the player interaction with the game is described, and the procedure to be used during the experiment is outlined.
Technical procedure for data collection: in this step the technical procedures for the research are defined based on the research goal and the data collection strategy. For instance, interview, observation, questionnaire, focus group, etc.
Data analysis strategy: in this step the method of analysis of the gathered data is established. For instance, using comparison with previous studies, using information from the literature, among other possibilities.
Exploratory experiment: this step aims to verify with the target research user, the strategy of data collection, techniques, materials, and the quality of the gathered data.
Final report: this step refers to the writing of the final report. The report will include the performance of the used method, the results based on the research problem and contributions to the game design field.

Research question formulation

Based on the literature review and scope of this dissertation, the following question has been chosen for the experimental game design: **How to set up the motivational elements of the educational digital game so as to promote and sustain the motivation of children with dyscalculia in neuropsychological rehabilitation?**

Defining the unit of analysis

In this dissertation, the unit of analysis of the experimental game design is the motivation of children with dyscalculia when playing educational digital games in neuropsychological rehabilitation. The children under consideration are those assisted at the Developmental Neuropsychology Laboratory (DNL), at the Federal University of Minas Gerais (UFMG), Brazil. The laboratory's main research focus is developmental dyscalculia (mathematics learning difficulties). Besides their research project, the team at DNL has an extension program with two ambulatories, ambulatory *Número* and "*Neuroplá*".

Ambulatory *Número* represents the case unit of this dissertation. This laboratory offers services to children and teenagers from the local community who have mathematics learning difficulties or present a genetic syndrome. The laboratory also offers neuropsychological rehabilitation to students with mathematics learning difficulties, as well as behavioral interventions to the parents.

Defining the number of cases

This investigation is limited to a single case for two main reasons. First, the process of selecting and diagnosing children with dyscalculia is a complex and long one, as it requires a team of qualified professionals and specific standard tests. Thus it is important to stress

that the support from the DNL (UFMG) researchers was imperative for this dissertation. Second, based on the prevalence of children with dyscalculia and the time available to complete this research, it would not be possible to properly consider more than one case. An additional reason is that the procedure for the experimental game design was established according to the activities and schedule of the laboratory.

In one of the experiment tests (described below) the user verification was done with American children with typical development at the Learning Games Lab (NMSU). Although these children do not have dyscalculia, this verification was done to test the questionnaire and data quality, that is to say, as preparation for the final user verification with children assisted at the DNL (UFMG-Brazil).

Criteria for the selection of participants

This dissertation is aligned with the activities of the Developmental Neuropsychology Laboratory (DNL-UFMG), and for this reason, the user verification received support from the laboratory. Owing to their research and extension activities, the DNL (UFMG) has a large database, mainly composed of children (from different schools of Belo Horizonte – Brazil) already diagnosed with dyscalculia, TDHA, dyslexia and other leaning issues or development disorders. The criteria for selection of participants were that children should be between 9 and 13 years old, and diagnosed with developmental dyscalculia. The user verification of this dissertation comprises three phases (see figure 14 below):

- **Experiment 1:** user verification with four Brazilian children with dyscalculia;
- **Experiment 2:** user verification with six American children with typical development;
- **Final verification:** with four Brazilian children with developmental dyscalculia

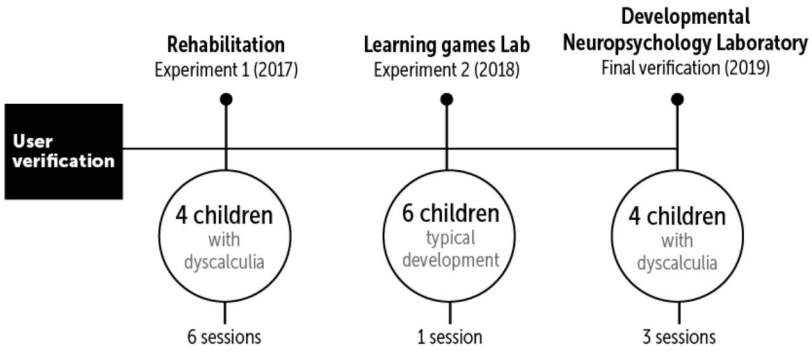


Figure 14: The three phases of data collected during the investigation.
Source: the author.

Material elaboration

During the user verification with the experimental game design method, two different games were used to interact with the user (children with dyscalculia): (1) Multicorrida; (2) Monster school bus. These games are described below.

Implementation of a simple game – Multicorrida (figure 15):

This game was used only in experiment 1. The game was implemented in September 2017 in Portuguese, focusing only on the game design recommendation about characters, namely: Use characters as a visual stimulus to attract the player's attention to the activity.

Figure 15: Multicorrida screenshots.
Source: the author.

The primary educational goal of Multicorrida is to practice arithmetic facts, primarily the times tables 1 to 10. This content was outlined with the collaboration of researchers from the DNL (UFMG). In the game, the player helps a character to win a race. For the character to run faster and have strength the player needs to complete some multiplication tables correctly. At each level of the game the player needs to provide ten arithmetic facts. The degree of difficulty increases as the complexity of the times tables increases; and the time available for answering the questions decreases as the level increases. If the player performs well, as a reward, they can collect a golden star.

After clicking on the play button, the player goes to the screen where the game system introduces the character, a short narrative, and the game goal, see figure 16.

Figure 16: Game introduction screen (in Portuguese).
Source: the author.

After the narrative screen, the player can choose between three levels of difficulty (figure 17 - A). The next menu screen presents the fifteen levels of the game (figure 17 – B). The player then chooses the rooms and can see how he/she is progressing in the game based on the opened rooms and the number of golden stars collected (figure 17 - C).

Figure 17: (A) Menu selection for levels of difficulty; (B) Menu for room selection; (C) Menu showing the player's progress.
Source: the author.

The game starts when the player selects a room. The gameplay is simple. The player needs to select among four options the correct answer for the presented arithmetic fact. In figure 18 – A the player chooses the right answer; in figure 18 – B the player chooses the wrong answer.

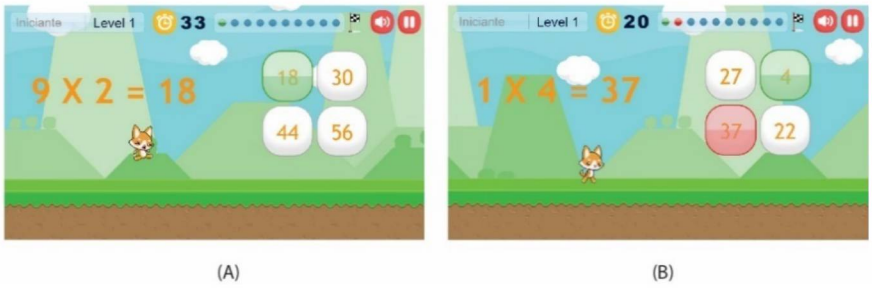


Figure 18: (A) When the player chooses the right answer; (B) When the player chooses the wrong answer.
Source: the author.

At the end of each room, the player goes to the result screen, where, based on their score, they can receive a golden star (figure 19). Figure 20 shows a simplified version of the game information architecture.

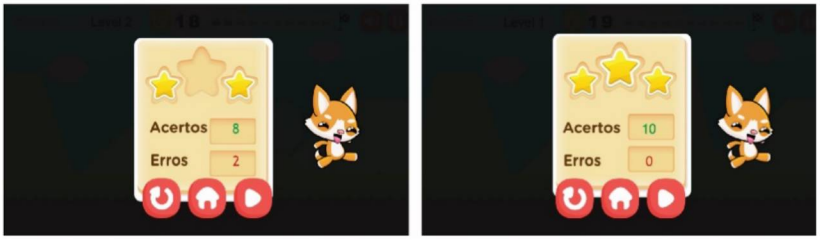


Figure 19: Result screen, after the player finishes the room.
Source: the author.

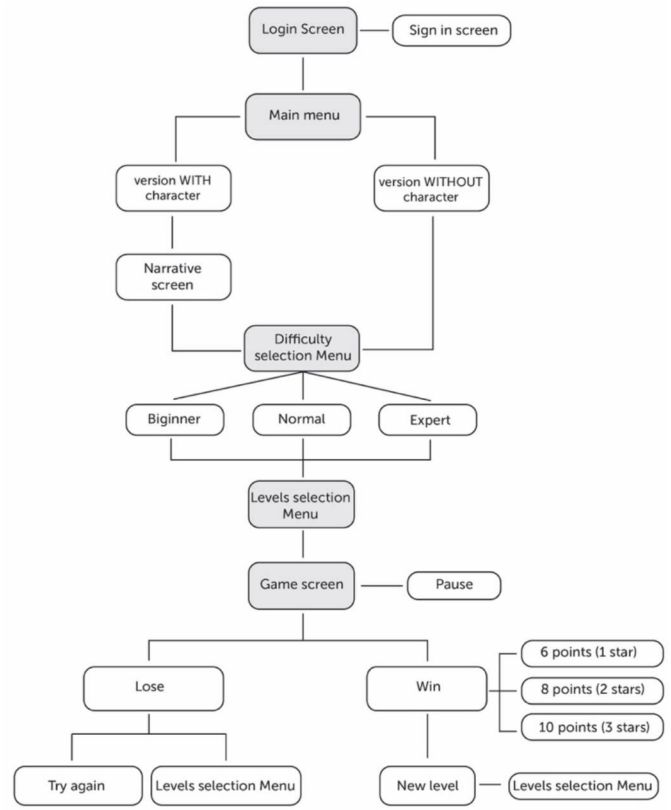


Figure 20: A simplified version of the implemented game information architecture.
Source: the author.

For this game implementation, the orientations of Mohseni, Liebold and Pietschman (2015) were followed. These authors suggest that in order to reduce costs and time, a pre-existing game can be used. The authors suggest that instead of implementing a game from the beginning, modifications may be made to an existing game. Thus, this study used the store *Scirra* from the software Construct 2 (used for this implementation), which has a game template that is suitable for this dissertation. Once the game template was bought, the following modifications were made with the support of a programmer.

- Modification in the game character (characteristics, actions);
- Creation of a simple narrative;
- Content modifications;
- Creation of levels of difficulty and rooms;
- Creation of audio effects (feedback);
- Reward system (graphical).

With the aim of investigating the impact of the game character on the player's motivation, two different versions of the same game (Multicorrida) were created:

- Version A: WITH the character.
- Version B: WITHOUT the character.

In version A, the character gives players instructions and visual feedback during the gameplay, whereas in version B instructions are given without the character.

Selection of a pre-existing and well-developed game – Monster School Bus.

The game Monster school bus was used during experiment 2 of this dissertation, and also in the final data collection with children with dyscalculia. This game is part of the project Math Snacks, developed by the Learning Games Lab (NMSU) (see figure 21). This game was selected because the games produced at the Learning Games lab have a high level of quality and are available online in English and Spanish. Moreover, the lab is renowned for its design process which is user-centered, interdisciplinary, and collaborative. The game Monster School Bus was also selected for the following two reasons:

- The game content is the arithmetic base 10. Thus it represents a useful tool for the multiplication module of the DNL (UFMG);
- The game has the three elements investigated in this dissertation, i.e. character, world building, rewards.

Figure 21: Initial screen from the game Monster School bus.
Source: mathsnacks.com/monster-school-bus.html

The player can choose between two options of characters, Johnny and Jenny, before starting the game (figure 22, left). After choosing the character, the player goes to the narrative screen, which takes place in a garage. The player character applies for a job as a bus driver and receives some instructions from the employer. After the player completes the neighborhoods, there are some cut scenes of the narrative with more instructions (figure 22, right). Before the game starts there is a short interactive tutorial about how to play the game (figure 23).

Figure 22: (Left) Character screen selection; (Right) Screenshots from the game narrative.
Source: mathsnacks.com/monster-school-bus.html

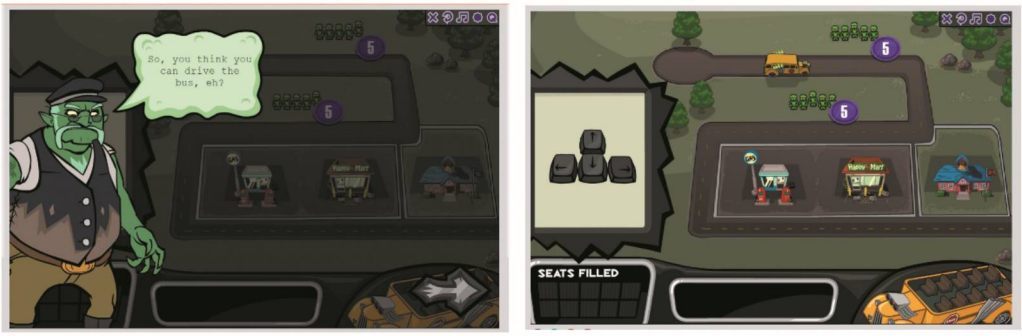


Figure 23: Screenshots from the game tutorial.
Source: mathsnacks.com/monster-school-bus.html

In the game, the player goal is to fill up the school bus with monster kids from the different neighborhoods and to deliver them to the school with as many full busloads as possible. The player is the driver of the bus and must decide the best route to pick up the children so as to have a full bus load (figure 24).

Figure 24: Screenshots from the gameplay.
Source: mathsnacks.com/monster-school-bus.html

To achieve the perfect score the player must drop off full busloads of students at the school. The size of the children/monsters is different in each neighborhood (figure 25). The player can see how many seats on the bus are filled in the graphic of the bus at the bottom of the screen (figure 26).

Figure 25: Screenshots with the types of monsters from the game.
Source: mathsnacks.com/monster-school-bus.html

Figure 26: Screenshots with some of the bus seats filled and with a full load.
Source: adapted from mathsnacks.com/monster-school-bus.html

After each level, players can see their score and receive stars as a reward for good performance, based on the number of full loads and rocked out buildings (figure 27, left). Players can also check the star for each level in the map screen menu. Additionally, in each room when players complete a full busload, flasks filled with a green potion pop up as a bonus. The player should smash as many green flasks as possible before they disappear. When the player smashes a flask, a building in the neighborhood turns into its "Rocked-out" version (figure 27, right).

Figure 27: (Left) Game score after the room; (Right) Green flask after a full load.
Source: mathsnacks.com/monster-school-bus.html

The Monster School bus game is not available in Portuguese. Thus, the game was translated so that Brazilian children could play it and take part in this study. The game translation was part of the material creation of the experimental game design method.

In meetings with Prof. Dr. Barbara Chamberlin and the developers from the Learning Games Lab, it was realized that to have the translation in the actual game would take a long time, as the game had been developed in adobe flash, a technology that is no longer available. Hence, using the original art from the game, and with the help of the Learning Games Lab team, the game cut scene and screens were translated. The idea was to show the translated version to the children on a different laptop during the game play (see figure 28 and figure 29).

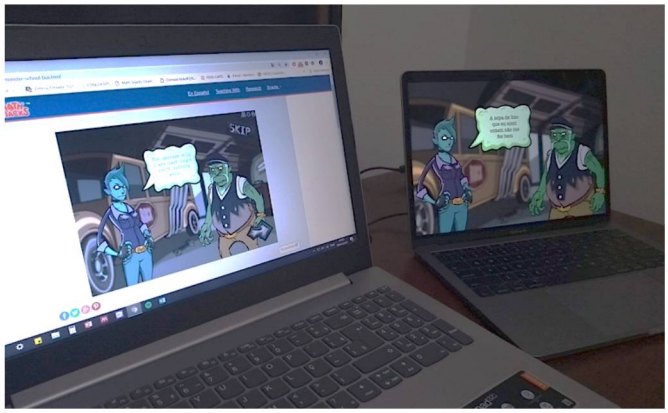


Figure 28: (Left) Laptop with the game to be played; (Right) Laptop with the game translation in Portuguese
Source: the author

Figure 29: (Left) Original screen of MSB cut scene; (Right) A translated version of MSB cut scene (Portuguese).
Source: the author

Although this alternative presented some limitations, it represented a suitable approach for this dissertation. For that reason, during the material creation all efforts were made not to affect the gameplay experience in any way.

Technical procedure for data collection

In the experimental game design method, two technical procedures were used for data collection with the user (children with dyscalculia), namely **semi-structured interview and observation**. For each technique, scripts were designed based on the moment of use. In this user verification, these moments are the three listed below (see table 27).

Table 27: Technical procedures and the moment of their application.
Source: The author.

Script	Application moment
A	Before playing
B	While playing
C	After playing

Semi-structured interview

This technique was selected because it offers a structure that can guide the interviews, being at the same time flexible enough to allow for changes to be made when necessary. The in-depth interview approach (COTE and RAZ, 2015) was used as a reference for the application and creation of the scripts. These authors suggest the use of this technique when the goal is to investigate in detail or in-depth, qualitative aspects of a small or specific group of players, such as players' preferences, opinions, experience. Hence, this technique fits with this dissertation's aim, which is to investigate with children with dyscalculia, their motivational preferences during the use of an educational digital game in neuropsychological rehabilitation.

To design the scripts of the semi-structured interviews, theoretical information from the literature review was used. Each script has a base question that represents the focus of the questionnaire. This means that each script has a set of questions that together in their final compilation answer the base question (a broader question). The interview is brief so as not to tire the children, and the questions are primarily open-ended to allow the children to detail their experience and motivation with the game. As for the vocabulary, it is simple and acknowledges the children's universe. The full scripts are in the appendix of this document (see p.240), and table 28 shows all the interview scripts used in this dissertation.

Table 28: The scripts for the user verification.
Source: the author.

Script	Application moment	Base question
A	Before playing	**Script A** What is the child profile? Does the child have some previous experience with digital games? **Script A1** What are the child's preferences for the game elements? Why?
B	While playing	**Script B** (observation)
C	After playing	**Script C** Was the game motivating? What does the child think about the game elements? **Script C1** Was the game fun (motivating)? What would a very cool game be like?

Observation

During the user verification, the technique of observation was used as a complement to the interview, to enhance the understanding of children's motivation during the interaction with the game. Marconi and Lakatos (2010) define observation as a technique used to gather information through the senses, and which provides the researcher with a better examination of the facts or artifacts investigated.

This study used the observation technique to gather information about the children's motivation while playing the game, based on their behavior and verbalizations. The observation followed the structure proposed by Marconi and Lakatos (2010). Thus, a script/questionnaire to be completed during the observation was designed. The questionnaire structure allowed to record the main events that took place during the observation, with regard to the player's motivation, during the user verification. Table 29 outlines the observation structure.

Table 29: Observation structure.
Source: the author.

Moment	Notes
Start of play	Difficulties Verbalizations Loss of attention Seems to be engaged/distracted
After 10 minutes of play	
At the end of play	

Data collection strategy

This dissertation's user verification has a specific data collection strategy, which aims to verify the user's preferences and motivation for three dramatic game elements, namely character, world building and rewards. This strategy is based on methodological orientations from the literature and was built during the dissertation development.

In this dissertation the user verification process has three stages: **Experiment 1, Experiment 2, and Final user verification**. All three stages of verification follow the same technical procedure, data collection strategy, and analysis strategy. However, each verification stage differs slightly from one another. These differences can be seen as improvements or adjustments to the context of research. Each user verification stage is described below.

Experiment 1

In this dissertation, the experiment tests were used to verify the data quality and the technical procedures of the experimental game design. Experiment 1 took place during the second semester of 2017, from October to December during a neuropsychological rehabilitation at the DNL (UFMG). Four children (ages 10 to 13) diagnosed with dyscalculia participated in this experiment. Each child had a different mediator. The mediators were psychology undergraduate students from UFMG, who are members of the laboratory. It was not possible for the author of this dissertation to participate in this experiment due to other doctoral commitments (e.g. courses).

The multiplication module and the implemented game Multicorrida were used in this experiment. The entire rehabilitation process lasted eight weeks: six weeks of rehabilitation, plus one week of pre-testing and one week of post-testing (see figure 30).

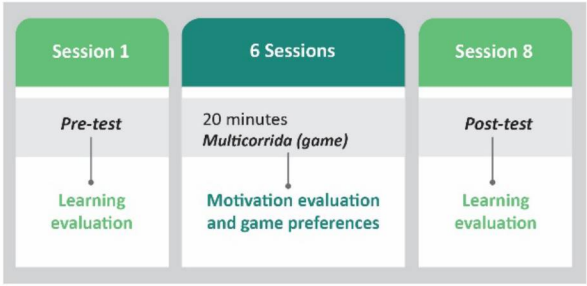


Figure 30: Arrangement of the activities in experiment 1.
Source: the author.

The research was still under development during the planning and application of experiment 1, therefore this phase focused only on the recommendation related to the game character: **Use the characters as a visual stimulus to attract the player's attention to the activity.**

In order to verify with the user their motivational preferences in relation to the game character, a semi-structured interview to be applied at specific moments of the gameplay was used in experiment 1 (see figure 31). The two versions of the game Multicorrida were also used. In the first week of the experiment the children played the game with the character. In the second week they played the version without the character. In the remaining sessions, they could choose which of the two versions they would like to play. It was during these weeks that the mediators conducted the interviews.

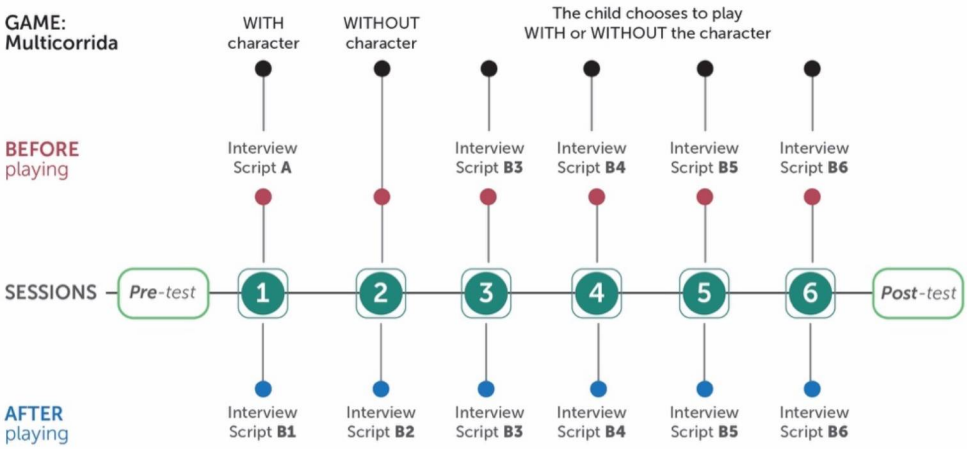


Figure 31: A summary of the procedure applied in Experiment 1.
Source: the author.

Experiment 1 followed the data analysis strategy described previously in this chapter. However, some procedures were different in experiment 1, for instance, there was no observation. This was because the research was in its initial stage when the opportunity for the experiment emerged.

Experiment 2

Experiment 2 took place in October of 2018 during the author's doctorate exchange at the New Mexico State University. The user verification took place at the Learning Games Lab during one of the lab's regular user testing sessions, and 6 children with typical development (ages 9-10) took part in it. Although these children do not have dyscalculia, this verification was done to test the questionnaire and data quality, that is to say, as preparation for the final user verification with children assisted at the DNL (UFMG-Brazil).

The Learning Games Lab conducts user verification regularly, so they have expertise in identifying users and obtaining their parents' consent. The lab also offers the technical structure required (e.g. environment, computers, team) to set up user verification.

In this experiment, the children played the game Monster School bus for 20 minutes. Each child had their own laptop. The children were interviewed by the author of this dissertation. The purpose of the study and their role (design consultant) in the user verification were explained to them. They were also asked whether they allowed the researcher to record the interview.

After the gameplay, the children were interviewed in pairs. The semi-structured interview script was used. This joint interview was different from the approach defined for this dissertation, where the children were interviewed individually. This alternative was chosen to verify whether interviewing the children in pairs would increase the data quality or not. The purpose of this experiment was to check the quality of the data and verify if the questions were suitable for the children's age and vocabulary. The investigation focused on the children's motivation, specifically the children's preferences for the three game dramatic elements being investigated (character, narrative, rewards). See figure 32 for a visual synthesis.

The children were organized in pairs mainly based on their grades, and each pair answered questions from a different script:

- **Pair 1:** A boy and a girl, both 10 years old and 5th graders. They answered the questions in script A (profile) and script C3 (rewards).
- **Pair 2:** Two boys, both 10 years old and 5th graders. They answered the questions in script A (profile) and script C1 (character)
- **Pair 3:** A girl and a boy, both 9 years old and 4th graders. They answered the questions in script A (profile) and script C2 (narrative).

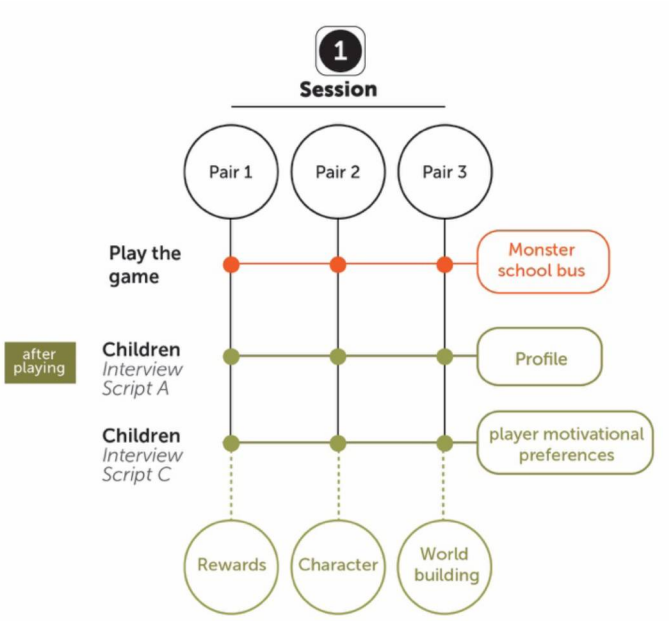


Figure 32: A summary of the procedures applied in experiment 2.
Source: the author.

Final User Verification

This phase investigates with the user their motivation and preferences regarding three dramatic elements studied in this dissertation, namely character, world building, and reward. This dissertation, through the experimental game design, creates variations of these elements in a simple game. However, this approach showed to be inappropriate to measure the child's motivation because when a game element was disabled, it affected the gameplay experience, and consequently the player's motivation. This happens because games are complex and connected systems. This verification represents experiment 1 of this dissertation (see p. 133). This dissertation used a pre-existing well-developed game as a tool to verify with children information about the three game elements researched.

The Monster School Bus (by Learning Games Lab – NMSU) was the game used during the final user verification of this dissertation. The aim was to verify with the user information about each game element individually immediately after the gameplay.

The data collection took place during the first semester of 2019 at the DNL (UFMG) and had the support of the researchers from the lab. The aim was to verify some game information with children with dyscalculia during neuropsychological rehabilitation. However, at the time of this research, the lab did not have any rehabilitation program in place. Therefore, the children and their parents were invited exclusively to take part in the research.

Both parents and children were given detailed information about the research. Four Brazilian children with dyscalculia took part in this user verification (ages 9 to 13). The lab has a large data base of children diagnosed with dyscalculia, however most of them are outside the target age for this study (e.g. 16 or 17 years old).

In summary, the final user verification comprises four main stages:

- **Stage 1 – Consent and Assent forms:** Before the first session, every child and their cares were informed about the purpose of the research and its benefits. Main information in the Consent and Assent form was also explained. This information was given to the participants in simple language, and participants were given the opportunity to ask questions regarding the study. The sessions were recorded with the permission of the children and their cares. The forms were approved by the Ethics Committee of the Federal University of Paraná.
- **Stage 2 – Rapport:** It is a technique used by psychologists to develop a connection with the patient, make them feel comfortable before starting the treatment. Before starting the session, quick and simple board games (i.e. *Vire a mesa, Uno stacko* – figure 33) were used as a rapport strategy for the session. This allowed the child to feel more comfortable with the researcher. While playing the board games, the researcher and the child talked informally about school, games, cartoons, and other topics that interested the child.
- **Stage 3 – Gameplay**: The child played the game *Monster School Bus* in each session for 20 minutes. During the gameplay, the child was observed by the researcher, who took notes of verbalizations, main difficulties and level of engagement with the game.
- **Stage 4 – Interview:** After having played the game the children were interviewed. The general aim of the interviews was to obtain information about the child's motivation during the game and their preferences. The focus of the interviews was different in each session: Session 1 (profile + character); Session 2 (world building); Session 3 (rewards). In addition to being interviewd after playing the game, in session 1 only, the children were also interviewed before playing the game. This interview focused on the child's profile and previous experience with games. In each session, before starting the interview the researcher made clear to the child that (1) they could ask any questions about the research at any time during the interview; (2) there were no right or wrong answers, only the child's opinion; (3) children were the specialists in fun and games, so the researcher was there to learn from them.

To sum up, in this Final User Verification, each child played a game under the researcher's supervision for approximately twenty minutes, once a week over a period of three weeks. Each session lasted one hour and was composed mainly of three activities (see figure 34):

- 10 minutes of rapport, playing board games;
- 20 minutes of gameplay with the game Monster school bus;
- 30 minutes of interview, after the gameplay.

Figure 33: *Vire a mesa* and *Uno Stacko* – games used as a rapport (in Portuguese).
Source: the author.

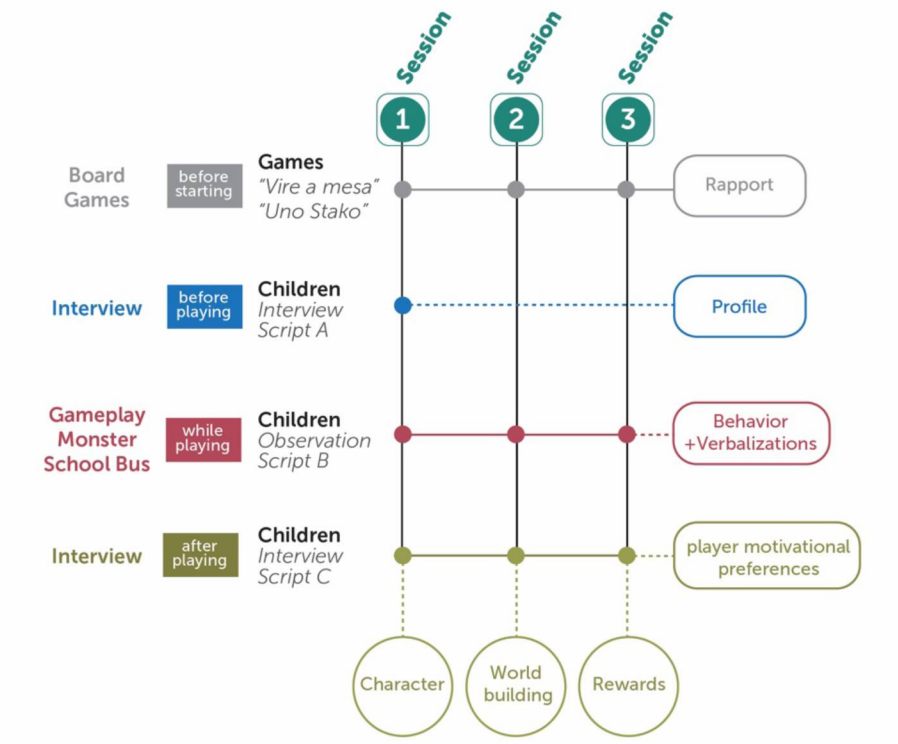


Figure 34: Summary of the procedures and strategies used in the data collection with the user.
Source: the author.

Data analysis strategy

Triangulation was the strategy used to analyze the data from the experimental game design. This strategy allowed to cross-examine information/data from different sources (YIN, 2001; MINAYO, 2005). As previously mentioned in this document, the analysis of qualitative data follows a strategy that has been created for this dissertation, based on Gil (2002); Miles and Hubberman (1994); Cote and Raz (2015), see figure 35.

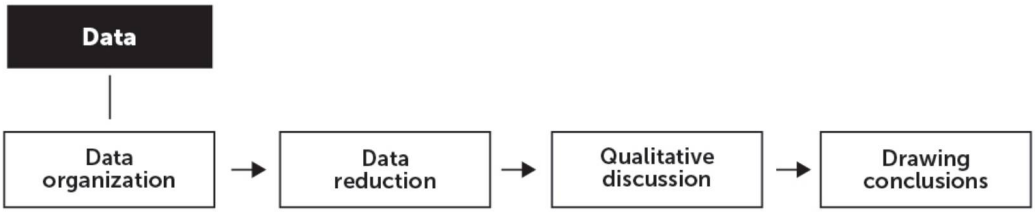


Figure 35: Steps for the qualitative analysis in this dissertation triangulation.
Source: the author based on Gil (2002); Miles and Hubberman (1994); Cote and Raz (2015).

Firstly, the data from different sources (interviews, observations) were organized in an excel table according to child and session **(data organization).** The information was then categorized and coded **(data reduction).** Once coded, the data were analyzed qualitatively correlating the sources **(qualitative discussion).** Finally, conclusions were drawn considering the data concerning the child and also the group **(drawing conclusions).**

4.2.5 Doctorate exchange at the Learning Games lab

As part of this doctoral research, the author of this dissertation spent six months (August 2018 to January 2019) at the Learning Games Lab at the New Mexico State University (NMSU - Las Cruces, USA), as an affiliate scholar. This exchange was funded by CAPES (Brazilian Federal Agency for Support and Evaluation of Graduate Education) sandwich doctorate program, and took place under the supervision and co-orientation of **Professor Dr. Barbara Chamberlin,** director of the Learning Games Lab and a specialist in extension instructional design and educational technology.

The experience at the lab was unique and contributed significantly to the development of this research. The support of Prof. Chamberlin and of all the members of the Learning Games Lab during this exchange and throughout this research was invaluable for this dissertation. The main activities from this period and how they contributed to this dissertation are described below.

- **Weekly meetings:** During the six-month period at the Learning Games Lab, the researcher had weekly meetings with Prof. Dr. Barbara Chamberlin to discuss the progress of the dissertation. Prof. Chamberlin's contributions were fundamental for this dissertation.

- **Interaction with the development team:** the researcher participated in several meetings with the lab team (figure 36 and figure 37). At these meeting the team discussed their projects, and the different educational products they were developing, such as interactive animation, educational apps, and educational games. These meetings provided a better understanding of the lab's process of design, interaction with clients, and team management;

- **Interaction with researchers from the College of Education:** the researcher participated in meetings with the researchers from the Math Snacks Lab, from the College of Education at NMSU. These meetings provided the opportunity to exchange ideas with a variety of researchers and to learn about their projects.

- **PI testing:** the researcher participated in a Principal Investigators (PI) testing, where the principal investigators from the game in development sat together to

play an Alpha version of the game. They discussed some possible changes and improvements for the game, and tested the quality of the data gathered from the players.

- **User testing session:** the researcher participated in a user testing session for one of the games in development at the lab. This user testing focused on the bonus level of the game Curse reserve, which practices pre-algebra with elementary students (see figure 38). Fifteen children from 4th and 5th grades took part in the testing. During the session, the researcher helped supervise the children (e.g. playing board games). He also observed the children playing and discussed his observations with the lab team at their debriefing session. The researcher learned many useful practices during these sessions and applied them to the users verification of this dissertation: (1) interaction with users - the use of ludic language to explain to children their roles in the user testing, making it clear that they are the experts in games (design consultants); (2) the use of short and straightforward board games to initiate interaction with the children and introduce them to the other children and the researchers; (3) note-taking - one researcher is responsible for taking notes, while other researchers interact with the children during the gameplay; (4) after the gameplay - the researchers meet to discuss their observations.

- **Game design process workshop:** This workshop was the result of Prof. Barbara Chamberlin and Jesse Schell work – the transformational game design framework. The workshop was given by Prof. Chamberlin and held at the Learning Games Lab (see figure 39). It provided the researcher with a better understanding of the lab's game design process, which he had been researching since the start of his doctorate and which is well-known in the game literature;

- **Support for the creation of materials for this dissertation:** During the creation of the interview script for this dissertation, the researcher had access to the game assessment and other materials used by the lab in the user testing with the game Monster School bus (used in this dissertation). The access to this material provided many insights and guided the creation of materials for this dissertation.

- **Experiment 2:** During his time at the lab, the author developed a experiment test with 6 American children (figure 40). This allowed him to verify the interview script and the data quality of this dissertation, before the final data collection with Brazilian children.

- **The use of a game in this dissertation:** The lab team allowed one of their pre-existing games to be used during the user verification of this dissertation. This was extremely beneficial for this dissertation for two reasons. First, because of the high quality of the game used (Monster School Bus). Second, because to implement a game from the very beginning would have been very time consuming.

- **Work in one of the lab projects:** During the exchange, the author collaborated on a graphic project for a new game under development. The author created some printed cards (see figure 41), as supplemental material for teachers who use the game Agrinautica, which aims to develop children's math expression.

- **Enhance active English skills:** During his time at the lab, the author could enhance his English writing and speaking skills. A good command of the English language is vital for a researcher, as it makes it possible to share results and make broader connections in the academic/research community.

Figure 36: The multimedia and animation development studio -NMSU.
Source: the author.

Figure 37: Posters of the games and animations developed by the lab.
Source: the author.

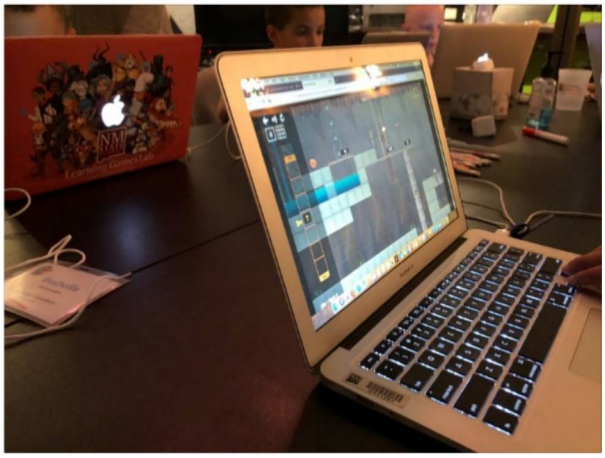


Figure 38: User testing with the two new games in development at the lab.
Source: Learning Games Lab facebook page.

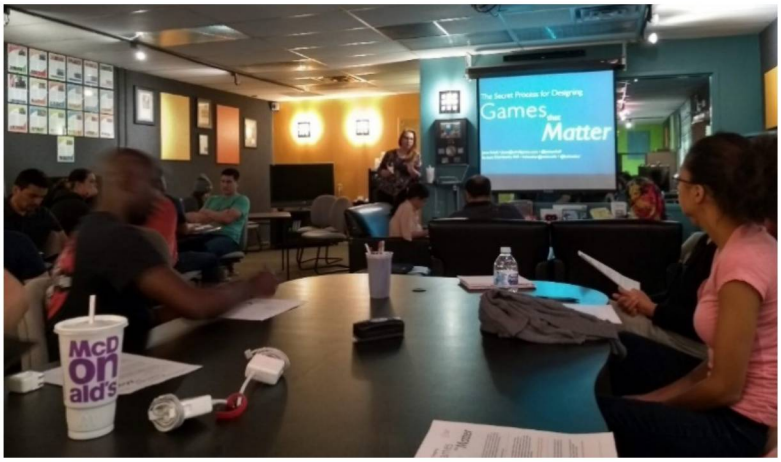


Figure 39: Transformational game design framework workshop.
Source: the author.

Figure 40: User verification for experiment 2 of this research. Children playing the Game Monster School Bus.
Source: the author.

Figure 41: Agrinautica game cards.
Source: facebook.com/mathsnacks

4.2.6 Phase 5 | Detailing recommendations

This phase represents the last phase of the data analysis of this dissertation. Data triangulation is used in this phase as a strategy to analyze the data collected (YIN, 2001, MINAYO, 2005), covering the data from the **literature review, field research and experimental game design** (figure 42). Hence, through a variety of sources of information, this dissertation discusses how to promote and sustain the motivation of children with dyscalculia in educational digital games.

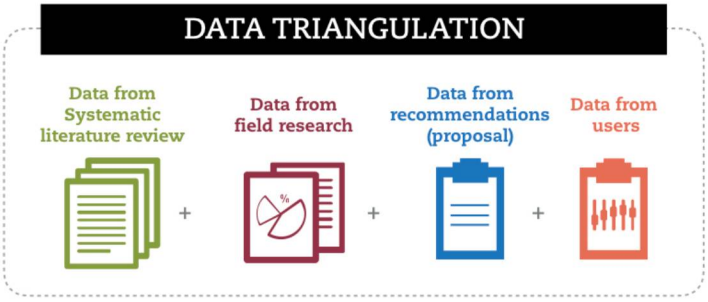


Figure 42: Final data triangulation.
Source: the author.

The game design recommendations made in this dissertation have as their starting point the recommendations found in the literature, and those made based on the results of the field research (chapter 5, p. 127). These recommendations have been further developed based on the preferences of children with dyscalculia which were identified in the final user verification (chapter 7, p. 133).

4.3 Methodology Reliability and Validity

To provide reliability in this dissertation methodology, each research phase used a different strategy, which are listed below:

- **Systematic literature review:** protocols were elaborated based on Conforto, Amaral, and Silva (2011); Kitchenham et al. (2009). The protocols provided for this review traceability and quality for the collected data.
- **Field research with game developers:** an exploratory questioner was used. Before creating the questions and predefining the alternatives for the field research, an exploratory questionnaire was administered with game developers (from IGDA Curitiba[22]). This exploratory questionnaire improved the questions and enhanced the data quality.
- **Field research with specialists in rehabilitation:** an external verification was used. An experienced member of the DNL (UFMG), performed a final check of the questionnaire (e.g. vocabulary, understandability, size) before the application with the specialists.
- **User verification:** two design experiments were elaborated before the final user verification. The design experiments were used to refine the methodology, test and selected the best approaches to address the dissertation's needs in the user verification.
- **Triangulation:** a framework was used during the triangulation process. Composed of four steps the framework was designed based on the literature (Gil, 2002; Miles and Huberman, 1994; Cote and Raz, 2015) to process qualitative information in this dissertation. The structure designed here can be followed by anyone interested in replicating this study or to use it in a different scope.

As for providing validity for this dissertation data, this document presents step by step all the researcher decisions. Also, the document details the ways used by the researcher during the data analysis process. The idea is providing a path that can be followed by anyone interested in replicating this study, so likely to get the same results and draw the same conclusions.

4.4 Summing up

This chapter detailed this dissertation's methodology, and it was divided into two main sections: (1) research classification; (2) phases and steps.

The first section described the **research classification**, covering all six categories: research type; data approach; goal; design approach; design research; procedures. This classification is elementary for the full comprehension of this dissertation's methodology.

The second section provided the full particulars **of the research methodology, describing its phases and steps.** This dissertation comprises five methodological phases: (1) systematic literature review concerning educational game recommendations, (2) field research with game developers and specialists in rehabilitation, (3) game design recommendations proposal, (4) user verification with children with dyscalculia, and (5) detailed recommendations. In this section, the technical procedures for data collection, the

[22] The International Game Developers Association (IGDA) is a non-profit professional association and a global network of collaborative projects by professionals involved in the game development process (e.g., programmers, artists, game designers) (IGDA, 2016). The IGDA in Curitiba, Brazil (IGDA-CWB) aims to bring together local communities, the game industry, the academy, and society in general (IGDA-CWB, 2016).

process of materials elaboration, the criteria for sampling selection, and the analysis strategy for each one of these five phases were explained. In addition, the main activities which took place during the author's doctorate exchange at the learning games lab, and how they contributed to this dissertation were described.

A graphic representation of these five interconnected phases is presented in section 1.9 (figure 3, research methodology overview, p.24).

5 FIELD RESEARCH RESULTS

This chapter presents and discusses the results of the field research. During the field research information regarding educational digital games was gathered with two different stakeholders[23], namely game developers and specialists in rehabilitation. The full methodological description of this field research is presented in chapter 4 of this document (research method). This chapter is divided into two parts. In the first part the data gathered by interviewing specialists in rehabilitation are discussed. In the second part the data obtained by interviewing game developers are considered. Section 3 of this chapter summarizes the information provided.

5.1 Field research with specialists in rehabilitation

This section presents the data analysis of the responses from 12 Brazilian specialists in rehabilitation. That data was gathered online using the tool Google Forms. A qualitative questionnaire containing mostly open-ended questions was used. The aim of this field research was to fulfil the second specific goal of this dissertation, namely: **To investigate, from the perspective of specialists in rehabilitation, what the requirements to develop educational digital games for children with dyscalculia in neuropsychological rehabilitation are.**

5.1.1 Data organization

Excel sheets were used to **organize the gathered data**. The questions from the questionnaire were organized in an excel table according to their content:

- 3 questions about the specialists' profile;
- 7 questions about children rehabilitation and educational games in general;
- 2 questions focusing on games and rehabilitation of children with dyscalculia.

These questions sought to gather information on the game requirements, particularly those games used in the neuropsychological rehabilitation of children with dyscalculia.

5.1.2 Data reduction & qualitative discussion

Due to the connection between Data reduction & Qualitative discussion these steps are better described together. Thus they are presented together in this section. This section presents the data through data visualization (when applicable) and offers a qualitative

[23] The specialists in rehabilitation and the game developers who took part in this field research were from Brazil, therefore the questions were in Portuguese. Questions and answers were later translated into English.

discussion of the questions, considering the responses from the 12 specialists in rehabilitation interviewed.

The data analysis began by considering the profile of the participants so as to know what the samples represented. In order to do that, in the questionnaire, three questions focused on participants' profile. Most of the professionals in the sample are psychologists, from Belo-Horizonte (Brazil), and they all have prior knowledge of rehabilitation and learning disabilities. However, not all of them consider themselves experts in the subject.

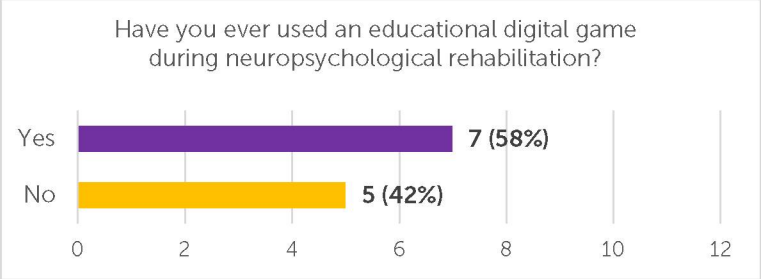
Table 30 shows the profile of each participant. A code name is used so as to keep participants' identity private, and to facilitate the analysis of the open-ended questions. Firstly the answers are individually analyzed, and then a general discussion is provided. The questions are also presented and analyzed below.

Table 30: Specialists' profile information with code names.
Source: the author.

Codename	City (State)	Background	Experience Level
Specialist #1	São Manuel (SP)	Psychology	I know well the topic. However, I am not an expert. (EL.2 - Good knowledge)
Specialist #2	Belo Horizonte (MG)	Psychology	I am familiar only with some aspects of the topic (EL.1 - Moderately familiar)
Specialist #3	São José do Rio Pardo (SP)	Psychology	I am an expert (EL.3 – Expert)
Specialist #4	Belo Horizonte (MG)	Psychology	I know well the topic. However, I am not an expert. (EL.2 - Good knowledge)
Specialist #5	Ponte Nova (MG)	Education	I am familiar only with some aspects of the topic (EL.1 - Moderately familiar)
Specialist #6	Belo Horizonte (MG)	Psychology	I know well the topic. However, I am not an expert. (EL.2 - Good knowledge)
Specialist #7	Belo Horizonte (MG)	Psychology	I am familiar only with some aspects of the topic (EL.1 - Moderately familiar)
Specialist #8	Belo Horizonte (MG)	Psycho-pedagogy	I am an expert (EL.3 – Expert)
Specialist #9	Belo Horizonte (MG)	Psychology and Neuropsychology	I am an expert (EL.3 – Expert)
Specialist #10	Belo Horizonte (MG)	Psychology	I know well the topic. However, I am not an expert. (EL.2 - Good knowledge)
Specialist #11	Belo Horizonte (MG)	Psychology undergraduate student	I know well the topic. However, I am not an expert. (EL.2 - Good knowledge)
Specialist #12	Belo Horizonte (MG)	Psychology undergraduate student	I know well the topic. However, I am not an expert. (EL.2 - Good knowledge)

In Question 1 (a Yes or No question) participants were asked if they had ever used educational games during a neuropsychological rehabilitation. As it can be seen in Chart 1, most of the specialists had previously used an educational game during neuropsychological rehabilitation, which represents 58% of the sample (7 specialists). On the other hand, 5 specialists had never used an educational game in this context, which represents 42% of the sample.

Chart 1: The use of digital games during rehabilitation.
Source: the author.



In question 2, participants were asked which game they used in the rehabilitation and how that experience was. The analysis of their answers to this question is presented below.

- Specialists #1, #3, #4, and #5 did not reply to this question because they had never used an educational game in an intervention context.
- Specialist #2 said that she had only used the game "multicorrida", and that it had not been a good experience. The game "multicorrida" was used in the experiment test of this dissertation to test the questionnaires, and the information quality gathered from users. The experiment test of this game is fully described in chapter 7.
- Specialist #6 said that the only game she had used was "*Pedro em uma noite muito assustadora*" (Pedro on a very scary night). This is a Brazilian therapeutic game, by CTS informatica, whose aim is to develop children's phonological awareness. The participant did not provide any information about her experience when using the game.
- Specialist #7 said that he had used the following games: "Multicorrida"; "Pedro no Parque" (Pedro in the park) and "Pedro numa noite muito assustadora" (Pedro on a very scary night), by CTS Informatica. The participant did not provide any information about his experience when using these games.
- Specialist #8 said that she had used several games, such as "Timez Attack" and "Memo Training". *Time Attack* is a well-known 3-D multiplication computer game developed by Big Brainz and commercialized by Imagine Learning. *Memo Training*, on the other hand, is a digital memory game developed by CTS Informatica. This participant did not provide any information about her experience when using these games.
- Specialist #9 explained that although she did not have experience of using an educational game during rehabilitation, she had supervised other professionals using this kind of technology. In her opinion, in general, games are an interesting tool to motivate children during rehabilitation. However, she warned that if the game is too repetitive, it can be demotivating, especially for children with a low level of intrinsic motivation. According to Rubinsten and Tannock (2010) children with dyscalculia, due to their limitations, often may suffer from math anxiety, which prevents them from engaging in mathematical activities. Specialist #9 also said that although novel tools such as games are important, these should not be used as the only resource during the intervention.
- Specialist #10 said that he/she had used the game "Number race". This is a well-known computer game developed by INSERM-CEA Cognitive Neuroimaging

Unit[24], and especially designed to address mathematical learning difficulties such as dyscalculia. There are a few studies about this game, such as Wilson et al. (2006). This participant did not provide any information about his/her experience when using the game.

- Specialist #11 said that she had used a multiplication game. Although she did not mention the name of the game, she said that the experience of using it was useful. Because the children liked the game, they had fun and were motivated during the rehabilitation.
- Specialist #12 said that he/she had used the Game "Number Catcher" on a tablet. This game, also developed by INSERM-CEA, is an improved version of the game "Number Race". Specialist #12 described her experience with the game as positive. The child enjoyed playing the game, particularly because of the challenges presented at the different levels of the game.

In summary, based on the responses to question 2, it can be concluded that most of the specialists had some experience using games in rehabilitation. Also, the same game was used by some of the specialists. Of the games mentioned, most do not have a version in Portuguese, which presents a limitation for rehabilitation in Brazil. When answering question 2, only a few specialists described their experience with these games. Specialist #2 highlighted that when the math activity is too explicit in the game, it has a negative impact on the intervention. Specialist #9, on the other hand, stressed that despite the importance of the novelty aspect of games, these should not be the only tool used in rehabilitation. Both Specialist #11 and Specialist #12 referred to the fun aspect of the game. For Specialist #11 the fun element is the most important element in a game; and for Specialist #12, the challenges and levels to be achieved are essential for fun in games.

Question 3 asked the specialists' opinion about using educational digital games as an activity in neuropsychological rehabilitation. Their responses are shown below (table 31).

Table 31: Responses to question 3.
Source: the author.

3. What do you think about using educational digital games as an activity in neuropsychological rehabilitation? Justify your answer.	
Specialist #1	"I think it is important to be implementing methods that the patients are familiar with, such as mobile phones."
Specialist #2	"I believe that it is very interesting because it represents a great motivator for the child. When it is used with a well-defined purpose, it can result in great clinical benefits."
Specialist #3	"I believe that in the current world technology well-applied can be beneficial and a great motivator."
Specialist #4	"I think it is cool, mainly because children's motivation is often low."
Specialist #5	"I think it is very valid."
Specialist #6	"I think it is very interesting. Digital games can be a tool that keeps children motivated and engaged in the task. Moreover, it can practice in a ludic way some important aspects of the intervention."
Specialist #7	"It is a very useful practice, but it cannot be the only one. Games usually have a motivational role for children and can help in non-cooperative situations."
Specialist #8	"It is quite efficient, as long as there is mediation. It is possible to stimulate executive functions such as attention, work memory, focus, impulse control."

[24] INSERM-CEA Cognitive Neuroimaging Unit is an international institute that researches mathematical cognition.

Specialist #9	"I think they are very interesting tools, which can contribute to the success of the intervention, mainly to motivate and engage children."
Specialist #10	"I think it is a good complementary tool, to be used mainly as a motivational tool."
Specialist #11	"Based on my experience they are interesting. The individuals learn and keep motivated with games."
Specialist #12	"I think the use of games can be very positive, as long as they are used with other rehabilitation activities. They help motivate and engage children, since they are more interested in games than in traditional activities."

To sum up, based on the responses to question 3, it can be concluded that all 12 specialists consider the use of educational digital games in rehabilitation beneficial to the patient. Specialists #2;3;4;6;7;9;10;11;12 highlight the fact that digital games can motivate and engage patients in the activities. Another argument presented by some of the specialists (Specialists #1;2;3) in favor of using games in rehabilitation was the fact that games are a current and familiar technology to children, and which often captures their attention. Specialist #8 emphasized that through games important aspects of the intervention (e.g. attention, work memory, focus, impulse control) can be practiced. It can also be seen in the responses, that the specialists were also aware of some of the aspects to be considered when using games. Specialists #2 and #3 highlighted the importance of having a well-defined goal for the game as well as a clear purpose. Specialists #7; 8; 10; 12 made it clear that games should be used as a complementary tool during the intervention and not as the only tool. Moreover, Specialist #8 stressed the relevance of having a professional as a mediator when using the game.

Question 4 asked the specialists (based on their experience working with children from 9 to 13 years old) what they thought must be included in an educational digital game. Their responses are presented in table 32.

Table 32: Responses to question 4.
Source: the author.

4. Based on your experience with rehabilitation of children (9 to 13 years old), what must be included in an educational digital game? (e.g. what children like, what children expect from the activities)	
Specialist #1	"Levels, competition, challenge."
Specialist #2	"I think levels in the game, so the children can progress when they respond correctly, which works as a reinforcement. Moreover, feedback and a way to allow children to interact with the game (manipulate the characters)."
Specialist #3	"Action, challenges, and interaction with the game."
Specialist #4	"To be challenging and provide children with awards when they complete the levels."
Specialist #5	"Sound, levels, animated cartoons."
Specialist #6	"Rewards in the games."
Specialist #7	"The degree of difficulty in the different levels should increase progressively and linearly. If the game is not at the same level as the child's knowledge, he/she may not be motivated."
Specialist #8	"Positive stimuli."
Specialist #9	"As I have said, the novelty aspect during the session is important. Moreover, the game should give some feedback on the child's performance. Also, I think it is important that the games correspond to the child's level of competence."
Specialist #10	"Feedback and repetition of the same problems. However, these problems need to be presented in different ways."
Specialist #11	"Characters, child interaction, rewards. The game needs to be fun, colorful and motivating."

Specialist #12	"It must have levels, so the child can move forward, starting with an easy level and progressing gradually (errorless learning). Moreover, the child becomes more motivated when they receive feedback on his/her performance in each level, for instance, stars. The game should measure the child's performance and the tasks should match the child's skills, that is, they should be neither too easy nor too difficult. I have mediated the use of the game "Number Catcher" on a tablet. I believe that it was very positive, the child interacted better with the game using a touchscreen."

A summary of the responses given to question 4 is provided below (table 32). The game element/feature mentioned by most of the specialists was **"levels"** (Specialists #1;2;4;5;7;12). For those specialists, it is through levels that children progress in the game, and their degree of difficulty should increase progressively and linearly. According to Specialist #12, this means progressing gradually from the easiest level, based on the errorless learning approach (MIDDLETON and SCHWARTZ, 2012). For Specialist #2, levels also lead to reinforcement.

The importance of the element **"Rewards"** was also highlighted (Specialists #4; 6; 8; 11; 12). Rewards were seen as "positive stimuli" (Specialist #8), and could take the form of an award (Specialist #4), or positive feedback such as stars (Specialist #12). Thus, rewards represent something the children will receive from the game system as they progress in the game, through its levels and challenges.

Other elements mentioned by the specialists were: **"Feedback"-** Specialists #2; 9; 10; 12 stress the importance of providing the children with feedback on their performance in the tasks. **"Interactivity"** – Specialists #2; 3; 11; 12 call attention to the importance of providing interactivity in the game, such as the manipulation of a character, or the use of a touchscreen on a tablet; **"Challenge"** – Specialists #1; 3; 4 consider this element relevant because challenges make the activities in the game more interesting. Notice that levels, challenges, and rewards are interconnected.

Specialist #5 mentioned the element **"Character",** and similarly Specialist #11 mentioned **"an Animated Cartoon".** Specialist #11 also stressed that the game **needs** "to be fun, colorful and motivating". Specialist #9 and #12 alluded to the importance of being adaptive. For them a game should adapt to match the skills of the children. For Specialist #10 **"Repetition"** is important. This specialist explains that this is because repetition is an essential element when teaching children to solve math problems, and these problems need to be presented to children in different ways. This opinion is reinforced by Specialist #9 who refers to the importance of the novelty element in games, specially during intervention sessions.

Question 5 asked the specialists what should be avoided in games used in the rehabilitation of children. The specialists' responses are listed in table 33. The specialists' responses to question 5 are discussed below.

Table 33: Responses to question 5.
Source: the author.

5. Based on your experience with the rehabilitation of children (9 to 13 years old), what should be avoided in an educational digital game? (e.g. limitations that you have found in games, problems you had when using a game during a rehabilitation session)	
Specialist #1	"The need to be connected to the internet."
Specialist #2	"It should not be something monotonous and purely repetitive. Sometimes only because it is played on a computer, it is seen as something fun. However, as I have said before, I believe that the game should be interactive, what needs to be learned can be repeated, but in different ways".

Specialist #3	"Repetitive content."
Specialist #4	"Games sounding or looking like a class."
Specialist #5	"Aggressiveness, fights."
Specialist #6	"Tasks which are too repetitive and mechanical, which do not reinforce what was presented to the children."
Specialist #7	"Games without a theoretical and statistical base."
Specialist #8	"Excessive negative stimulus."
Specialist #9	"I do not agree with the idea that the child can do the activities without a mediator. I think the games, more specifically those focusing on mathematical interventions, have failed in providing the arithmetic's conceptual and procedural knowledge. Nevertheless, they are a good tool to enhance fluency, for instance."
Specialist #10	"Game which are too long with no clear rewards; a game that focuses directly on the pedagogical aspect and not much on the ludic aspect; the lack of clear objectives; the lack of challenges."
Specialist #11	"As children face some difficulties, the game should guarantee errorless learning, where the level of difficulty is compatible with what a child can offer."
Specialist #12	"A game which is too repetitive should be avoided. It is interesting that there is a real variation of objectives, also in between the levels, not only in the design. As the child will play the game many times, when it is very repetitive, he/she gets tired, and the game becomes boring and uninteresting. Bonuses which are not related to the game objective should also be avoided. For example, the game "Number Catcher" gives extra points for patterns of similar combinations, which is not part of the objective. So, the child wastes too much time to obtain this bonus, and consequently, he/she departs from the objective."

As it can be seen in table 33, according to the specialists, several things need to be avoided in games. Specialist #1 says that it is important that the game does **not require access to the internet to be played.** Specialist #4 states that games should not **sound or look like a lesson.** Specialist #5 suggests that games should avoid **aggressiveness and violence.** Specialist #7 says that games **with no theoretical or statistical** base should be avoided. Specialist #8 argues that **excessive negative stimuli** should be avoided in games. For Specialist #9, games in which the child does the activities without a mediator should be avoided. According to her, educational games for rehabilitation should always be **used under the supervision of a mediator.** She adds that many games focusing on math intervention fail to provide arithmetic conceptual and procedural knowledge. She finishes by saying that games are still a good tool to improve children's fluency in math. Specialist #10 says that games which are too long, and without clear rewards, objectives, and challenges should be avoided. According to her, games which **focus solely on the pedagogical content forgetting the ludic** aspect should also be avoided.

Specialists (#2; 3; 6; 12) highlighted that **repetitive content and repetition of mechanical tasks** should be avoided in games. Specialist #2 pointed out that the fact that the activity is done on a computer does not necessarily mean that it will be fun and not monotonous. She added that games should be interactive and should teach content using repetition but with variations. This view was also shared by Specialist #12, who said that a game should have a variety of objectives, not only with respect to its design, but also in relation to its different levels. She explained that because children play the game many times during rehabilitation, if the game is too repetitive they will become tired and uninterested. Specialist #12 added that **extras bonuses,** that is, bonuses which are not related to the game goals and which can make the player lose focus on the task, should be avoided.

Question 6 asked the specialists what they thought games used in neuropsychological rehabilitation must offer them. Their answers are presented below (table 34).

Table 34: Responses to question 6.
Source: the author.

6. What do games used in neuropsychological rehabilitation need to offer you? (e.g. progress evaluation, time per activity, number of mistakes)	
Specialist #1	"Progress, mistakes, average by age, expectations."
Specialist #2	"Accuracy, time per activity, number of errors, error patterns. A way to visualize the child's mistakes and to analyze them qualitatively."
Specialist #3	"Progress evaluation, time, number of mistakes and successes."
Specialist #4	"Number of mistakes, progress evaluation, time spent."
Specialist #5	"Progress evaluation, levels."
Specialist #6	"Number of mistakes, response time."
Specialist #7	"Progress evaluation, number of mistakes, motivational aspects for the child."
Specialist #8	"What I have mentioned before, such as, reinforcement and positive stimuli, so the child does not get discouraged."
Specialist #9	"I think for the type of interventions that I work with it is important to know the time per activity and accuracy. Maybe something that evaluates the type of calculation strategies."
Specialist #10	"The game has to have levels, it should not be very long, and should allow easy access to the performance of the participant in the game."
Specialist #11	"Progress evaluation, types of mistakes."
Specialist #12	"It is essential to have a record of the participant's performance so that it can be analyzed by the mediator after the rehabilitation session. What interests us: progress evaluation, time per activity, successes, and mistakes. I need to know exactly what stimulus and content were presented in each part of the game. For example: Knowing that the child's performance was 100% does not tell me exactly in which part or content of the game the child was good at." (Talking about Number Catcher)

For most of the Specialists (#1; 3; 4; 5; 7; 10; 11; 12), it is essential that a game to be used in neuropsychological rehabilitation offers **Progress evaluation**. In other words, they consider as a requirement that the game system can measure the player's progress and performance in the game activities. Specialist #12 explained that it is essential that the game system records participants' performance data so that it can be analyzed by the mediator. She adds that it is essential to know exactly what stimulus and content were presented in each session of the game, and that only knowing that the child's overall performance was 100% does not tell them exactly in which part or content of the game the child was good at (Talking about Number Catcher).

To have information on **the mistakes made by the player in the game tasks** was also considered a requirement by most of the Specialists (#1;2;3;4;6;7;11;12). Specialists #3 and #12 also considered important to know **the player's number of successes**. For Specialists #2 and #11 it is also essential to have information on the **type of mistake and error patterns of each player,** such as some visual aid that allows a qualitative analysis.

Other aspects of the game considered essential were: information on the duration/time per activity and response time (Specialists #2; 3; 4; 6; 9; 12); information on

player's accuracy and calculation strategies (Specialists #2 and #9); the game should be structured in levels and not very long, so that the mediator can assess the player's performance in each completed level (Specialists #5 and #10).

Besides the requirements aforementioned, a few specialists also alluded to the following: **average responses by age** (Specialist #1), **player's level of motivation** (Specialist #7), **reinforcement and positive stimuli** so as to keep the child engaged (Specialist #8).

As it can be noticed, questions 1 to 6 are rather broad in scope and are concerned with the use of games in neuropsychological rehabilitation in general. **Questions 8 and 9**, however, are specific, and focus on the use of games in the rehabilitation of children with dyscalculia. For that reason, the purpose of question 7 is to identify the relevant specialists.

Question 7 asked the specialists if they had ever worked as a mediator in the rehabilitation of children with dyscalculia or with a mathematical learning disability. If the specialist answered yes, he/she was invited to answer questions 8 and 9. If the specialist answered no, he/she was directed to the last page of the questionnaire. Of the 12 Specialists interviewed, only 3 answered no (see table 35). Thus, 9 Specialists were asked to also answer questions 8 and 9.

Table 35: Responses to question 7.
Source: the author.

7. Have you ever worked as a mediator in neuropsychological rehabilitation of children with dyscalculia or with a mathematical learning disability?	
Specialist #1	No
Specialist #2	Yes
Specialist #3	No
Specialist #4	Yes
Specialist #5	No
Specialist #6	Yes
Specialist #7	Yes
Specialist #8	Yes
Specialist #9	Yes
Specialist #10	Yes
Specialist #11	Yes
Specialist #12	Yes

Question 8 asked specialists what a game used in the rehabilitation of a child with dyscalculia or with a mathematical learning disability should stimulate. Their answers are presented in table 36 and discussed below. Notice that Specialists #1; 3; 5 did not reply to questions 8 and 9 as they did not have experience with this specific user.

Table 36: Responses to question 8.
Source: the author.

8. What should educational digital games stimulate during the neuropsychological rehabilitation of a child with dyscalculia or with a mathematical learning disability? (e.g. specific content, conceptual knowledge from mathematics, progressive activities, repetition)	
Specialist #1	/
Specialist #2	"I believe that it needs to have levels, it can start with the basic arithmetic notions from base 10, and present the concepts and procedures. After that, it needs to progress to more complex knowledge including addition, subtraction, multiplication, and division. Practical concepts are also important

	and need to be present. That is, applicable concepts which allow the child to understand why she/he needs to learn that content."
Specialist #3	/
Specialist #4	"The procedural aspects of math operations, conceptual aspects through examples and mathematics in daily life."
Specialist #5	/
Specialist #6	"Progressive activities in a dynamic way, based on errorless learning."
Specialist #7	"Repetition, aspects from the errorless learning."
Specialist #8	"Everything that was mentioned above, plus positive reinforcement."
Specialist #9	"I believe the games need to stimulate numerical and basic arithmetic skills (number sense, counting, number recognition, base 10 number system, calculation, etc.). Conceptual knowledge and knowledge related to the different steps. The activities need to be presented progressively because mathematics is hierarchically learned. The [game should make] use of concrete and visual examples. Promotion of fluency and revision of the concepts that have been learned previously."
Specialist #10	"Link between quantities and number, comprehension of magnitudes, calculation. It is good when the level of difficulty of the game can be adapted to match the child's level."
Specialist #11	"Repetition, concepts."
Specialist #12	"The game needs to have various contents because the difficulties presented by children vary. The initial levels of the game should focus on simpler contents (e.g. counting, conceptual knowledge of the operations). Then the advanced levels should focus on more complex contents (e.g. arithmetic facts, procedural knowledge of the facts). The games should help us with repetition because through the digital material children are exposed to the repetition of concepts learned earlier in a less tiring way."

- Specialist #2 believes that the **game needs to have levels**, **that is, start with basic content and progress to more complex ones**. For her, the game should start with the basic arithmetic notions (base 10) covering conceptual and procedural knowledge, and progress to more complex arithmetic content (addition, subtraction, multiplication, and division). She also highlighted that it is important to offer practical concepts to the child, so that they understand why they need to learn that specific content.
- Specialist #4, corroborating with Specialist #2, says that the game should stimulate **procedural knowledge from math operations**. For her, **math conceptual knowledge should also be stimulated and** should be taught through examples from daily life.
- Specialist #6 mentioned that the **activities should be presented in a dynamic way**, and should be **based on errorless learning.**
- Specialist #7 also alluded to the **errorless approach to learning. He also mentioned repetition**.
- Specialist #8 said that **positive reinforcement should be simulated**;
- Specialist #9 stated that the game should stimulate the learning of numerical and basic arithmetic skills such as number sense, counting, numbers recognition, base 10 number system, calculation, etc. **Conceptual and step-by-step knowledge were also referred to.** For her, this content should be stimulated **progressively, considering the hierarchical nature of mathematics.** She also highlighted the importance of using **concrete examples,** and added that **the game should promote children's fluency in math and allow them to revise concepts previously learned.**
- Specialist #10 said that **the link between quantitates and numbers, comprehension of magnitudes, and calculation should be stimulated**. For her, in a game, the level of difficulty of the activities offered should correspond to the level of the skills of the children.

- Specialist #11 believes that it is important **to use repetition and stimulate math concepts.**
- Specialist #12 maintained that **the game should stimulate a variety of contents,** since children differ in the difficulties in math they presented. She also maintained that it is important to **start with simpler contents (e.g. counting, conceptual knowledge of the operations), and then progress to more complex ones (e.g. arithmetic facts, procedural knowledge of the facts)**. In addition, for her, **repetition in-game helps the mediator,** because the repetition of concepts learned seems to be less tiring for the child in a game context.

The last question, question 9, asked the Specialists what a game should have in order to be useful for the rehabilitation of a child with dyscalculia or with a mathematical learning disability. The Specialists' responses are presented in table 37 and discussed below.

Table 37: Responses to question 9.
Source: the author.

9. In your opinion what do educational digital games need to be like or need to have, in order to work as an intervention for children with dyscalculia or a mathematical learning disability?	
Specialist #1	/
Specialist #2	"Interactive (e.g. the player can select the characters), have a background story and levels."
Specialist #3	/
Specialist #4	"Mainly, the content of base 10 and the four arithmetic operations."
Specialist #5	/
Specialist #6	"It needs to be dynamic, adaptive, and focuses on errorless learning."
Specialist #7	"A strong theoretical and experimental base."
Specialist #8	"Levels of difficulty, repetition, positive reinforcement, remarkable characters."
Specialist #9	"I believe all the elements mentioned above. I think the game characteristics may vary. However, the aspects mentioned above may not."
Specialist #10	"It should focus on a specific math content, have adaptable levels of difficulty and have as one of its goals to entertain the child."
Specialist #11	"Errorless learning, progressive levels, motivating."
Specialist #12	"The game needs to be interesting, not too infantilized, because the children can be older. It should present the content in a more implicit way (ludic) and in levels, being different from the traditional way of learning. Children show more interest if the content is preented as part of the game's goal, based on the game's context. (e.g. if the game explicitly asks the child to solve a math calculation, they do not engage with it. The game is more interesting if the learner needs to solve a math calculation to help a character while shopping at the supermarket)"

- Specialist #2 mentioned that the game **should be interactive (e.g. allow the player to select the characters), have a background story and levels.**
- Specialist #4 referred to the content of the game, and argued that the game should **cover base 10 and the four arithmetic operations.**
- Specialist #6 said that the game needs to be **dynamic, adaptive and based on the errorless learning approach.**
- Specialist #7 pointed out that the game must have a strong theoretical and experimental base.
- Specialist #8 said that **levels of difficulty (e.g. ladders), repetition, positive reinforcement (feedback), and remarkable characters** are very important in a game.

- Specialist #9 stressed that the game should stimulate the learning of a specific content (e.g. numerical and basic arithmetic skills (number sense, counting, numbers, number recognition, base 10 number system, calculation, etc.). For her, the content should include conceptual and step-by-step knowledge. She added that visual and concrete examples should be used to promote fluency through progressive and hierarchical levels. For her, the game characteristics can vary, the content, however, should not vary.
- Specialist #10 believes that the game needs to **address a specific mathematical content, offer different levels of difficulty and have as its goal** to entertain the child.
- Specialist #11 believes the game should be based on errorless learning, have progressive levels, and be motivating.
- Specialist #12 thinks that the game **needs to be interesting for the child, not too much infantilized.** She explains that the game needs to **present the content implicitly** because children are more interested when the required tasks in the game **are presented as part of the ludic environment (e.g. with goals, levels, characters).**

5.1.3 Drawing Conclusions

This section considers the last stage of the analysis process. It looks at how the data collected relate to the second specific goal of this dissertation: **To investigate, from the perspective of specialists in rehabilitation, what the requirements to develop educational digital games for children with dyscalculia in neuropsychological rehabilitation are.**

In order to fulfill this goal, field research with 12 specialists in rehabilitation was carried out. Through a qualitative questionnaire, the Specialists consulted were asked to express their views on the requirements for games in the dyscalculia rehabilitation context. The following is a summary of the **specialists' profile:**

- Most Specialists are from Belo Horizonte, Minas Gerais (Brazil);
- Most of them have a background in Psychology;
- Most of the specialists (6) have a good knowledge of the topic, but are not experts. Only 3 Specialists are experts in the topic. 3 Specialists are familiar with only some aspects of the topic;
- The majority of the specialists (7) have used an educational game during neuropsychological rehabilitation, which represents 58% of the sample.

Regarding the use of a game in rehabilitation, it was identified that:

- All specialists consider the use of an educational digital game in rehabilitation as something positive, important or interesting;
- The Specialists acknowledge the motivational and engaging potential of digital games, and appreciate how patients can benefit from their use;
- For some Specialists, games are a current and a familiar technology to children, and for that reason they usually catch their attention;
- For most Specialists, games can exercise important aspects of the intervention (e.g. attention, work memory, focus, impulse control);

The following is a summary of what the Specialists (based on their experience of working with children from 9 to 13 years old) considered that **games for rehabilitation SHOULD HAVE:**

- **Levels:** it is through levels that children can progress in the game. Levels should have a progressive and linear degree of difficulty (from easy to more complex tasks). For some Specialists levels also provide reinforcement of the content presented to the children;
- **Rewards:** these are considered positive stimuli, and can take the form of an award, or positive feedback (e.g. golden stars). The children are rewarded by the game system when they progress in the game, through its levels and challenges. Rewards can be seen as a type of feedback. However, a reward is usually more elaborated than simple positive feedback;
- **Feedback:** it is some positive stimulus in the game based on the child's performance during and after a task;
- **Interactivity:** it refers to how much interaction the game offers to the child. For example, the manipulation of a character, or the use of a touchscreen on a tablet;
- **Challenges**: they refer to how difficult or challenging the game activities are.
- **Well-defined goals:** the purpose of the game and its tasks should be clear;
- **Adaptivity:** the level of difficulty of the game needs to be adaptive so as to match the level of the skills of the child;
- **Repetition:** it is important in the training of math problems, since these problems need to be presented to children in different ways;
- **Novelty:** the game should offer new things during the intervention session;
- **Ludic environment:** the game needs to be part of a ludic environment (e.g. with goals, levels, remarkable characters, background story), rather than just a tool to solve math problems;
- **Other aspects mentioned were:** the game needs to be fun, colorful and motivating. Moreover, it must have a character or an animated cartoon.

What follows is a summary of what the Specialists (based on their experience of working with children from 9 to 13 years old) considered that **games to be used in rehabilitation SHOULD AVOID:**

- Requiring access to the internet in order to be played;
- Sounding or looking like a lesson (math activities too explicitly presented in the game);
- Aggressiveness and violence;
- Lacking in theoretical or statistical base;
- Excessive negative stimuli;
- Being used with no supervision from a mediator;
- Neglecting to train arithmetic conceptual and procedural knowledge;
- Being too long, without clear rewards, objectives, or challenges;
- Focusing solely on the pedagogical content forgetting the ludic aspect;
- Using too much repetition, monotonous and mechanical tasks;
- Extras bonus (which are not connected with the content of the game);

- Being used as the only tool in the rehabilitation;
- Being too infantilized.

Based on the Specialists' responses, the following has being identified as what the game needs to offer the specialist during neuropsychological rehabilitation:

- **Progress evaluation:** the game system needs to be capable of measuring players' progress and performance in the game activities. This evaluation should include information on the mistakes made by the player, that is, the type of mistakes made and the error patterns of each player, as well as information on his/her successes in the game tasks;
- **The time per activity** or response time: the game should keep a record of the players' response time in each of the activities, and of how accurate they were;
- **A hierarchical structure:** the game should offer short and different levels, so that the mediator can access information on the players' performance in each completed level;
- **Other requirements identified were:** the game should be able to measure the players' average responses by age, and the level of motivation of the player; the game should use reinforcement as a positive stimulus to keep the child engaged.

Through this field research it was also possible to identify what educational games used in rehabilitation should offer children, particularly those with dyscalculia:

- **The game needs to have levels,** starting with basic content and moving on to more complex ones (following the hierarchy of math). These levels should be **based on errorless learning**, **using repetition with novelty as part of the training, and positive reinforcement as feedback;**
- **As regards content, according to the Specialists, the game should cover** numerical and basic arithmetic skills, which includes number sense, counting, number recognition, base 10 number system, calculation, addition, subtraction, multiplication, and division. The game should also **cover math conceptual and procedural knowledge (the step-by-step);**
- The game should **provide children with an understanding of why they need to learn that specific content.** Additionally**, the game should use concrete and visual examples from daily life;**
- The game should promote **math fluency** in children and allow **revision and consolidation of concepts previously learned**.

In conclusion, this section looked at the requirements for an educational game to be used in neuropsychological rehabilitation according to the specialists. Figure 43 below offers a summary of the information presented in this section.

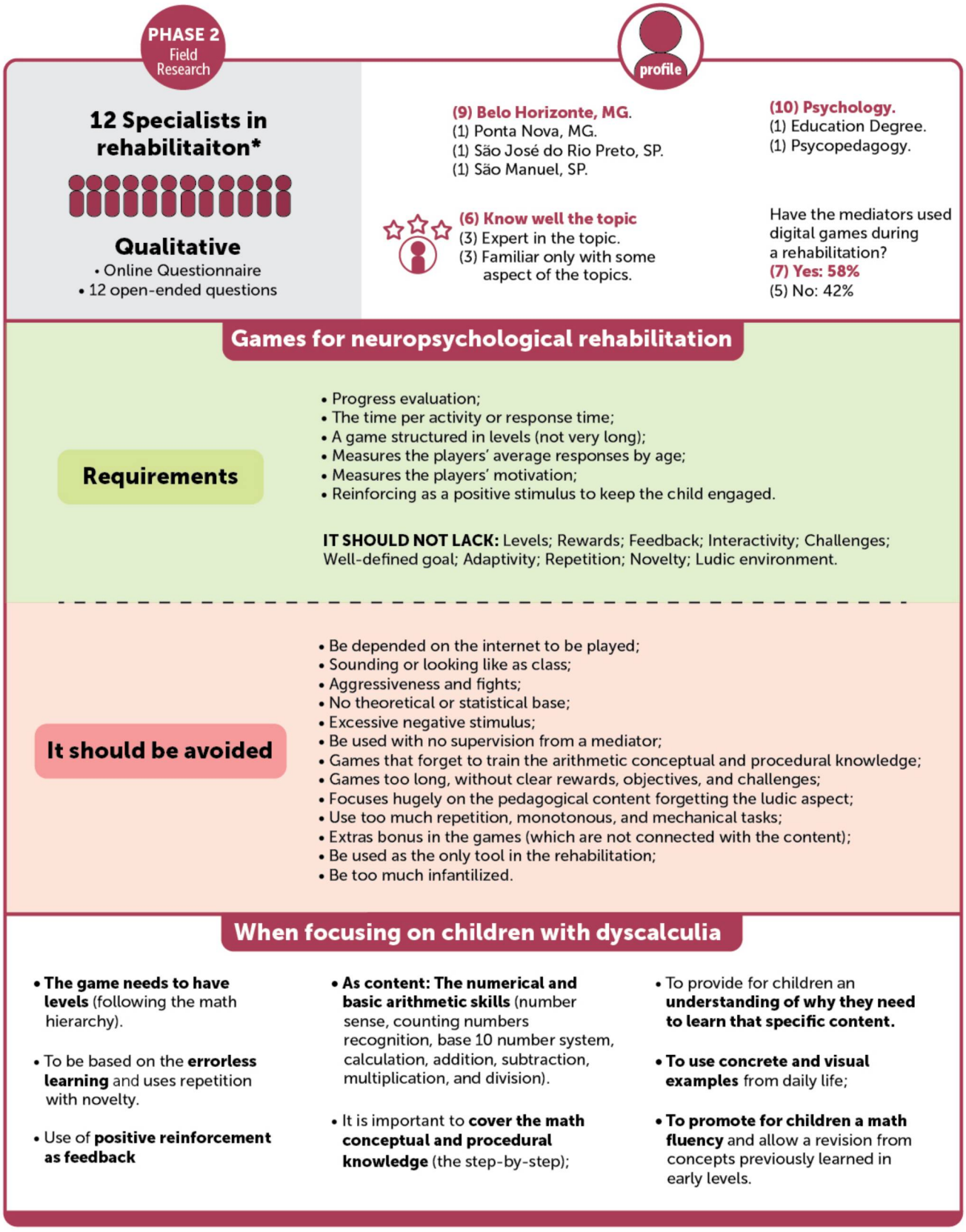


Figure 43: Summary of the specialists' data.
Source: the author.

5.2 Field research with game developers

This section presents the analysis of the answers provided by 41 Brazilian game developers. The data was gathered through a questionnaire composed of closed-ended questions. The questionnaire was administered using the tool Google Forms, during the SBGames[25] 2017 (Curitiba- Brazil). This stage of the field research corresponds to the 3rd specific goal of this dissertation, namely: **to investigate what motivational game elements are used by game developers to promote player motivation, and how these elements are set up during an educational game project. Also, to contrast this information with the data from the literature.**

5.2.1 Data organization

Although Google Forms exported the responses from the questionnaire into an Excel sheet, further organization of the data was necessary before starting the analysis process. Thus, the software Excel was used to **organize the data** into specific sheets in the first instance. Although simple, this step proved to be essential for the analyses process.

5.2.2 Data reduction & Qualitative discussion

This section discusses two steps of the analysis process: Data reduction and Qualitative discussion. These steps are closely related and therefore better described together. For each question of the questionnaire, in addition to the qualitative discussion, a data visualization is offered, considering the sample of 41 Brazilian game developers. The questionnaire was composed of 12 closed-ended questions:

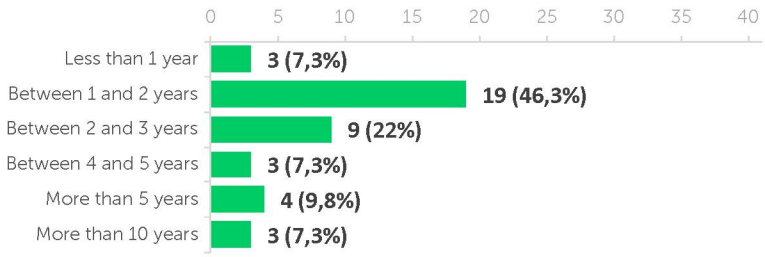
- 4 questions about the game developers' profile and experience;
- 8 questions about game elements and their connection with players motivation.

The first four questions were concerned with the participants' profile, and as such asked them about their experiences as game developers. The participants' profile is relevant because it helps to contextualize the questionnaire responses.

Question 01 (Chart 2) asked the developers how much experience they had with educational games. Nearly half of the respondents (19 developers) said that they had between 1 to 2 years, which represents 46,3% of the sample. 09 developers said they had between 2 and 3 years of experience (22%), and 04 developers said they had more than 5 years of experience (9,8%). 03 developers (7,3%) had less than one year of experience, and 03 developers (7,3%) had more than 10 years of experience.

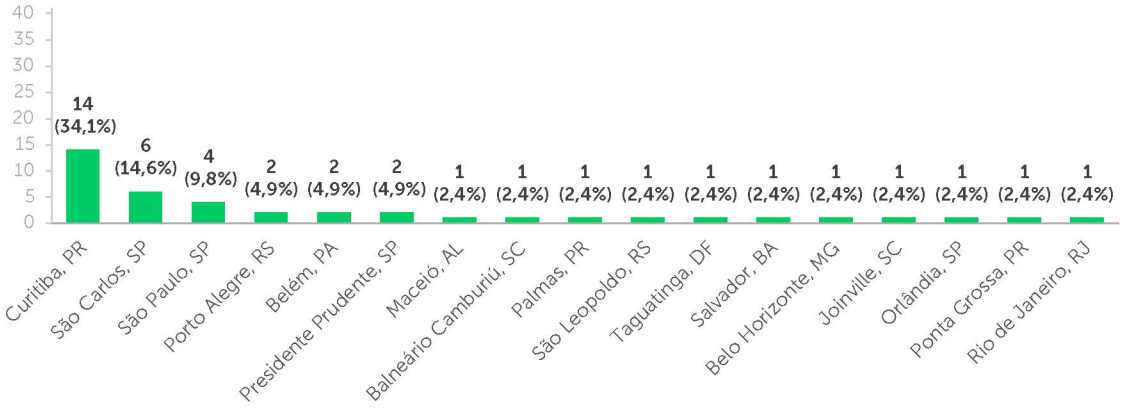
[25] SBGames (Brazilian Symposium on Computer Games and Digital Entertainment) is the largest academic event for games and digital entertainment in Latin America. The Brazilian Computer Society has been organizing the event since 2004. The 2017 edition is available at <http://www.sbgames.org/sbgames2017/> (Accessed on 2018, March 1).

Chart 2: Question 01, how much experience the developers have with educational games.
Source: the author based on the questionnaire responses.



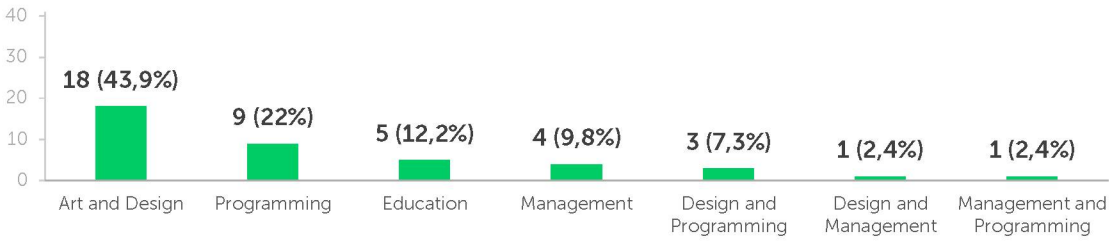
Question 02 (Chart 3) **asked participants where they were from.** The answers provided showed that the developers were from different parts of Brazil. Most of the participants were from Curitiba-PR Brazil (14 participants - 34,1%), São Carlos-SP Brazil (06 participants - 14,6%), and São Paulo-SP Brazil (04 participants - 9,8%). Although the sample was small for a statistical analysis, the fact that the developers were from different areas of the country was of significance for the research.

Chart 3: Question 02, places where the sample is from.
Source: the author based on the questionnaire responses.



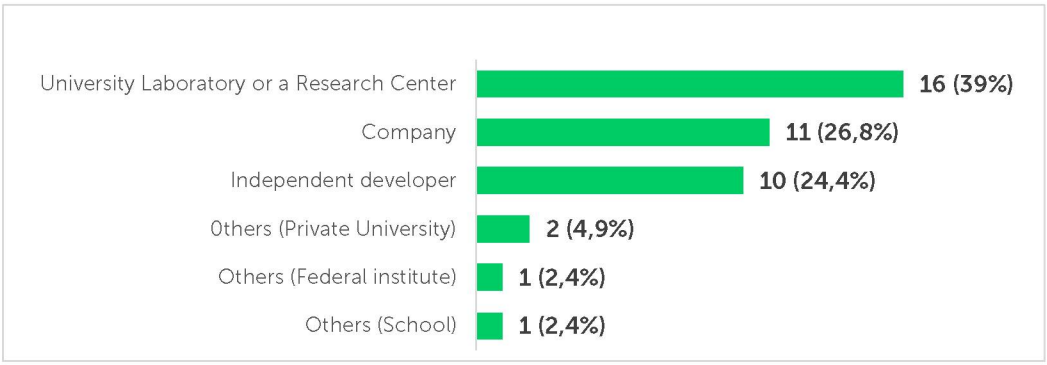
Question 03 asked participants in what field of educational digital games they worked. Chart 4 shows that most of the developers (18) worked in the Art and Design field (43,9%), 09 developers worked in game programming (22%), 05 in the educational field (12,2%), and 04 in the management field (9,8%). It can also be seen that 05 developers worked in two different fields at the same time, which represents 12,2% of the sample. Mattar (2010) observes that it is often the case that in educational game companies one professional is responsible for several aspects of the game development. According to him, this is due to the small number of professionals in their teams.

Chart 4: Question 03, the educational digital game field in which the developers work.
Source: the author based on the questionnaire responses.



Question 04, which can be considered an extension of question 3, asked participants what their place of work was. Chart 5 shows that most of the developers (16) worked at a university laboratory or a research center (39%), 11 developers worked for a company (26,8%), and 10 worked as independent developers (24,4%). Additionally, 04 participants (9,6%) worked as teachers in schools, universities, and/or federal institutes, where they provided support to students learning about and/or developing educational games.

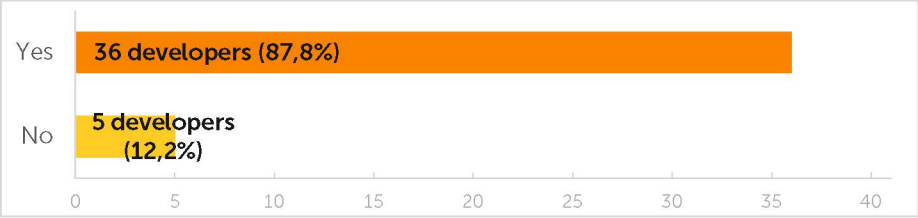
Chart 5: Question 04, developers' place of work.
Source: the author based on the questionnaire responses.



Questions 5 to 12 were concerned with the motivational elements of games and how these are set up by the developer. Each question and the answers provided are discussed below.

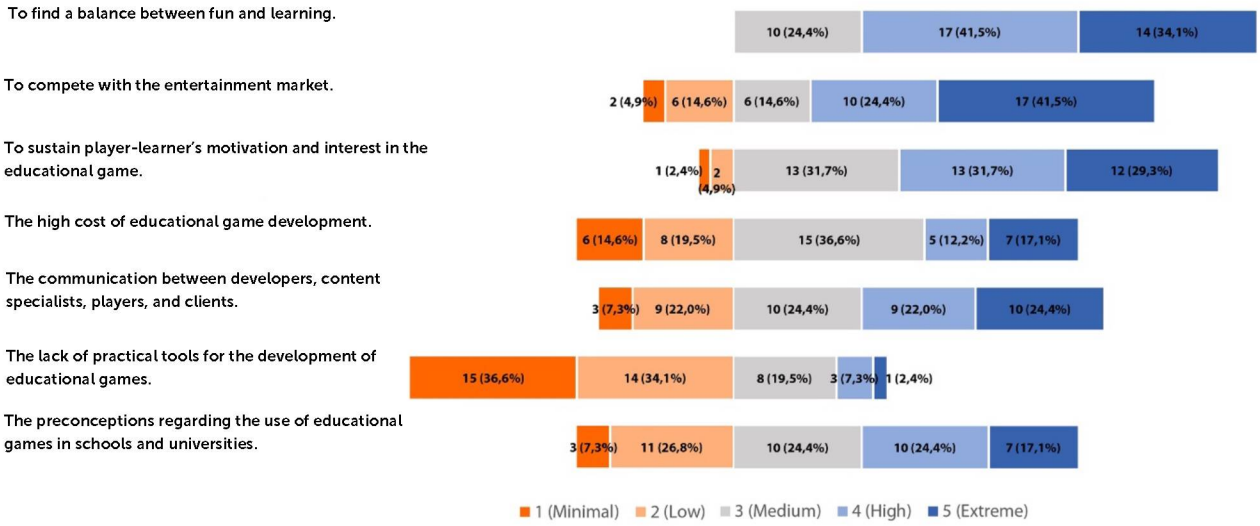
Question 05 asked the participants whether they thought that the development of a digital educational game was a complex task. As shown by Chart 6, most of the developers (36) considered a complex task to develop an educational digital game capable of providing and sustaining players' motivation, which represents 87,8% of the sample. On the other hand, 05 developers (12,2%) did not consider this a complex task.

Chart 6: Question 05, whether or not to develop educational games is a complex task.
Source: the author based on the questionnaire responses.



In questions 06 and 07 a Likert scale was used. Question 06 asked developers to rate the level of difficulty of the challenges developers are usually presented with during the process of developing an educational game. Participants were presented with seven potential challenges and asked to rate each one according to their level of difficulty: (1) minimal; (2) low; (3) medium; (4) high; (5) extremely. The results obtained are shown in Chart 7.

Chart 7: Question 06, developers' assessment of potential challenges in the development of digital games.
Source: the author based on the questionnaire responses.



The majority of the developers rated "to find a balance between fun and learning", "to compete with the entertainment market" and "to sustain player-learner's motivation and interest in the educational game," as having a high or extreme level of difficulty.

"To find a balance between fun and learning" was considered as of a high level of difficulty by 17 developers (41,5%), and extreme level of difficulty by 14 developers (34,1%). It was the only aspect not to be assessed as having minimal or low level of difficulty by any of the respondents. These results confirm what is presented in the literature. Authors such as Bjorner and Hansen (2010); Mayer and Johnson, (2010); Rooney (2012); Mayer (2014) have previously claimed that **to find a balance between fun and learning** is one of the main challenges in designing educational games.

"To compete with the entertainment market" was considered extremely difficult by 17 developers (41,5%), and as such, the most difficult challenge according to the developers. A distinction is usually made between educational games (based on a pedagogical content) and games used solely for entertainment (without a pedagogical content). Mattar (2010) notes that educational games are often considered boring and not

fun for players. According to Chamberlin (2003), this is because in educational games the player's preferences are not taken into account. Chamberlin adds that players see educational games negatively, and that this is due to the absence of fun elements in these games. Portugal (2009) says that the learning process needs to be pleasant and motivating for the learner. Thus, the entertainment and fun aspects of the game should not be ignored.

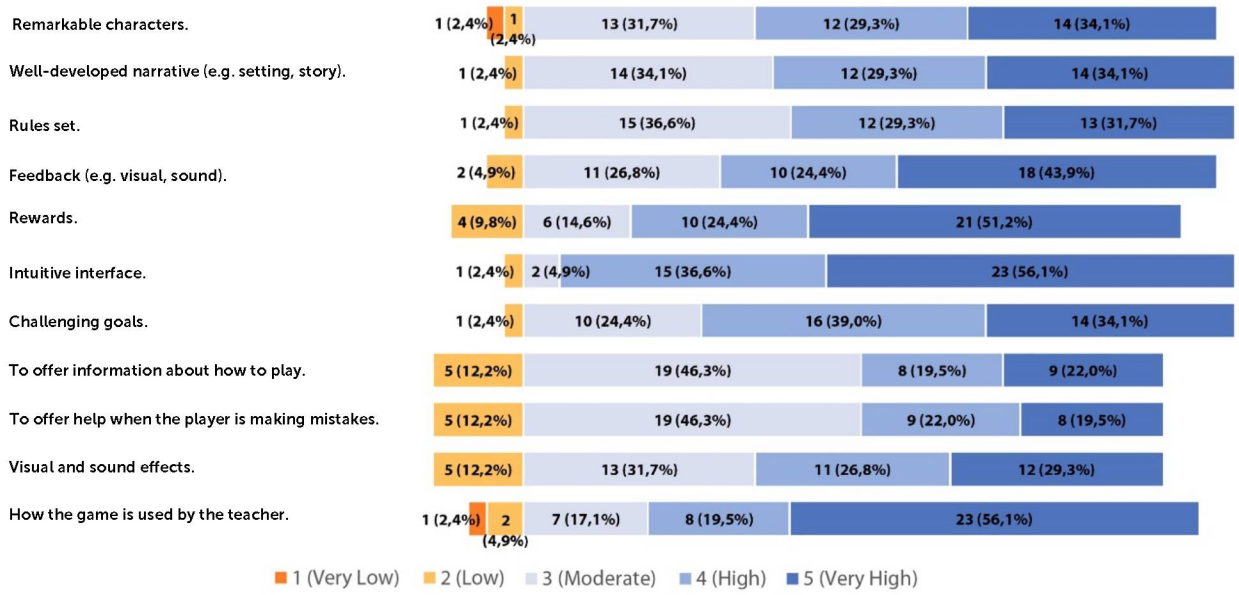
"To sustain the player-learner's motivation and interest in the educational game" was also considered of high or extreme difficulty by a number of respondents. However, as shown in Chart 7, opinions were divided. 13 developers (31,7%) considered it as of medium difficulty, another 13 developers (31,7%) considered it as of high difficulty, and 12 developers (29,3%) considered it as of extreme difficulty. Alves and Battaiola (2011) point out that players' intrinsic motivation changes continually, hence it is difficult to sustain the initial intrinsic motivation throughout the educational game.

Opinions were also divided with regard to "the high cost of educational game development", "the communication between developers, content specialists, players, and clients" and "the preconceptions regarding the use of educational games in schools and universities". 15 developers (36,6%) considered **"the high cost of educational game development"** as of medium difficulty, 7 developers (17,1%) considered it of extreme difficulty, and 6 developers (14,6%) considered it as of minimal difficulty. **"The communication between developers, content specialists, players, and clients"** was considered of extreme difficulty by 10 developers (24,4%). Another 10 developers (24,4%) considered it as of medium difficulty and 9 developers (22%) as of low difficulty. Finally, a similar pattern can be seen in the way **"the preconceptions regarding the use of educational games in school and universities"** was rated. 11 developers (26,8%) considered it as of a low level of difficulty, and 10 developers (24,4%) considered it as of medium difficulty. On the other hand, 10 developers (24,4%) considered its level of difficulty as high and 7 developers (17,1%) as extreme.

Finally, of the seven challenges presented, **"the lack of practical tools for educational game development"** was considered the least difficult challenge. The results show that 15 developers (36,6%) considered it as of minimal difficulty, and 14 developers (34,1%) as of low difficulty. Only 3 developers (7,3%) rated it as highly difficult, and one developer (2,4%) as extremely difficult. These results corroborate with the literature. Almeida and Silva (2013) have shown that the game industry's tools and methods have been enhanced over the years. For instance, new engines for software developers, 3D modeling software, sound creation tools, new computing technologies, etc. Also, according to Fleury, Sakuda, and Cordeiro (2013), Brazilian game companies are flourishing thanks to the advances in broadband internet, and to easier access to development tools. In the past, the development of digital games focused solely on consoles and desktops, which required an expensive development process with limited tools. The popularization of smartphones and tablets have greatly improved this scenario. However, according to Almeida and Silva (2013), despite this improvement in software development, little has changed with regard to game design development. These authors observe a lack of formal, standard and useful game design tools, such as vocabulary lists and game design documents. In this context, Neil (2012) clarifies that although researchers have proposed formal and semi-formal game design models, the game design community still makes very little use of this scientific knowledge. Neil also calls attention to the lack of evidence regarding the dialogue between practitioners and researchers. Even in the research community, this is not very evident. Thus it can be concluded that the lack of game design tools, both conceptual and concrete tools, constrain the advancement of the design process.

In question 07 a Likert scale was also used. This time the scale was used to measure how strongly respondents felt with regard to eleven game elements. Participants were asked to rate the level of importance of these eleven game elements according to how effective they were in fostering and sustaining the player's motivation when interacting with an educational digital game. The scale range used was: 1 (Very Low); 2 (Low); 3 (Moderate); 4 (High); 5 (Very High). Chart 8 shows the results and the patterns which emerged.

Chart 8: Question 07, developers' opinion about the importance of game elements.
Source: the author based on the questionnaire responses.



"Feedback" (18 developers, 43,9%), **"Rewards"** (21 developers, 51,2%), "**Intuitive interface"** (23 developers, 56,1%) and **"How the game is used by the teacher"** (23 developers, 56,1%) were considered of very high importance by most of the developers.

Of the 11 elements, "**Intuitive interface"** and "**How the game is used by the teacher**" were the ones considered the most important by the developers. Both these elements are classified as formal elements[26] in this dissertation, based on Fullerton, Swains, and Hoffman (2004) and Järvinen (2008). "**Rewards"**, on the other hand, is classified as a dramatic element, and of the dramatic elements[27] considered, it was the only one rated very important by the developers.

The dramatic elements **Remarkable characters; Well-developed narrative; and Challenging goals** showed a different pattern. As it can be seen in Chart 8, these dramatic elements were similarly rated. All three were considered as having either moderate, high, or very high level of importance. **"Remarkable characters**" was regarded as of low and very low level of importance by only 02 developers. The formal elements **"Rules set",** and **"Visual/Sound effects"** also presented similar ratings.

Regarding the dramatic elements, the results differ from the literature. According to Fullerton, Swains, and Hoffman (2004) the dramatic elements are required to stimulate the

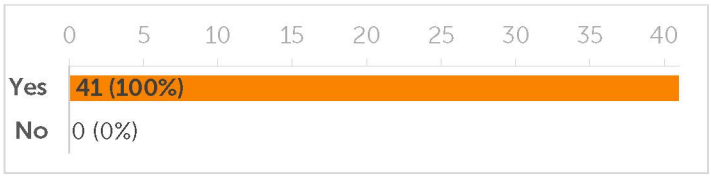
[26] **Formal elements:** Component; Rules; Players; Resources; Objectives; Procedures; Mechanics; Outcome; Information; Theme; Interface; Boundaries; Context. **Dramatic elements:** World Building; Narrative; Conflict; Challenge; Play; Premise; Character; Dramatic Arc; Rewards - (see chapter 2 for further details).

player's imagination, emotion, and motivation in the game. Furthermore, the guidelines (e.g. Alfadhli and Alsumait, 2015), heuristics (e.g. Desurvire and Wiberg, 2009) and recommendations (e.g. Chamberlin, 2003) available in the literature, all emphasize the relevance of these elements to the design of digital games, particularly in what concerns player's experience. Hence, it should be stressed that more importance must be given to these elements in the design of educational digital games.

Lastly, the elements **"to offer information about how to play"** and **"to offer help when the player is making mistakes"** were rated as being of a moderate level of importance by almost half of the respondents (19 developers, 46,3%). Some developers considered these elements as of high or very high importance. Again, these results differ from the literature. Authors such as Desurvire and Wiberg (2009) consider these elements as part of their heuristics to evaluate game playability. Moreover, according to Alfadhli and Alsumait (2015), these elements are an important part of the guidelines for the design of educational digital games.

Question 08 was concerned with user participation during the development of the game, and asked participants whether they thought the player could help with the set up of the motivational elements of the game. As it can be seen in Chart 9, all participants answered yes to this question. According to all participants, users could help the development team to set up the motivational game elements in educational projects.

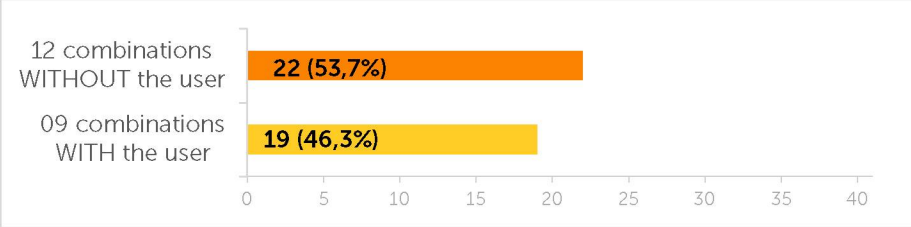
Chart 9: Questions 08, developers' opinion about whether the player can help developers during the development of educational games. Source: the author based on the questionnaire responses.



This is an interesting result. This is because although the user-centered design approach is often considered as a requirement for designing educational games (e.g. KHALED and VASALOU, 2014, KHALED et al. 2014), it is not as yet fully applied in game design, especially when compared with other fields, such as human-computer interaction. Chamberlin (2003); Farrel and Moffat (2014) warn that one of the main challenges in the design of educational games is to guide the development process based solely on the team's intuition. **Question 09 of the questionnaire** addresses this issue.

Question 09 inquiries into how the developers set up the motivational game elements. That is to say, it aims to find out if developers and their development teams use a user-centered design approach. Participants were presented with six options and could choose as many options as they wanted. They could also provide their own answer. The answers to this question produced 21 different combinations. As it can be seen in Chart 10, 54% (12 combinations by 22 developers) do not consider the user during the development process. In contrast, 46% (9 combinations by 19 developers) consider the user in the development process (Chart 10).

Chart 10: Questions 09, how the developers set up the game elements.
Source: the author based on the questionnaire responses.



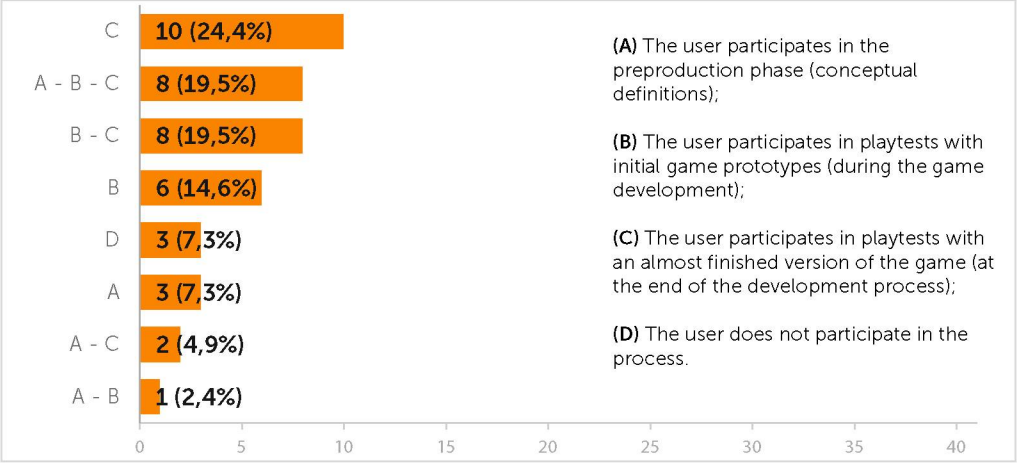
Based on the answers to **questions 08 and 09**, it can be concluded that developers recognize the value of considering the user in the game development process, although most development teams are yet to apply a user-centered approach.

As regards the combinations, the most common combinations (12%) used in the set up of the game elements were (Chart 11): (a) The development team using a creative process (e. g. artists, programmers, managers); (b) The development team with teachers or content specialists; (c) The development team with the client of the project; (d) The development team and theoretical guidelines by well-known developers (e.g. books, papers); (e) The development team and successful entertainment games; (f) The development team and information gathered with users (during the development process).

Chart 11: Question 09, the main combinations.
Source: the author based on the questionnaire responses.

Question 10 sought to find out in what moment of the game development process the player takes part. Similarly to question 9, question 10 offered a number of options and participants could choose as many options as they wished, or provide their own answer. The answers, as shown in Chart 12, produced eight different combinations. In these combinations, 10 developers (24,4% of the sample) affirmed that the user only takes part in playtests with the almost finished version of the educational game.

Chart 12: Question 10, when the player usually takes part in the development process of an educational game.
Source: the author based on the questionnaire responses.



Based on these data, it can be inferred that when developing an educational game, most of the developers tend to rely solely on their intuition, and only consult the user at the end of the development process. Although the developers' experience and intuition are important to the design process, a design process based uniquely on these could negatively affect some important aspects of the game development process (FARRELL and MOFFAT, 2014; CEZAROTTO, BATTAIOLA, and KISTMANN, 2017). If the user is consulted only at the end of the project, their contribution to the development process of the game will be very limited, and they will have a small impact on the game.

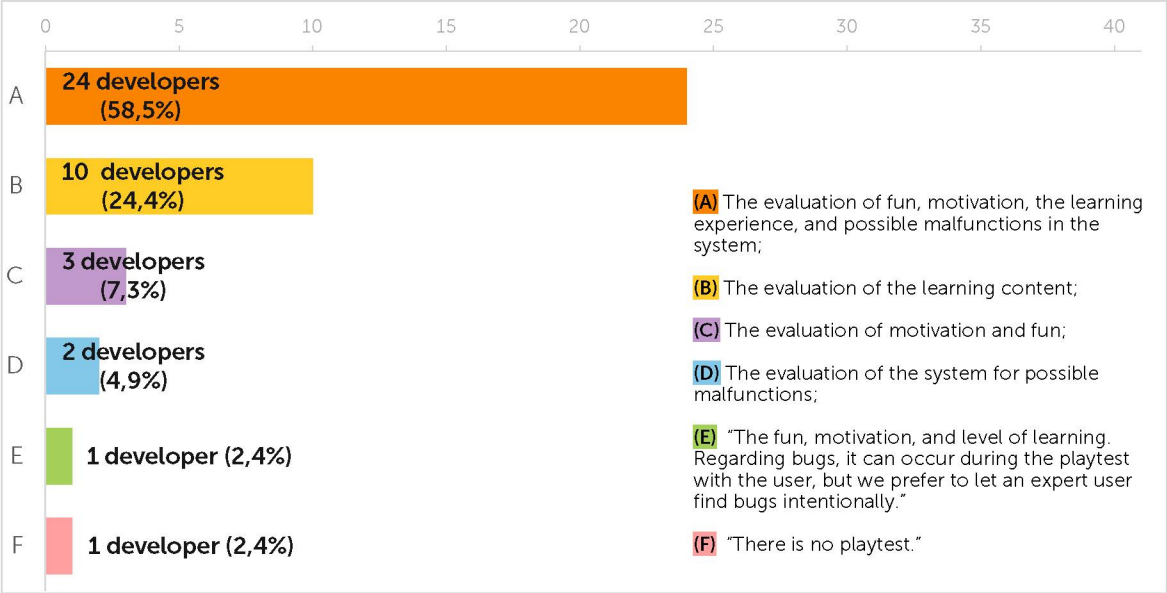
User participation should occur throughout the game development process, at distinct stages of the development. Some models and orientations to promote and assist with user participation have been proposed, for instance, Chamberlin, Trespalacios and Gallagher (2012); Khaled and Vasalou (2014). How much user participation is possible, however, varies from project to project. At times user participation is not at all possible. For instance, a limited budget and tight deadlines can be seen as obstacles to user participation in the development process. However, the development team should always look for ways to include the user in the process, as well as doing what is suitable for the team. Fullerton, Swains and Hoffman (2004) clearly state that games are developed for the user (player), and that without the user games do not make any sense.

Question 11 is concerned with what aspects are evaluated and/or verified with the user during a playtest of an educational game. The answers show that during a playtest, most of the developers (24) evaluate the fun aspect, motivation, learning outcomes, and possible malfunctions in the system. This represents 59% of the sample. 10 developers (24,4%) said that they only evaluate the learning content; 03 developers (7,3%) only evaluate the motivation and fun aspects; 02 developers (4,9%) only check the system for possible malfunctions (Chart 13).

The remaining two respondents did not choose any of the options provided but gave their own answers. Their answers offered some interesting insights into the topic. Regarding what is evaluated, one developer said: *"the fun, motivation, and level of learning"*. Regarding identifying possible malfunctions, his answer was: *"it can occur during the playtest with the user, but we prefer to let an expert user find bugs intentionally."* This answer offers a good way to optimize time during the development process, since an

expert player can easily identify malfunctions in the system. This, however, does not mean that testing the game with the real target-player would no longer be a requirement. The other developer's answer to the question was: "*there is no playtest*". The implications of this answer to game development will be discussed below.

Chart 13: Questions 11, what the developers usually evaluate in a playtest.
Source: the author based on the questionnaire responses.

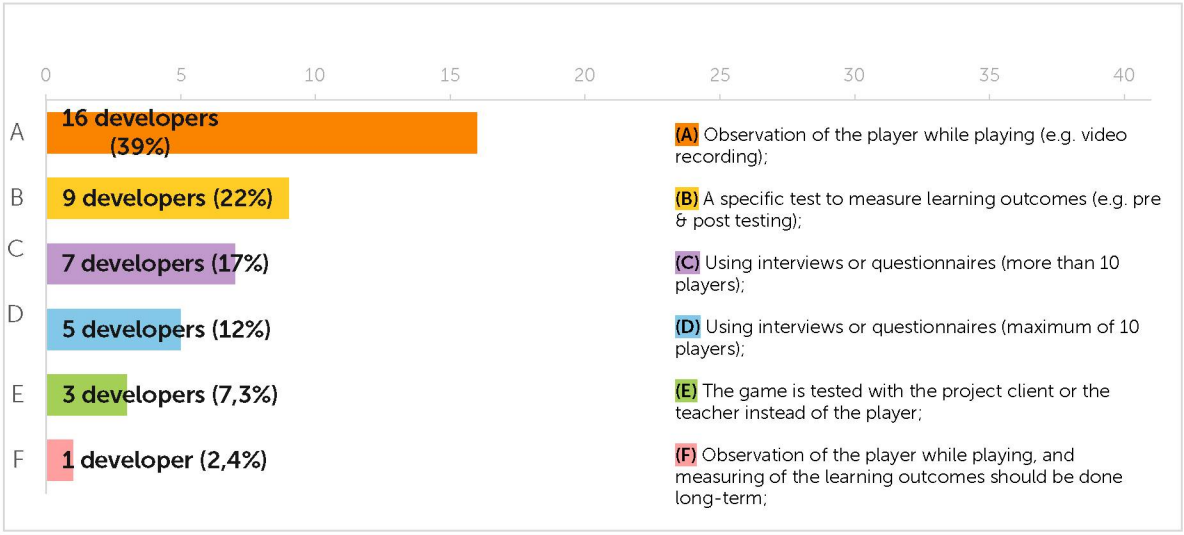


Lastly, **question 12 sought to find out how the developers and their development teams gathered data during a playtest with users.** Chart 14 shows that the vast majority, 16 developers (39%), conduct an observation of the player while playing the game (e.g. video recording). 09 developers (22%) carry out specific tests to measure the learning outcomes (e.g. Pre & Post testing). 07 developers (17,1%) conduct interviews or apply questionnaires with more than 10 players. 05 developers (12,2%) also conduct interviews or apply questionnaires with a sample of fewer than 10 players.

Of the 41 developers consulted, 03 (7,3%) do not test the game with the players. Instead, they test the game with the project client or the teacher. Moreover, one of these three developers said that he did not carry out a playtest at all. This absence of playtesting with the player is cause for concern. Although the educational game industry has thrived over the past years, thanks to advances in technology and to easier access to development tools, some basic concepts, such as playtest with the player and user-centered design, have not been adequately developed in the game field. In the 1st Census of the Brazilian industry of digital games, for instance, Fleury, Sakuda, and Cordeiro (2013) pointed out that a considerable number of game companies do not use any methodological process to guide the game development. For these authors, this lack of professionalization of the game industry in the country is cause for concern.

Another developer, who also provided their own answer, said that "the observation of the player while playing, and the measuring of the learning outcomes should be done long-term". The assessment of the learning outcomes over a period of time is indeed something that is done in most development teams. It is nevertheless, still an area in need of further research.

Chart 14: Question 12, how the developers and their development teams gathered data during a playtest with users. Source: the author based on the questionnaire responses.



5.2.3 Drawing conclusions

Based on the data organization, reduction, and a qualitative discussion correlations can be made between the data gathered and the 3rd specific goal of this dissertation, namely: **To investigate what motivational game elements are used by game developers to promote player motivation, and how these elements are set up during an educational game project. Also, to contrast this information with the data from the literature.**

For the investigation with game developers, based on the literature review, game elements (formal and dramatic) which are seen as capable of promoting and sustaining players motivation were considered. Through a questionnaire, 41 developers were asked to say how important they considered each one of these elements to be. They were also asked to provide information on how they set up these elements in the design process. The profile of the developers consulted is summarized below:

- They have between 1 and 2 years of experience in the design of educational games;
- They are from different parts of Brazil, mainly from Curitiba - Paraná;
- Most of the sample work in art and design. The majority of the developers work at university laboratories, companies, or as independent developers.

Overall, the developers considered all the given game elements as being of at least moderate importance for player's motivation in educational games. **The elements considered as having very high level of importance were:**

- Feedback (visual or sound);
- Rewards;
- Intuitive interface;
- How the teacher uses the game.

It is important to notice that, although "how the teacher uses the game" is not strictly speaking a game element, it directly influences players' motivation when it comes to using an educational game.

As for the elements given a **low level of importance rate**, these were:

- To offer information about how to play
- To offer help when the player is making mistakes.

Regarding how the developers set up these game elements, the results show that:

- Most of the developers considered as complex to develop an educational game capable of promoting and sustaining player's motivation;
- All developers agreed that players can help in the set up of the game elements, although more than half of these developers do not use a game design process centered on the player;
- Opinions differ with regard to player's participation in the game design process. 10 developers say that they refer to players only in playtests with the almost finished version of the educational game. 08 developers consult the user in playtests with the initial game prototypes and with the almost finished versions. Another 08 developers turn to the user in the pre-production phase, and in playtests with initial prototypes and with the almost finished version of the game;
- Players usually take part in the design process through playtesting. In these playtests, players are usually asked to evaluate the fun aspect of the game, motivation and learning outcomes, and to identify possible malfunctions in the system;
- Playtests provide developers and their teams with an opportunity to gather data. For example, by observing the player while playing the game (e.g. video recording);

These results show that player's participation in the development of educational games is still minimal, and not always effective. This state of affairs can diminish the motivational and teaching potential of these games. Figure 44 offers a visual synthesis of the data from the field research with the game developers.

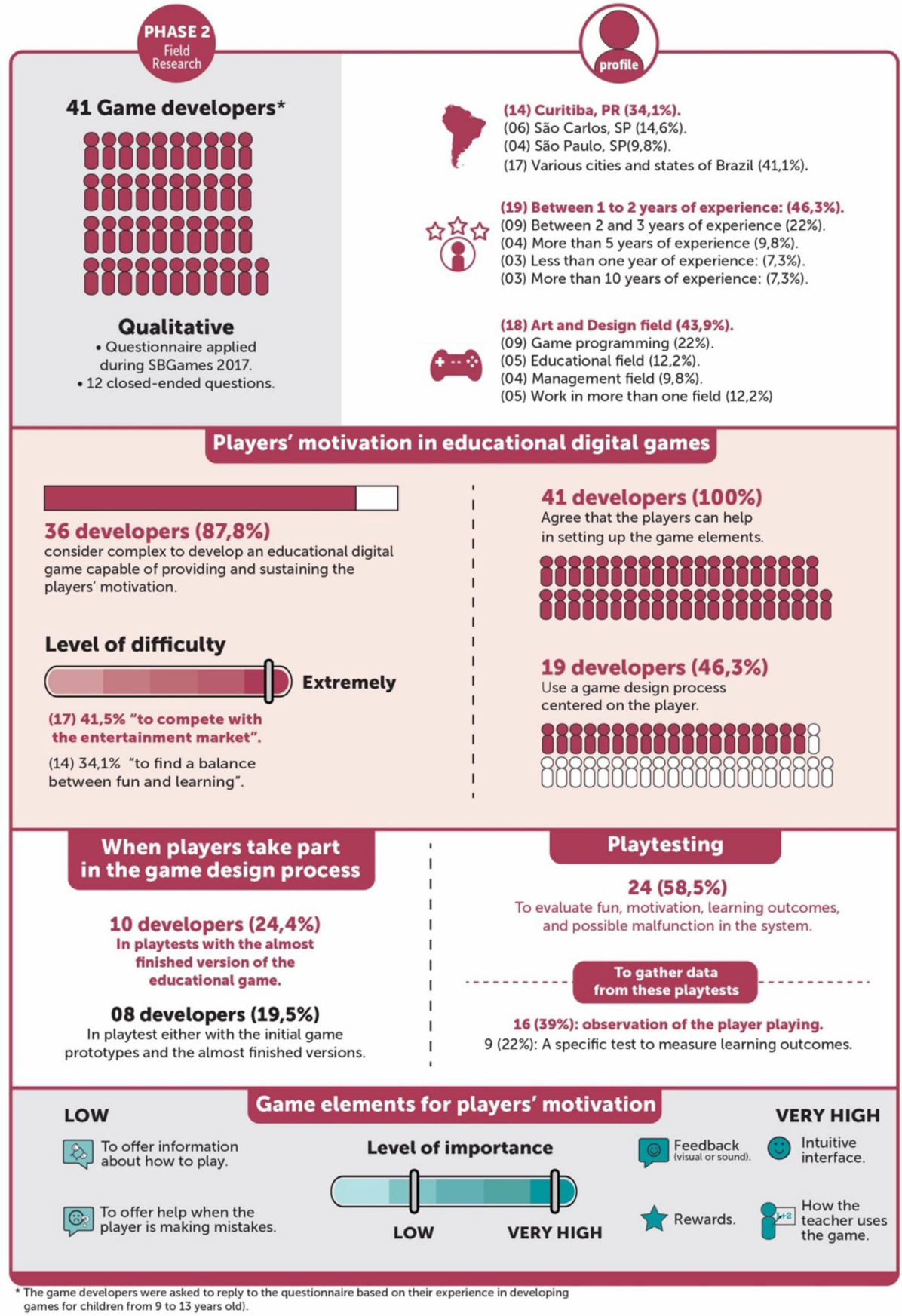


Figure 44: Summary of the game developers' data.
Source: the author.

5.3 Summing up

This chapter presented the analysis process and the results of both parts of the field research. The first part of the field research focused on the specialists in rehabilitation, whereas the second part focused on the developers of educational games.

In **the first part of this field research, 12 Brazilian specialists in rehabilitation** (Mediators) were asked to respond to an online questionnaire. The aim was to identify, based on these specialists' experience in working with children with dyscalculia, what features an educational game should have in order to be used as an intervention. This part of the investigation aimed to fulfil the **second specific goal of this dissertation**. What follows is a summary of these requirements.

Educational games need to offer mediators: an evaluation of the players' progress; a record of the time players spent on each of the game tasks and their level of accuracy. In addition, the game needs to have levels. **As for what educational games should offer children, particularly dyscalculic children in rehabilitation, the following was highlighted by the Specialists:** activities with different levels of difficulty based on the hierarchy of math; the errorless learning approach; repetition with the element of novelty; positive feedback. **As regards content**, the game should cover math conceptual and procedural knowledge of the numerical and basic arithmetic skills (number sense, counting, numbers recognition, base 10 number system, calculation, addition, subtraction, multiplication, and division). **In order to achieve this**, Specialists recommend the use of concrete and visual examples from daily life. The game should also provide children with an understanding of why they need to learn a specific content. In addition, the game should promote math fluency and allow the revision of concepts previously learned during the game.

In the second part of this field research, 41 Brazilian game developers composed the sample. This data collection was done through a questionnaire containing 12 closed-ended questions, 4 regarding the developers' profile and 8 about game elements and players motivation. This part of the field research was conducted during the SBGames 2017. This part of the investigation aimed to fulfil the **third specific goal of this dissertation.** The results obtained are summarized below.

Of the game elements the respondents were presented with, the following were considered of a very high level of importance for players' motivation: **Feedback, Rewards, Intuitive Interface**, and **How the teacher uses the game**. In contrast, **To offer information about how to play** and **To offer help when the player is making mistakes were both considered of** low level of importance**.** Concerning the dramatic game elements, only the element **Rewards** was considered very important. Opinions were divided with regard to t**he other three dramatic elements, namely, Narrative, Character and Challenging goals.** These were considered to be of moderate, high, or very high level of importance.

Regarding how the developers and their teams set up the game elements, the majority were of the opinion that to develop an educational game capable of promoting and sustaining players' motivation is a complex task. All the developers consulted **agreed that players can help setting up the game elements**. However, more than half of the developers **do not use a game design process centered on the player.** As for what moment in the game design process there is player participation, the results showed that **players usually take part in the design process through playtest,** to evaluated the level of fun and motivation of the game; to evaluate the learning outcomes; and to identify possible

malfunctions in the system. These playtests provide developers with an opportunity to gather data by observing the players while they interact with the game.

Despite the contributions made by this field research, as any research, the current investigation presents limitations. Due to its qualitative approach and to the small sample size used, it was never the aim of this investigation to offer generalizations based on the data collected, or to provide a statistical analysis. Instead, the purpose of this study is to foster a qualitative discussion considering the research scope.

6 GAME DESIGN RECOMMENDATIONS

This chapter proposes a set of game design recommendations. These recommendations are the result of the qualitative analysis of the data collected, in which data triangulation of the results obtained from the theoretical data, data from game developers and data from professionals involved in neuropsychological rehabilitation was done. The aim was to fulfil the 4th specific goal of this dissertation, namely: **To propose a set of game design recommendations for educational games capable of fostering and sustaining motivation in dyscalculic children during neuropsychological rehabilitation.** This chapter comprises three sections: Triangulation strategy; Discussion; Summing up.

6.1 Triangulation strategy

Based on Minayo (2005), the recommendations for the game design followed the three steps summarized below. For a detailed description of the methodology see chapter 4 of this document.

- **Data organization:** the data previously selected were organized.
- **Data categorization:** Once the data were organized, the information was categorized. The categories proposed were based on three dramatic game elements, namely Character; World building; Rewards (FULLERTON, SWAIN, and HOFFMAN, 2004).
- **Proposing process:** The categorized data were then analyzed with a view to identify the elements which can promote and sustain motivation in children with dyscalculia when playing games.

6.1.1 Character

As regards the game element Character, **theoretical research** (see chapter 2) has led to the following recommendations:

Main recommendation: An emotional connection between the players and the game character should be established (MALONE and LEPPER, 1987; DESURVIRE and WIBER, 2009, ALFADHLI and ALSUMAIT, 2015). This connection, based on the player's level of identification with the character (e.g. motivation, skills) brings new experiences to the player (LEITE and MENDONÇA, 2013). Thus, the game character can draw the player's attention to the game's activities (CEZAROTTO and BATTAIOLA, 2016). For this connection to happen the following is necessary:

- Stimulate the player's imagination through the game environment (MALONE and LEPPER, 1987; DESURVIRE and WIBER, 2009, ALFADHLI and ALSUMAIT, 2015).

- Use humor to create entertaining and remarkable characters (DESURVIRE and WIBER, 2009).

- For each game character, create a backstory which can catch the player's curiosity (ALFADHLI and ALSUMAIT, 2015; DICKEY, 2015).

- Develop ethical and interesting characters whose movements can be controlled by the player. Moreover, allow the game character to become more powerful as the game progresses (ALFADHLI and ALSUMAIT, 2015).

- Make it clear to the player what the character's role in the game is, especially its connection to the game conflict. Also, detail the visual appearance, movements, and dialogues of the game character according to its role (DICKEY, 2015).

- Involve the player in the creation of the character. The creation of a well-developed character requires user participation. Players like to control and take part in creative activities, such as designing or customizing the character. Moreover, developers should use familiar elements based on the player's earlier experiences, but also surprise the player with new things (CHAMBERLIN, 2003).

The results from the field research with the 41 game developers (see chapter 5) show that whereas some developers consider character as a game element of high level of importance for players' motivation, others consider it as having a moderate level of importance. This shows that developers are not in agreement with regard to the importance of this game element. Moreover, these results differ from the information found in the literature, where high importance is given to this dramatic game element.

The results from the field research with the 12 specialists in neuropsychological rehabilitation (see chapter 5) show that for these specialists, the game element character plays an important role in promoting players' motivation. They stress that a game to be used in the rehabilitation of children should have a ludic environment that comprises the character, among other elements. In these specialists' opinion, the character provides interactivity in the game, through allowing players to move and select them. The character also allows the player to see the game as a ludic world, rather than a digital place to solve math problems.

6.1.2 World building

As regards the dramatic game element World building, **theoretical research** (see chapter 2) has led to the following recommendations:

Main recommendation: Both a narrative and a story should be used as the base base for creating the game's world building and ludic context (e.g. character, rewards, mechanics) (CEZAROTTO and BATTAIOLA, 2016). It is through the narrative and the fictional world the player can become immerse in the game. Both the player's imagination and curiosity are stimulated by the different and engaging experiences provided by the narrative and the fictional world of the game (DESURVIRE and WIBER, 2009; LEITE and MENDONÇA, 2013; DICKEY, 2015). In order to achieve this the following is necessary:

- Use visual and sound effects to stimulate the player's curiosity about the game world (MALONE and LEPPER, 1987; FEDEROFF, 2002).

- Create a game world that works either with or without the character, and which is based on an interesting storyline (FEDEROFF, 2002).

- Allow players to create content in the game world, to give them a customized experience (FEDEROFF, 2002; CHAMBERLIN, 2003). Additionally, allow players to have a sense of control over the game world, in other words, allow them to make choices in the game world (DESURVIRE and WIBER, 2009).

- Allow players to participate in the creation of the game world. In the game world, elements such as characters, sounds, humor, surprise, and fantasy are important for the player's experience. Thus, the creation of an interesting and engaging game world requires players' participation (CHAMBERLIN, 2003).

- Run the game through an engaging, clear and fast storyline. The story should consider the players' earlier experiences with both the real world and the non-real world (ALFADHLI and ALSUMAIT, 2015).

- An attractive game narrative should follow the three-act structure (i.e. beginning, middle and end), and include the following three main elements: function (exogenous or endogenous); type (linear or nonlinear); the quest (plot, character, setting, conflict) (DICKEY, 2015).

- A narrative for game-based learning should contain at least the following elements: setting, characters with their roles, the conflict of the story and how it relates to the learning goals, obstacles, backstory, and plot integration (DICKEY, 2015).

In the field research with the 41 game developers (see chapter 5) the game element world building was considered part of the element "Well-developed narrative (e.g. setting, story)". The results of this field research show that, similarly to the game element character, developers' differ in their opinion with regard to the importance of the element world building for players' motivation. Whereas some developers consider "Well-developed narrative" as a game element of a high level of importance for players' motivation, others consider it as being of a moderate level of importance. Also, similarly to the game element character, these results contradict the information found in the literature, where this dramatic game element is considered to be of great importance for players' motivation in the game.

The results from the field research with the **12 specialists in neuropsychological rehabilitation** (see chapter 5) show that these specialists are in agreement about the importance of the game element world building. For these specialists, this game element is essential. According to them, a game used in rehabilitation with children must offer a ludic environment, which includes the goals of the game, levels, remarkable characters, and background story, rather than just a digital environment for solving math problems.

6.1.3 Rewards

Theoretical research (see chapter 2) has also led to some recommendations with regards to the dramatic game element rewards. In contrast to the elements character and world

building, the information found in the literature about game rewards is rather limited. The information collected has led to the following recommendations:

Main recommendation: Players should be provided with rewards as these contribute to the development of their skills, and increase their engagement and level of immersion during the game activities (ALFADHLI and ALSUMAIT, 2015; DESURVIRE and WIBER, 2009). In addition, rewards can increase players' self-efficacy as the game system gives them feedback according to their efforts (LEITE and MENDONÇA, 2013). This feedback (e.g. scores, badges, rewards) helps the player to progress in the game, since it works as a stimulus for facing the challenges. Moreover, in educational games, feedback can reflect the player's learning strategy (CHAMBERLIN, 2003). Thus, rewards should be seen as a type of feedback on the game challenges, goals, and objectives. For this to occur, the following is necessary:

- The game should consider the acquisition of knowledge as a type of reward (FEDEROFF, 2002).
- Use several types of rewards. These rewards need to be systematically designed to increase players' engagement. Provide both small and big rewards based on the difficulty of the challenges completed (CEZAROTTO and BATTAIOLA, 2016).
- Use elements such as feedback on their progress, scores, badges, as rewards to stimulate players' self-efficacy in the game tasks (CEZAROTTO and BATTAIOLA, 2016).

The game element rewards was also evaluated in the **field research with the 41 game developers** (see chapter 5). The results show that the majority of the developers consider rewards as a very highly important element for players' motivation in educational games. In fact, rewards were the only dramatic element to be considered as highly important by the majority of the developers. Moreover, these results are in agreement with the information provided in the literature, despite being the least researched element of the three game elements considered.

The results from the field research with the **12 specialists in neuropsychological rehabilitation** (see chapter 5) show that according to these specialists, the use of rewards is essential in games to be used with children during rehabilitation. For these specialists, rewards can take the form of a positive stimulus, an award, or positive feedback (e.g. golden stars).

6.2 Discussion

The recommendations presented in the above section draw on the information on dramatic elements available in the literature. These recommendations will be used in this research as the basis for the detailed analysis of the game design process with the player, which is the main goal of this dissertation. Each one of the recommendations highlights the importance of a particular game element for player motivation. Although useful, most of the orientations found in the literature do not offer sufficient or detailed information regarding the game design process. Hence the need to involve the player in the game design process. The player will be the source of valuable information, particularly in the case of games with educational purposes.

Whereas a number of orientations concerning the elements character and world building can be found in the literature, not much is available with regard to the application of the element rewards in educational games, although both game developers and academics consider this game element important for player motivation. In fact, the element reward was the only dramatic element to be considered of very high importance for player motivation by most of the game developers interviewed. The other game element these specialists considered essential for player motivation were "Intuitive interface" and "How the teacher uses the game", which are not dramatic elements.

Additionally, all the developers recognize the importance of considering the user during the game development process, particularly in the set up of the game elements. This user-centered design approach to the development of educational games is also supported by the literature. However, this approach is still not used by most development teams, as shown by the field research results.

Finally, most of the specialists in rehabilitation, consistent with the information in the literature, acknowledge the relevance of the ludic aspect of the game in the treatment of children, particularly of the elements world building and characters. Moreover, the specialists highlight the importance of rewards, not only for their motivational aspect, but also for the contribution they make to the treatment (positive stimulus). These specislists consider the three dramatic elements investigated, namely character, world building, rewards, as being essential elements in games to be used with children with dyscalculia in neuropsychological rehabilitation.

6.3 Summing up

This chapter considered the triangulation of the data collected so far (theoretical orientations + data from field research with game developers + data from field research with specialists in neuropsychological rehabilitation). Based on this data intersection, a number of game design recommendations focusing on player motivation were made. This stage of the investigation aimed to fulfil the 4th specific goal of this dissertation. The recommendations are centered in three dramatic game elements: Characters, World building, and Rewards (see table 38 below).

The recommendations made here will be further discussed with a view to broaden their scope. Further consideration will be given to the player's perspective, that is, to the perspective of children with dyscalculia playing an educational game during a neuropsychological rehabilitation.

Table 38: Game design recommendations.
Source: the author based on the indicated references.

Character: An emotional connection between players and the game character should be established. This connection, based on the player's level of identification with the character (e.g. motivation, skills) brings new experiences to the player. Thus, the game character can draw the player's attention to the game's activities.
• Stimulate the player's imagination through the game environment (MALONE and LEPPER, 1987; DESURVIRE and WIBER, 2009, ALFADHLI and ALSUMAIT, 2015). • Use humor to create entertaining and remarkable characters (DESURVIRE and WIBER, 2009).

- For each game character, create a backstory which can catch the player's curiosity (ALFADHLI and ALSUMAIT, 2015; DICKEY, 2015).
- Develop ethical and interesting characters whose movements can be controlled by the player. Moreover, allow the game character to become more powerful as the game progresses (ALFADHLI and ALSUMAIT, 2015).
- Make it clear to the player what the character's role in the game is, especially its connection to the game conflict. Also, detail the visual appearance, movements, and dialogues of the game character according to its role (DICKEY, 2015).
- Involve the player in the creation of the character. The creation of a well-developed character requires user participation. Players like to control and take part in creative activities, such as designing or customizing the character. Moreover, developers should use familiar elements based on the player's earlier experiences, but also surprise the player with new things (CHAMBERLIN, 2003).

World Building: Both a narrative and a story should be used as the base for creating the game's world building and ludic context (e.g. character, rewards, mechanics). It is through the narrative and the fictional world the player can become immerse in the game. Both the player's imagination and curiosity are stimulated by the different and engaging experiences provided by the narrative and the fictional world of the game. The game should not be just a digital environment to solve math problems.

- Use visual and sound effects to stimulate the player's curiosity about the game world (MALONE and LEPPER, 1987; FEDEROFF, 2002).
- Create a game world that works either with or without the character, and which is based on an interesting storyline (FEDEROFF, 2002).
- Allow players to create content in the game world, to give them a customized experience (FEDEROFF, 2002; CHAMBERLIN, 2003). Additionally, allow players to have a sense of control over the game world, in other words, allow them to make choices in the game world (DESURVIRE and WIBER, 2009).
- Allow players to participate in the creation of the game world. In the game world, elements such as characters, sounds, humor, surprise, and fantasy are important for the player's experience. Thus, the creation of an interesting and engaging game world requires players' participation (CHAMBERLIN, 2003).
- Run the game through an engaging, clear and fast storyline. The story should consider the players' earlier experiences with both the real world and the non-real world (ALFADHLI and ALSUMAIT, 2015).
- An attractive game narrative should follow the three-act structure (i.e. beginning, middle and end), and include the following three main elements: function (exogenous or endogenous); type (linear or nonlinear); the quest (plot, character, setting, conflict) (DICKEY, 2015).
- A narrative for game-based learning should contain at least the following elements: setting, characters with their roles, the conflict of the story and how it relates to the learning goals, obstacles, backstory, and plot integration (DICKEY, 2015).

Rewards: Players should be provided with rewards as these contribute to the development of their skills, and also increase their engagement and level of immersion during the game activities. In addition, rewards can increase players' self-efficacy as the game system gives them feedback according to their efforts. This feedback (e.g. scores, badges, rewards) helps the player to progress in the game, since it works as a stimulus for facing the challenges. Moreover, in educational games, feedback can reflect the player's learning strategy. Thus, rewards should be seen as a type of feedback on the game challenges, goals, and objectives.

- The game should consider the acquisition of knowledge as a type of reward (FEDEROFF, 2002).
- Use several types of rewards. These rewards need to be systematically designed to increase players' engagement. Provide both small and big rewards based on the difficulty of the challenges completed (CEZAROTTO and BATTAIOLA, 2016).
- Use elements such as feedback on their progress, scores, badges, as rewards to stimulate players' self-efficacy in the game tasks (CEZAROTTO and BATTAIOLA, 2016).

7 USER VERIFICATION

This chapter describes the results of the user verification research. The aim of this user verification was to fulfil the 5th specific goal of this dissertation, namely: **To verify, with children with dyscalculia, the game design recommendations made by this research, and explore how these recommendations contribute to increasing the motivational element in educational digital games.** The experimental game design method was the method used to conduct the verification of the motivational preferences of children with dyscalculia regarding the game elements character, world building[28] and rewards. The chapter is divided into the following sections:

- **Section 1 - Experiment 1**: user verification with four Brazilian children with dyscalculia.
- **Section 2 - Experiment 2:** user verification with six American children with typical development.
- **Section 3 - Final verification:** with four Brazilian children with developmental dyscalculia.
- **Section 4 - Summing up.**

7.1 Experiment 1

Experiment 1[29] aimed at verifying the data quality and to detail some game design recommendations. The methodology of this experiment and the materials used are described in chapter 4. The following is a summary of the structure of the experiment:

- **Goal:** To verify with children with dyscalculia their motivational preferences for the game character, during the use of a game in a rehabilitation session;
- **Sampling:** Four Brazilian children diagnosed with dyscalculia, aged 10 to 13;
- **Mediators:** Three psychology students from UFMG;
- **Selected game:** Multicorrida (see figure 45), implemented especially for experiment 1;
- **Recommendation:** With reference to the element Character;
- **Place:** Developmental Neuropsychology Laboratory (UFMG – Brazil);
- **When:** October to December 2017;

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[28] To make it easier for the children, the words 'narrative' and 'story' were used in the questions, instead of the expression 'world building'.

[29] The children who took part in experiment 1 were from Brazil, therefore the questions were in Portuguese. Questions and answers were later translated into English.

- **Number of sessions:** Six sessions of game interaction (1 session per week);
- **Technical procedure:** A semi-structured interview.

Figure 45: Multicorrida screenshots.
Source: the author.

The results of experiment 1 are described below. These have been divided into two parts: **Part A (children's profile)** and **Part B (children's motivation and preferences).** The implications of this experiment for this study are then discussed.

7.1.1 Part A – Children's profile

In this part of the experiment information was gathered in order to build a profile of the users and to learn about their previous experience with games. The interview script was divided into four main sections: user **profile; fun; use of digital artifacts; use of digital games.** The data collected are presented below.

User profile: the information was organized into two groups according to the users' characteristics:

- **Two girls (child 2 and child 3)**, 13 years old, 7th and 8th graders in a public school. Both girls were diagnosed with dyscalculia and dyslexia by DNL (UFMG).
- **Two boys (child 1 and child 4)**, 10 years old, 4th graders. Child 1 goes to a public school, while child 4 is the only one in the sample who goes to a private school. Both boys were diagnosed with dyscalculia by DNL (UFMG).

Fun: the children mentioned the use of several artifacts, such as computers, video games, tablets, board games, and television. However, the cellphone was the most popular artifact. Three out of the four children said that the cellphone was the artifact they used the most to have fun. When asked to justify their answers they said:

- **Child 2:** "Cellphone, I do not know why".
- **Child 3:** "Cellphone, it is what I have".
- **Child 4:** "Cellphone. I can play and see videos".

Child 1 preferred a tablet "because it is what works better". Of the three children who preferred the cellphone, only child 4 offered a valid justification. The answers given by the other two children suggest that they use a cellphone simply because that is what is available to them.

Use of digital artifacts at school: the children use digital artifacts to: do activities in the informatics class and to play educational digital games. Of the four children, child 2 was the only child to have never used a computer or a tablet at school. All four children use a digital device for watching cartoons or videos on YouTube at home. The activities they mostly use the devices for are:

- **Child 1:** to play "zombie killing games".
- **Child 2:** To play online games; educational digital games; to research school assignments.
- **Child 3:** To research school assignments.

Use of digital games: all the participants play digital games on a cellphone, a tablet or a video game console. None of the participants plays digital games on a computer. **Regarding how much time they spend playing they said:**

- **Child 1:** Every day, for approximately one hour.
- **Child 2:** Sometimes during the week, for approximately 10 minutes.
- **Child 3:** Sometimes during the week, for a few minutes.
- **Child 4:** Sometimes during the week, for approximately half an hour to an hour.

Also regarding the **use of digital games,** when asked about their favorite type of game and their favorite digital game, the children replied:

- **Child 1:** Shooting games. Favorite game "Grand Theft Auto (GTA) and Zumbi".
- **Child 2:** Action, adventure, sports, and shooting games. Favorite game "Subway surfers".
- **Child 3:** Puzzle games. Favorite game "those fashion games".
- **Child 4:** Sports and shooting games. Favorite game "GTA".

When the participants were asked **what they most liked about the games they played,** they said: the challenges and rules; the game rewards; the possibility to create (e.g. character, game items); the game art and colors. When asked about what they thought a game must have to be fun, they said:

- **Child 1:** "Character and fight".
- **Child 2:** "Action".
- **Child 3:** "I do not know".
- **Child 4:** "Open world, a game that is possible to do anything, like GTA".

Lastly, the children were asked **to give their opinion regarding educational digital games.** Most of the participants said that they liked educational digital games, because these games teach something. When asked whether they liked educational digital games, they said:

- **Child 1:** "Yes, because it teaches me (something)".
- **Child 2:** "Yes, because I learn many things".
- **Child 3:** "Yes, because the game teaches (something)".

- **Child 4:** "Some. Because some educational digital games are boring and hard".

To sum up, part A outlined the children's profile and their previous experience with educational digital games, which is also summarized in figure 46. All four children have some previous experience with digital games and are familiar with digital devices, using them either at school or at home. Child 1 and child 4, however, seem to have more experience with games, as they spend more time playing them. This information is key to the analysis of the users' motivational preferences, which is presented in part B.

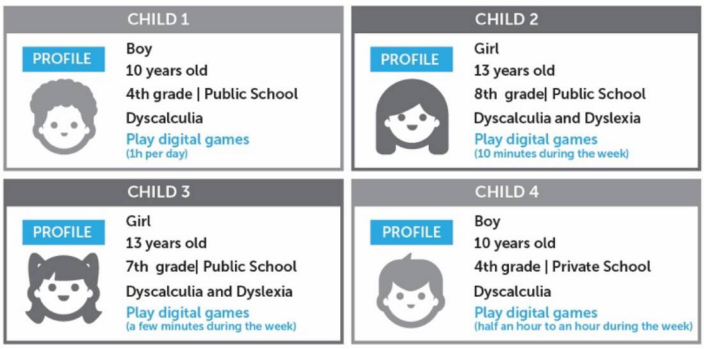

Figure 46: Summary of the children's profile (experiment 1 sample).
Source: the author.

7.1.2 Part B – Children's motivation and preferences in games

This part of the user verification aimed to verify with children with dyscalculia what their motivational preferences as regards specific game elements were. Experiment 1 focused on the game character. The children were interviewed during the neuropsychological rehabilitation sessions, so that their motivation during their interactions with the game while undergoing treatment could be measured.

Participants' responses were organized in individual tables (per child), to facilitate their analysis later on. Experiment 1 consisted of six semi-structured interview scripts. The purpose of the interviews was twofold: (a) to verify with the users whether they felt motivated during the sessions; (b) to gather information about their preferences with regard to the game character. Table 39 summarizes the dynamics used in experiment 1. Participants' responses are discussed in the next sections.

Table 39: The dynamics used in experiment 1.
Source: the author.

Session 1	The child played the game for the first time with the character.
Session 2	The child played the same game without the character.
Session 3	Before playing, the child could choose to play with or without the game character.
Session 4	
Session 5	
Session 6	

Child 1

With the exception of session 6, in all other sessions child 1 stated that he liked the game, because he thought that it was cool. However, his responses to the interview questions, suggest otherwise.

Child 1 said he was excited about the game only in the first sessions, but that after that the game became boring "because the time went by too slowly". He said he only felt confident in the last session but he did not say why.

Participants were asked to evaluate the game on a scale of 1 to 10. Child 1's scores for the game Multicorrida demonstrated that although he felt motivated at the start, his motivation gradually decreased.

- **Session 1:** "10", no justification provided.
- **Session 2:** "9", "because I kind of liked it".
- **Session 3:** "4", no justification provided.
- **Session 4:** "6", "the game is better with the character".
- **Session 5:** "5", no justification provided.
- **Session 6:** "6", no justification provided.

In all sessions, child 1 affirmed that he learned something by playing the game, but that the game becomes boring because "it has sums". Moreover, in most of the sessions child 1 said that he would not like to play the game at home, because "I like my games better"; "I think this game is kind of boring"; "because I prefer Zombie games; "I like other games". Therefore, it can be assumed that **child 1 did not like the game and consequently he did not feel motivated while playing it. Additionally, child 1's initial interest in the game was not maintained throughout the sessions.**

Regarding the game character, child 1's responses are summarized below:

- According to child 1, the character is important in the game "because without it the game is not very cool".
- Child 1 liked the game character because "he is cute". In addition, when allowed to choose, he preferred to play WITH the character because "because he is cool".
- In child 1's opinion the game would be more fun if "(...) when I make a mistake, the character takes a shot of ketchup".
- When playing the version of the game without the character, child 1 said that he missed the character: "It was cooler with him" because "when we make a mistake, he jumps".

According to child 1, a cool and fun character should:

- Be interactive (the player can control the character) "because it is cooler".

- Let the player know when they make a mistake and when they do the right thing: "because otherwise, I will not know if I got it right".
- Teach them how to play (before they start the game): "otherwise I will not know how to play".
- Help them during the game (with the challenges): no justification provided.
- Provide information through audio "because if it is a text, I need to read".
- Change between the levels (I can choose): "because it is cooler this way".
- Be a thing (e.g. car, robot): no justification provided.
- "Be a killing zombie, to kill the zombie the player needs to solve some math problems".
- "Shoot a zombie and have a machine gun".
- Appear before the start of the game: no justification provided.

When the interviewer asked child 1 to imagine himself as the game developer, he said:

- "Some things are missing in the game. Laranjinha (game character) should have a bazooka. If you do it right Laranjinha kills a zombie using the bazooka. If you make a mistake, the bazooka does not work, and you die".
- The game should have a character and "he would have soldier clothes and guns".
- The character "would kill zombies and appear all the time".

Child 2

Child 2 showed consistency in her responses, and with regard to how she felt about the game, throughout the sessions. In all sessions, she consistently said that she liked the game, and thought that it was cool. She felt that the time went by fast in all sessions. She said the game was cool and challenging, even after playing it for a while.

Child 2 remained curious - "because I would know more" - and excited "because I would go faster and faster" throughout the sessions. Her evaluation of the game was also consistently positive. In session 1 she gave it an "8", without justifying her answer. In the other 5 sessions, she gave it a "9" "because I thought the game was challenging and exciting".

In all six sessions, child 2 affirmed that she learned something by playing the game. She also said that she would like to play the game at home, "because I thought it was cool"; "because it will help me"; "I thought it was interesting, I would like to play more". Thus, it can be assumed that **child 2 liked the game, and felt motivated in all the sessions. Also, child 2's initial interest in the game was sustained throughout the six sessions.**

Regarding the game character, child 2's responses are summarized below:

- For her the character is important in the game "because he motivates people to play".
- She liked the game character "because he is fun". However, when given the choice, sometimes she preferred to play WITH the character "because he is an

incentive", other times she did not have a preference, "whatever, it can be with the character"; "it can be with the character, I do not know".

- In the game version without the character, child 2 did not notice its absence: "no, I did not notice it".
- She did not think that the game was cooler with the character "because it does not make much difference to the game".

According to child 2, a cool and fun character should:

- Help the player during the game (with the challenges) because "sometimes we do not know how to play, then it would be good".
- Be customizable.
- "Speak".

When asked what she would change in the game if she were the game designer, child 2 said:

- "I would not change anything".
- The game would have a character: "It would have a boy and a girl".
- The character would "help sometimes".

Child 3

Child 3's play experience varied slightly during the 6 rehabilitation sessions. Child 3 affirmed that she liked the game. She felt that the time went by fast in all sessions and the game was cool and challenging until the last session. Moreover, child 3's assessment of the game was very positive. She gave it a "10" in all sessions "because I liked it"; "I thought it was cool".

However, child 3 often felt nervous when playing the game. She said "I was afraid of making a mistake"; "of not being able to complete the level"; "because I kept thinking about how much time I had to finish"; "because I needed to win the levels".

During all sessions, child 3 affirmed that she learned something by playing the game. She also said that she would like to play the game at home "because it teaches the times table". Therefore, it can be assumed that **child 3 liked the game, and felt motivated in all the sessions. In addition, child 3's initial interest in the game remained constant throughout the six sessions.**

Child 3's responses with regard to the game character are summarized below:

- For child 3, the character is important in the game "because he needs to win the race".
- She affirmed that she liked the game character because "he is cute".
- In the sessions where she could choose, to play with or without the character, child 3 did not seem to have a preference: "It can be with the character, I do not

know why"; "Without the character, I do not know"; "Now with the character, because last time it was without".

- In the game version without the character, child 3 did not notice its absence: "No, I have not noticed it".
- Child 3 did not think that the game was cooler with the character "because it does not make any difference to the game".

According to Child 3, a cool and fun character needs should:

- Help the player during the game (with the challenges) "to make it easier".
- Be a thing (e.g. car, robot) and "be able to compete with other players".

When asked what she would change in the game if she were the game designer, child 3 said:

- "The characters would compete more".
- The game would have a character just like the one in the game: "Yes, one just like that".
- In the game, the character "would appear all the time".

Child 4

Child 4 did not like the game used in experiment 1. In all sessions, with the exception of session 1, child 4 stated that he did not like the game. He thought the time went by very slowly and that the game was boring all the time. When asked to justify his answer, he said "I do not know, it got unfunny, it got boring"; "It takes so long to finish"; "It is always the same thing".

Consequently, child 4's evaluation of the game in all sessions was rather negative, with his scores ranging from 1 to 3. During the sessions, he felt confused "because I did not understand the purpose of the game very well", and bored because he thought that the game was repetitive, "the same question?"; "nothing new happens."

Although child 4 disliked the game, in all the sessions, he stated that he learned something by playing the game. He would not, however, play the game at home because "it is too boring, and I do not like these games"; "I prefer to play other things"; "I do not like educational games". This child seems to have a strong dislike of educational games. When asked about what he would change in the game, he said: "I would put games between the tasks to make it fun", showing that he did not consider Multicorrida a game. He also disliked the fact that the game had sums, "It has sums"; "I do not like sums, I think educational games are boring".

Therefore, it can be conclued that child 4 did not like the game, and as a result, did not feel motivated to play it. Initially, in the first session, he thought the game was "ok". However, he did not consider the game cool or motivating, mainly due to the game being an educational game.

Child 4's responses with regard to the game character are summarized below:

- The character is not important for the game, however, "it is cooler with the little animal".

- Child 4 liked the game character because "it is cooler".
- In the sessions where he could choose to play with or without the character, child 4's answers were not consistent. In session 3, he chose to play WITHOUT the character because "it is cooler". In session 5, however, he chose to play WITH the character "because it is more fun".
- In the game version without the character, when asked if he missed the character, he said "Yes, it is cooler with Godofredo" (Godofredo is the name child 4 gave to the game character).

According to child 4, a cool and fun character should:

- Be interactive (the player can control the character), no justification provided.
- Let the player know when they make a mistake or when they do the right thing: "To let me know when I completed the level".
- Teach them how to play (before the start of the game): "Those instructions".
- Help them during the game (with the challenges) "only in the challenges where I make many mistakes".
- Give information about the game through text or audio: "Whatever".
- Change between the levels (I can choose): "It is cooler".
- The character should appear "everywhere" in the game, and the character should have "clothes and shoes. It should be possible to choose the character".

When asked what she would change in the game if he were the game designer, child 4 said:

- "I would put games in between the tasks to make it fun".
- The game should have a character: "Yes, it could be like this fox, I would only change the clothes".
- In the game, "it (the character) would jump over obstacles and change the clothes, he would appear all the time".

7.1.3 Conclusions

Experiment 1 was conducted in Brazil over a period of six weeks, during the neuropsychological rehabilitation of four children with dyscalculia. After the data analysis, conclusions were drawn regarding the following aspects: **general information gathered from the experiment; the game's main motivational problems; the users' preferences with regard to the game character; limitations of the data collection.**

General information gathered from the experiment

- The challenges, the story and the levels were considered the most positive aspects of the game.

- All the participants, including those who did not like the game, believed that they learned something by playing the game during the sessions.
- Only **child 2 and child 3** liked the game and remained motivated throughout the sessions. **Child 1 and child 4** did not like the game and consequently, were not motivated to play it. It was expected that the older children (13 years old) would find the game too simple and as a result would not be motivated to play it. However, the opposite was observed. The older children were motivated to play the game, whereas the younger children (10 years old) did not like the game and did not feel not motivated to play it. The children's level of experience with digital games can be seen as the reason for that. Children with more experience in playing games have higher expectations of the game, which demands more from the educational game to motivate them. Child 1 and child 4 were the ones who spent the most time playing digital games, and can be seen as the participants in experiment 1 with the most experience in playing games.

The game's main motivational problems

- According to the children, the game was repetitive and lacked novelty during the activities, which made it boring.
- The math activities were too visible to the player. The children could easily see that is was an educational game and this affected their motivation.
- Children with previous experience with digital games have higher expectations of these games. Educational digital games cannot always meet these expectations due to various reasons, such as limited budget, small development team, need of a content. Therefore, more is required from the game in order to motivate the user and sustain their motivation. Moreover, children seem to dislike educational games because they believe these games are not fun.

User's preferences with regard to the game character

- In general, participants, even those who did not like the game, said that the game was cooler with the character. Some children, however, had difficulty explaining why they thought so. Some of the reasons given were: "[...] because he is an incentive"; "because the character is fun and motivates you"; "because it is more fun"; "because without him it is not very cool"; "because he motivates people to play".
- Although the children liked the character, two of them did not notice its absence in session 2, "because it does not make much difference to the game"; "no, I have not noticed it". This could be because in the game implementation the character was set up to not change the gameplay, that is, the presence or absence of the character does not affect the way the game is played.
- Regarding the role of the character in the game, all the children said that a cool and fun character needs to help them during the game (with the challenges) because: "sometimes we do not know how to play, then it would be good"; "to make it easier"; "only in the challenges that I make many mistakes". Thus the children want the character to help only at specific moments in the game. For

instance, when new challenges are introduced, or in challenges where the child is making too many mistakes, which affects his/her progress in the game.

- The children also mentioned that the character should "talk" and "compete with other players".
- Regarding the character's characteristics, the children said that it should be customizable, and it should be a thing (e.g. car, robot) or a zombie, a boy or a girl. The preferred character's characteristics varied from one child to another. Thus it is important to offer the user choices in terms of the character, or allow them to personalize the available characters (e.g. clothes, hair, type).
- Children 2, 3 and 4 said that if they could create a game, the character would be like the one in the game. Child 4, although also happy with the character, said he would make some changes: "I would only change the clothes," "it [the character] would jump over obstacles and change the clothes, he would appear all the time". Child 4 said that the character would appear "everywhere" in the game, and it would have "clothes and shoes. It would be possible to choose the character".
- Child 1 and child 4 did not like the game and did not feel motivated by it. For them, in order to be fun and cool the game character should: be interactive (the player can control the character) -"because it makes it cooler"; let them know when they make a mistake or do the right thing – "because otherwise, I will not know if I got it right", "let me know when I completed the level"; teach them how to play (before the start of the game) - "otherwise I will not know how to play"; give information about the game through audio - "because if it is a text, I need to read"; change between the levels (I can choose) - "it is cooler this way".
- Child 1 had a specific preference regarding the character: "I want that when I make a mistake, the character takes a shot of ketchup". For the character to be cool, according to child 1 it should: "shoot a zombie and have a machine gun"; "it would have soldier clothes, and guns"; "it would kill zombies and appear all the time". Regarding the character from the game used in the experiment, child 4 said: "some things are missing in the game. Laranjinha should have a bazooka. If you answer correctly, Laranjinha kills a zombie using the bazooka. If you make a mistake, the bazooka does not work, and you die".

Limitations of the data collection from experiment 1

- The semi-structured interview scripts need to be revised. Repetitive questions need to be avoided, so as to optimize the user's time. This would also prevent the children from getting bored during the interviews, which happened when the same question was asked multiple times in experiment 1.
- Some of the words and expressions used were too abstract for the children and need to be revised. Some of the questions also need to be revised. Yes or no questions should be avoided so as to allow children to express their opinions and preferences. In experiment 1, the use of such questions prevented the children from expressing their opinions at times.

- The technique of observation needs to be incorporated to the interview. Observation can help identify inconsistencies in the children's responses, which happened during the experiment when one of the children contradicted himself during the interview.
- This study will no longer use two versions of the same game, for instance, one with the character and one without. This approach proved to be inappropriate to measure the child's motivation in the scope of this dissertation, because when a game element was disabled, it changed the gameplay experience, and consequently the player's motivation. This happens because games are complex systems. Also, the time needed for the implementation of the game using this approach is considerable.
- The data quality was medium. Thus, with a view to increasing data quality, the interview questions need to be revised, the technique of participant observation should be used, and the game dynamics needs to be different.

Figure 47 provides a summary of the main data from experiment 1.

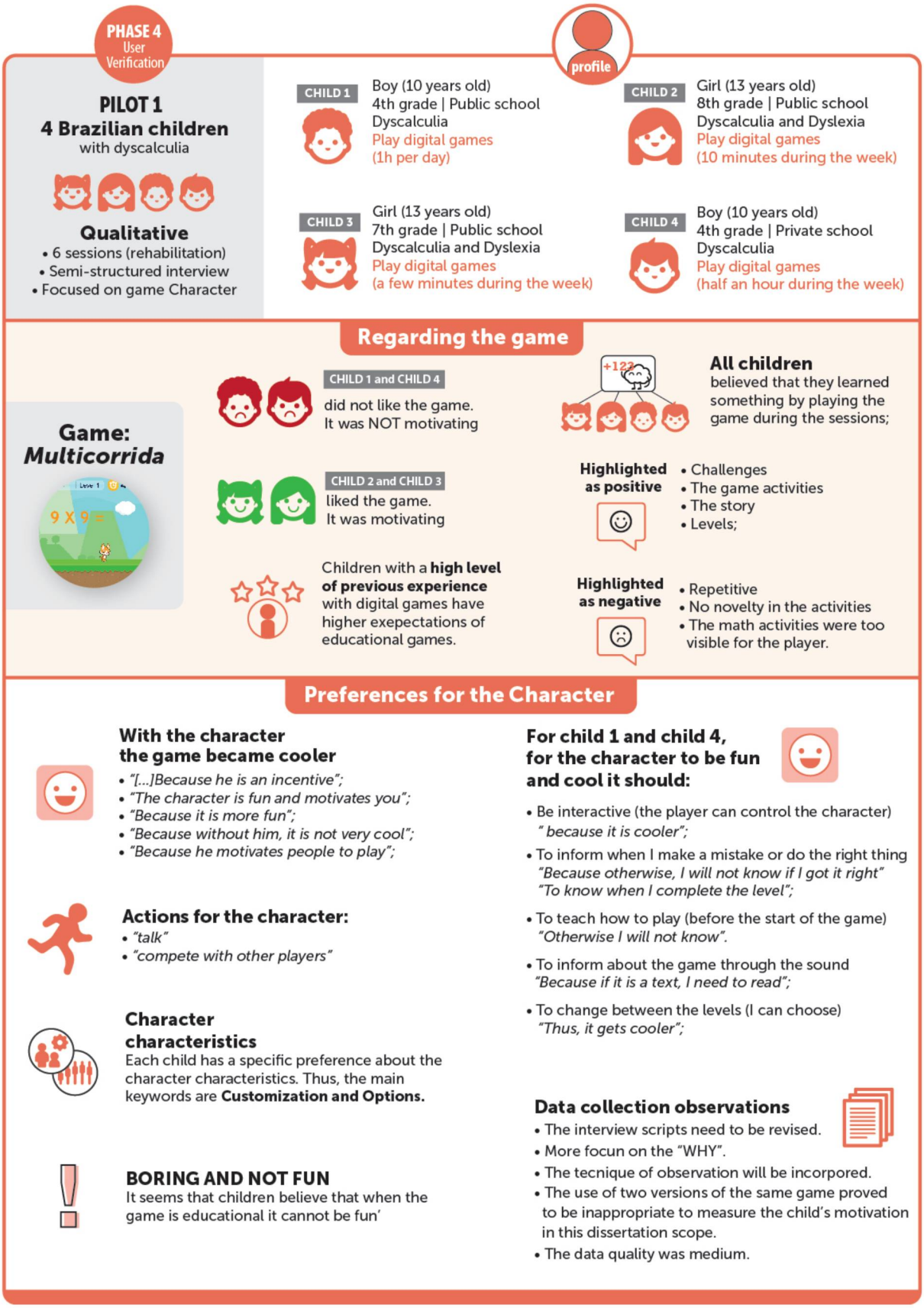

Figure 47: Summary of experiment 1 data.
Source: the author.

7.2 Experiment 2

Experiment 2 is an improved version of experiment 1. The methodology and the materials used in this experiment are described in chapter 4. The structure of this experiment is summarized below.

- **Goal:** To verify with children their motivational preferences for the game elements character, world building and rewards, during a user testing in the learning games lab.
- **Sampling:** Six American children with typical development, aged 9 to 10.
- **Mediators:** This dissertation's author/researcher.
- **Selected game:** Monster School Bus (see figure 48), a pre-existent game developed by the Learning Games Lab team.
- **Recommendation:** With reference to the elements Character, World Building and Rewards.
- **Place:** Learning Games lab (Las Cruces - USA, New Mexico State University).
- **When:** Afternoon of October 17, 2018.
- **Number of sessions:** One user testing session (not a rehabilitation session).
- **Technical procedure:** A semi-structured interview.

Figure 48: Monster School Bus screenshots.
Source: mathsnacks.com/monster-school-bus.html

The results of experiment 2 have been divided into two parts: **Part A (children's profile) and Part B (motivation and preferences),** and are discussed in the next sections. The implications of this experiment for this study are then discussed.

7.2.1 Part A – Children's profile

In this part of experiment 2, a semi-structured interview was used to collect information about the children mainly with regard to their previous experience with games and digital artifacts (e.g. computers, tablets). The information obtained is summarized below.

For the interviews, the participants were organized in pairs according to their school year. Thus the following three pairs were formed:

- **Pair 1 - child 1 (boy) and child 2 (girl)**: both children are 10 years old, 5th graders, and go to a public school;
- **Pair 2 - child 3 (boy) and child 4 (boy)**: both children are 10 years old, 5th graders, and go to a public school;
- **Pair 3 - child 5 (boy) and child 6 (girl)**: both children are 9 years old, 4th graders, and go to a public school.

As regards the element **fun,** the participants mentioned the use of several entertainment artifacts, the most popular ones being their phones, tablets, video games (console), computers and books. When asked to justify their preferences, some of the reasons provided were:

- **Child 1:** "I think it will be my phone. I can take it everywhere, I have it with me right now. And I can play games and listen to music".
- **Child2:** "Tablet. Because I like to play games and music".
- **Child 3:** "To me, video games (console), because you can have a lot more games on consoles".
- **Child 4:** "Hum probably console too. Because I agree with (child 3), I can have more games and stuff on there, and because it is better than playing on a phone, because you can't do certain stuff on the phone, and consoles focus on games and the phone focuses on other things".
- **Child 5:** "Computer, because I like technology and fixing things".
- **Child 6:** "Books, because you get more knowledge from a book and you learn words that you don't know".

Based on the participants' answers, it can be concluded that digital artifacts are the preferred option, when it comes to having fun. Only child 6 mentioned books, in addition to digital artifacts.

As for the **use of digital artifacts** at school, most of the children use them. These are mainly used to **play educational digital games; to do research for school assignments; to research**. Only child 2 does not use a computer or a tablet for school activities.

- **Child 1:** "Yes. To play educational digital games; to do research for school assignments; to do research".
- **Child 3:** "Yes. We use it when there is free time or when it is raining. To research or play games".
- **Child 4:** "Yes. To research and to play educational games".
- **Child 5:** "Yes. To research and play educational games".
- **Child 6:** "Yes. We do research".

Concerning the **use of digital games,** child 1, child 2 and child 4 preferred to play video games (on a console). Child 3, child 5 and child 6, on the other hand, preferred to play computer games on the internet. When asked **how often they played digital games**, most of the children said that they played sometimes. Only child 6 played more often, once a week. Also, regarding the **use of digital games**, all six children said that they had a favorite digital game:

- **Child 1:** "I think it would be a game from Cool math games".
- **Child 2:** "Does it count if it is one of the games that we used today? Then, the first one I thought was cool...The curse reverse".
- **Child 3:** "Fortnite".
- **Child 4:** "Mine is Rodeo Stampede, is on the phone".
- **Child 5:** "Roblox".
- **Child 6:** "Dolphin game, is a game that tells you all about dolphins".

When asked what they liked about playing computer or video games, the children said:

- **Child 1:** "I like that you can sit anywhere and get comfortable while you're playing".
- **Child 2:** "I like the same (things) as him".
- **Child 3:** "Hum, for example, my favorite game is Fortnite. The game never ends like as you can... there are no levels but modes, like the famous Battle Royale and you can do whatever".
- **Child 4:** "Recently I kind of like playing on the computer because you pretty much have your keyboard and your mouse, and so you like have the full screen for just whatever you are giving, instead like on the phone you have stuff blocking half of it (Child 3: and a lot of adds on the free games)".
- **Child 5:** "Because it is fun".
- **Child 6:** "Because (there are) some math computer games and there are reading computer games".

In summary, in **part A** of experiment 2 information about the participants was collected so as to create their profiles. Figure 49, summarizes the information that is relevant for this research. As it can be seen, all six children have previous experience with digital games and are used to digital devices (e.g. consoles, computers, tablets). Almost all the children use these devices either at school or at home. Moreover, based on how much time they spend playing digital games, it can be inferred that the children have the same level of experience with games. It is important to highlight that this information is key to the analysis of the users' motivational preferences, which is presented in part B of this experiment.

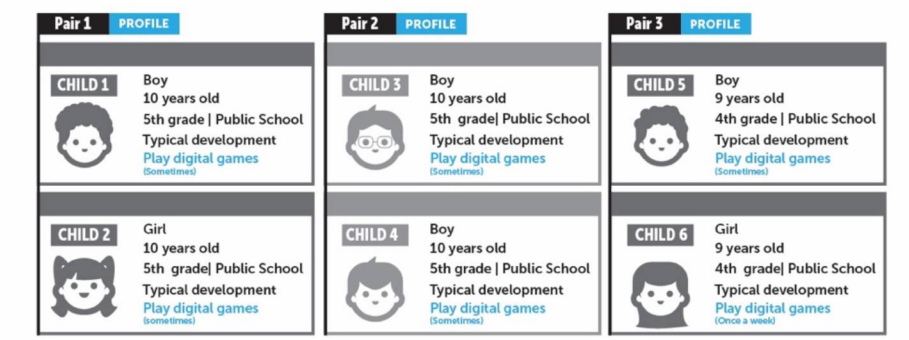

Figure 49: Summary of the children's profile (Experiment 2 sample).
Source: the author.

7.2.2 Part B – Children's motivation and preferences in games

Part B of experiment 2 aimed to verify participants' motivation and preferences with regard to the game elements character, world building and rewards. In this experiment, due to its configuration, only one type of script was used with each pair. Each script related to one game element, as shown below.

- **Pair 1** (Child 1 + Child 2): World building script.
- **Pair 2** (Child 3 + Child 4): Character script.
- **Pair 3** (Child 5 + Child 6): Rewards Script.

Before answering the questions about the game elements, all participants were asked to answer questions about their overall play experience with the game Monster School Bus. Their answers are discussed below.

When asked **what they thought about the game Monster School Bus,** although they all answered the question, most of the children found it difficult to justify their answers. This suggests that the question itself and the way it was put to the children need to be reformulated, in order to make it easier for the children to express their opinions. The children's responses are given below:

- **Child 1:** "I liked it, sure it was fun".
- **Child 2:** "I liked it".
- **Child 3:** "I think it is fun".
- **Child 4:** "Uh-huh, me too (agreeing with child 3)".
- **Child 5:** "It's fun".
- **Child 6:** "I think it's really cool because it has math in it, and like after you tried to collect 10, but you can't just go and pick up random ones, you have to pick 9 and 1 to make it ten".

The second question **was about participants' perception of how fast time went by during the gameplay.** How the children perceived the passing of the time, slow or fast, helped to identify if they were in a flow experience during the gameplay. The children's responses (see below) show that the way they perceived the passing of the time varied

according to their performance in the game, as it can be seen in child 1's answer. In general, all the children felt that the time went by fast, which may positively influence flow experience. This also indicates that the game challenges were appropriate for the children's skills.

- **Child 1:** "hum, I did not keep track of the time...sometimes fast and sometimes slow, depending on how I was playing. If I was losing, it felt like it was taking forever".
- **Child 2:** "I felt like it was going fast".
- **Child 3:** "Fast, uh-huh (Agreeing with child 4)".
- **Child 4:** "hum, I felt like it was fast. That was pretty good about the game".
- **Child 5:** "Fast".
- **Child 6:** "More medium, like it went fast and slow".

Question 3 asked participants **how they felt during the gameplay.** Overall, children had a fun and enjoyable time playing the game (see below). Child 2 explained that how she felt depended on her performance during the game. Similarly, child 6 said that she felt good because she felt that she was becoming smarter playing the game. Child 5 seemed to be distracted and simply said: "the same", agreeing with child 6's response.

- **Child 1:** "I felt good".
- **Child 2:** "It depends, like if I keep losing, then it makes me feel frustrated. But if I go to the next level I feel happy".
- **Child 3:** "Like I'm having fun".
- **Child 4:** "I kill pretty much driving the school bus".
- **Child 5:** "The same (agreeing with child 6)".
- **Child 6:** "I felt good, and I felt like I was getting smarter".

Question 4 asked the children **what they liked most about the game.** The children's answers varied (see below). For children 1, it was the game challenges. Child 2 also liked the challenges, but he also liked the monster and the scary stuff. Child 3 and child 4 liked the potions given in the game after a full load, which was a reward for good performance. Child 6 liked the fact that she was doing math while playing. Child 5 was again distracted and simply repeated the answer given by child 6.

- **Child 1:** "That it is really challenging".
- **Child 2:** "I like how it was challenging, and I like scary stuff, I like monsters".
- **Child 3:** "Yeah, I liked that too (agreeing with child 4)".
- **Child 4:** "Probably the...like when it gets me the full bus. Hum, and like go to the transforms stuff from the potions".
- **Child 5:** "The same (agreeing with child 6)".
- **Child 6:** "That you are doing math".

Question 5 asked participants **what they disliked most about the game** (see their responses below). They did not like that the groups of kids could not be split up to go to the school, which made the game challenging. Moreover, they did not like the fact that if

you cross the road in front of the school, when the bus is full, the bus automatically stops for the kids to get off, which sometimes makes the player miss the potions because they disappear quickly after the full load. Child 3 did not like the fact that he could not do something awkward in the game. Child 4 said she would like more levels. Child 5 would like to drive with more freedom. Child 6 disliked that she needed to learn and play at the same time. It is worth mentioning that this question showed that interviewing children in pairs can help them verbalize their ideas more freely, after listening to another child. For instance, both child 1 and child 2 had more to say after listening to one another.

- **Child 1:** "I think that at first I couldn't understand how to move around." After listening to child 2's response, child 1 added: "Oh, I have a few more. Another one is that I don't like it, is that you have like sometimes you need just one more and there is not enough to get that one more. Or whatever, I think you should give the choice to pick up the kids and drop them off at the schools. Because, whatever, I was driving around I trying to blow up the potions, and I was stopped at school, and I wasted a lot of my time, so I didn't get the potions".
- **Child 2:** "I don't like that you only can have a certain amount, but then if you get that you cannot keep picking up any other aliens." After listening to child 1's response, child 2 added: "It's like, first you need to stop, and then you can't get the potions".
- **Child 3:** "There's nothing awkward that I can do".
- **Child 4:** "Like some games have levels, like when we are done, and they go with more levels they add on stuff (like an endless game)".
- **Child 5:** "They don't let you drive freely".
- **Child 6:** "That you should get to learn and play the game at the same time".

Question 6 asked participants **whether they would like to play the game at home.** All the children said yes (see below) which means that they liked the game and would like to play it more.

- **Child 1:** "If I know how to get it, yes. It is really fun".
- **Child 2:** "Yes".
- **Child 3:** "Uh-huh".
- **Child 4:** "Uh-huh".
- **Child 5:** "Yes".
- **Child 6:** "Yes".

Question 7, by means of a Likert scale (smile), **verified the children's overall opinion about the game.** The scale was composed of 5 points (smiles): (1) Awful; (2) Not very good; (3) Okay; (4) Really good; (5) Fantastic. Five children considered the game really good, and one child considered the game fantastic. This evaluation also indicates that the participants liked the game and were motivated by it.

- **Child 1:** "Really good." (no justification provided).
- **Child 2:** "Really good." (no justification provided).

- **Child 3:** "Really good. Because I mean it still like other games, play with math.... I liked it...I liked it a lot while I play games".
- **Child 4:** "Really good. Hum, I like playing it and then just like I have so much fun then when you go to the last level you have to stop...".
- **Child 5:** "The same (agreeing with child 6). Because it is fun and educational".
- **Child 6:** "Fantastic. Because it's learning and at the same time it's fun".

Based on the children's responses with regard to the gameplay experience, it can be concluded that they liked the game and that playing it was a motivating experience for them. In the following sections, each one of the interview scripts is individually discussed: pair 1 (world building); pair 2 (character); pair 3 (rewards).

Pair 1 (Child 1 + Child 2) – World Building

To facilitate the children's understanding, the questions used the words 'narrative' and 'story' instead of the term world building.

The first question asked the children **what they thought about the game narrative**. Child 1 said "It is really good". Child 2, on the other hand, said: "I think it is good but then is kind of weird, because I don't know where the soup comes from." The soup part occurs immediately after the game tutorial, the character says that the soup he/she had the day before made him sick.

When asked to imagine **how the game would be without the story,** child 1 said "I think it would be kind of confusing because you don't know what you are doing". Child 2 said "Yeah and you would not pick up the job". Thus, based on their responses, it can be inferred that for them, it is the narrative that makes the purpose of the game clear and gives sense to the game.

When asked whether they would make any **changes to the Monster School Bus story to make it better**, child 1 said: "I think that to make it better, it should be like these guys that show up and if you pick them up, they all find a place in the bus." Initially, child 2 said that she had no idea. However, later, when answering the next question, she said: "Oh, I have an idea, you can make the bus go faster and then just like have a really hard turn to do and add more challenges."

When asked **whether the game story should teach them about the game challenges or tasks,** child 1 said: "Yeah"; Child 2: "I think that it's important". Neither child justified their answers.

When asked **at what moment in the game the story should appear**, child 1 said: "I think you should have a narrative during the levels so like if they get stuck, they can look up at the narrative and see what they might need to do". Child 2 appeared to be confused and simply said: "yeah, the same as him". Thus, according to child 1, the narrative should provide support during the levels, helping him with the game challenges, especially if he was stuck in some part of the game.

The next two questions verified the children's preferences in relation to how the narrative should be presented during the game. Firstly, they were asked **whether a narrative is more fun with static images or short animation**. Child 1 said:" A narrative with animations", Child 2 said "the same". Secondly, **the children were asked whether they preferred narrative with text on the screen or a narration**. Both children preferred text.

Child 1: "I like the texts", Child 2: "Me too". It should be pointed out that the Monster school bus game uses text on the screen.

When asked **whether they would like to make changes to the game story,** child 1 said: "I will add more funny parts, like the soup part."; Child 2:" I think to be funnier would be interesting". Thus, for both children humor and funny moments should be part of the game narrative.

Finally, the children were asked **whether they preferred a strong narrative (they need to know the story to play the game) or just a backstory.** Both children said that they preferred a game with a strong narrative, that is, in order to play the game the player needs to understand the story.

Pair 2 (Child 3 + Child 4) – Character

The first question of the script asked the children **what they thought about the game character.** Child 3 said: "It should add a couple more characters. Like, maybe one more boy and one more girl. Like maybe with different hairstyle on it." The children were then asked **whether** they would like **to choose the character or customized it** - Child 4 immediately said: "Yeah, customize that (the character) would be really cool". Child 3 added: "Yes, or at the beginning of the game you'd be able to customize your own.

In the next question the children were asked **what they thought would happen to the game if the character was removed.** Child 4 said, "I think it might be a problem". Child 3 agreed with child 4. Both children had difficulty in justifying their answers.

When asked **what would make the character from the game better**, child 3 said "like customizations"; and child 4 replied "Hum, maybe like a hat or sunglasses". Thus for both children, to be able to customize the character is something important. This can also be seen in their responses to the next question. When asked **what would make a character fun and cool,** child 4 said "Maybe if you like customizing it if you add that, maybe if you complete a round or something with 3 stars you get like a new outfit or something. I see this in other games". Child 3 agreed: "Oh yeah! (referring to the new outfit child 4 mentioned).

In the next question the children were asked **in what moment of the game they would like to see the character.** Child 3 said: "I think when you finished and when you started. Like at the begging". Child 4 agreed: "Yeah, like the beginning, like that man are talking to you about like at the end of the level and the beginning of a new one. Like at the beginning of levels you get like monsters, new monsters. Moreover, after the level he congratulates you".

When the children were asked **to describe what makes a game character cool**, both children said "customizations".

When asked **whether the character should give tips for the game challenges,** child 3 said: "I think that would be good, because if you like started the game, and you don't know what's going on, then it would help you". Child 4 agreed: "Uh-huh, because it can give advice". Thus both children would like to receive tips or advice from the character which

would help them with the game challenges. This would be particularly good when they do not know what to do in the game, according to child 3.

The next question asked the children **what they thought about being able to choose or customize the character**. Child 3 said: "I think that would be fun. Maybe we should be able to customize or car too, the bus". Child 4 said: "Customized it. Yeah (customize the car) that would be very cool too". Again both children emphasized how much they like customization, in this case, not only for the character but other game elements as well, such as the bus.

In the last question the children were asked **whether they thought the game character should teach them about the game (audio or text).** Child 3 said: "I think it would make it more fun". Child 4: "I think it would make it better too".

The children were also asked whether they thought the character should tell the player when they did the right thing or when they made a mistake in the game. Child 3 said: "Like if you do the wrong thing it should do like "Ops" or if you do the right thing it should do like "nice job". Child 4 said: "Yeah, one thing is like if you're not like fit at this game, if you did some wrong, it could discourage then". Thus, whereas child 3 likes the idea, child 4 thinks that to draw the player's attention to their mistakes may discourage them if they are not performing well in the game challenges.

Pair 3 (Child 5 + Child 6) – Rewards

The first question of the rewards script asked the children **what they thought about the game rewards.** Child 5 said: "It can give you a little bit more stars, but anywise it is fun". Child 6 said: "It should give you a new person." – **Like a new character?** – Child 6: "Yeah". When asked **what they thought the game would be like if the rewards were removed**, child 5 said: "It won't be fun", and child 6 agreed: "Yeah, we need the rewards."

When the children were asked **how they would make the game rewards better,** child 5 answered: "By getting more stars and getting cool items." Thus child 5 seemed to be interested in receiving more rewards, such as the stars used in the Monster School Bus game, or items. Child 6 answered: "By pay attention them, like pay attention till like the numbers...hum, how can I explain...like to get better at math so you could like see if you could understand it." Child 6's answer seems to suggest that she would like the rewards to be related to their knowledge of math. Although both children answered the questions, they had great difficulty justifying their answers.

When asked **what would be a cool and fun game reward,** child 6 said: "A potion for the, not like an actual potion but a potion for the game like you can go, you could have more time". Child 5 agreed: "the same". Child 5 seemed distracted and not fully engaged in the activity. This was perhaps because other activities were taking place in the lab at the time of the interview. Thus, although the participants were in a different room, this seems to have negatively affected child 5's participation in the interview.

When asked **at what moment in the game they thought a reward should be given,** child 6 said: "During the levels". Child 5 agreed with child 6: "Yes, and after. Yeah during and after".

As regards **the format of the rewards**, both children said that they preferred "physical rewards" – for instance, something printed from the game. They also preferred the rewards to be in the form of resources which they could use in the game, instead of something just for collection. Child 6 said: "Resources that you can use. Hmm, so it would be easier". Child

5 said: "Resources, yeah the same". Also, for them, a reward is more fun when it is an item, instead of a score.

When asked about **the best moment in the game to receive a reward**, child 6 said: "Like whenever when you get really confused so like in the middle." Child 6 seems to suggest that when the player is not doing well in the game, they should receive something (e.g. a reward) to encourage him/her to keep playing. Child 5 did not answer this question.

Finally, the children were asked **what would make a cool game reward.** Both children had difficulty in answering this question. Child 6 said: "Oh it's a hard one. Hmm, so a piece of candy"; child 5 agreed: "The same".

7.2.3 Conclusions

Experiment 2 was conducted during a regular user testing session at the Learning Games Lab (NMSU), in the Unites States. The participants (6 children) played the game Monster School Bus for 20 minutes, and afterwards they were interviewed in pairs. The data collected was then analyzed, and conclusions were drawn with regard to the following: **participants' motivation for the game overall; participants' preferences regarding the game elements; limitations of the data collection.**

Participants' motivation for the game overall

- All six children have previous experience with digital games and play these games regularly (once a week) or occasionally. This shows that digital artifacts (e.g. computers or tablets) are part of their daily lives.
- All the children liked the game Monster School Bus. For instance, child 1 said: "I liked it, sure it was fun"; child 3: "I think it is fun". Also, all the participants felt good, happy or had fun during the gameplay. For instance, child 6: "I felt good, and I feel like I am getting smarter."
- The children's perception of the time while playing the game was medium to fast, which is good and suggests that they were having a flow experience. It also indicates that the game challenges are appropriate for the children's skills.
- The aspects of the game the children liked the most were: the challenges, the monsters, the scary stuff, and doing math while playing.
- The children's opinions varied as regards what aspects of the game they disliked the most. Child 1 and child 2 disliked the fact that they could not split the group of kids up to fill the bus, and that the bus stopped automatically at the school, which made them miss the potions. Child 3 said: "There's nothing awkward that I can do"; Child 4 would like to have more levels in the game; Child 5 would like to drive freely with the bus; Child 6 disliked the fact that she needs to learn and play the game at the same time.
- All the children would like to play the game at home, which shows that they liked the game. Also, the game was rated 'really good', 4 on a scale of 5 points, by the majority of the children.

Participants' preferences: World Building (Pair 1 – child 1 + child 2)

- Pair 1 (child 1 + child 2) liked the game's narrative. For them, the game would be confusing without the narrative. Child 1: "I think it would be kind of confusing, because you do not know what you are doing". Child 2: "Yeah and you would not pick up the job". This suggests that for them, the narrative makes the purpose of the game clear and gives sense to the game.
- The children think that the narrative should teach them about the game challenges. For instance, child 2 said: "I think that it's important".
- Regarding the moment in the game when the narrative should be used, child 1 said: "I think you should have a narrative during the levels so like if they get stuck, they can look up at the narrative and see what they might need to do". Child 2 agreed: "yeah, the same as him". Thus, according to child 1, the narrative should help with the game challenges, especially if they are having difficulties.
- As regards the narrative format, both children prefer a narrative with animation instead of static images. Moreover, they prefer text on screen over a narration.
- The children said that they would like to make changes to the game story. Child 1: "I will add more funny parts, like the soup part". Child 2: "I think funnier is interesting". Thus both children think that humor and funny moments should be part of the game narrative.
- Finally, both children said that they prefer a game with a strong narrative, that is, in order to play the game the player needs to understand the story.

Participants' preferences: Character (Pair 2 – child 3 + child 4)

- Both children liked the game character, although for child 3, the game should have more character options: "It should add a couple more characters. Like, maybe one more boy and one more girl. Like maybe with different hairstyle on it". Both children would like to customize the character, child 4: "Yeah, customize that would be really cool". Child 3: "Yes, or at the beginning of the game you'd be able to customize your own".
- Both children think that if the character is removed from the game it might be a problem.
- In other to make the game character better, the children would like to be able to customize it. For both children, to customize the character is important as it makes a character cool and fun. They also would like to customize other game elements, such as the bus.
- With respect to the moments in the game when they would like the character to appear, child 3 said: "I think when you finished and when you started. Like at the beginning". Child 4: "Yeah, like the beginning, like that man are talking to you about like at the end of the level and the beginning of a new one. Like at the beginning of the levels you get like monsters, new monsters. Moreover, after the level he congratulates you".
- Both children would like the character to give them tips or advice about the game challenges. Child 3 said that this would be good particularly when you do

not know what to do in the game. The children think that if the character communicated (audio or text) with them during the game it would be fun and better. Child 3 said: "I think it would make it more fun". Child 4: "I think it would make it better too".

- The children think that it would be good if the character could tell the player when the player does the right thing or when the player makes a mistake in the game. Child 3 said: "Like if you do the wrong thing it should do like "Ops" or if you do the right thing it should do like "nice job". Child 4, on the other hand, thinks that to draw attention to mistakes may discourage the player if he/she is not performing well in the game challenges - child 4: "Yeah, one thing is like if you're not like fit at this game, if you did something wrong it could discourage then".

Participants' preferences: Rewards (Pair 3 – child 5 + child 6)

- Both children liked the game rewards, but both suggested some changes. Child 5: "It can give you a little bit more stars, but anywise it is fun"; Child 6: "It should give you a new person". Moreover, they think if the rewards are removed from the game, the game will no longer be fun. Child 5: "It won't be fun". Child 6: "Yeah (agreeing with child 5), we need the rewards".
- As to how to make the game rewards better, child 5 said: "By getting more stars and getting cool items"; and child 6 said: "By pay attention them, like pay attention till like the numbers...hum how can I explain...like to get better at math so you could like be see if you could understand it". Thus child 5 seems to be interested in receiving more rewards, such as the stars used in the Monster School Bus game, whereas child 6 would like the rewards to be related to their knowledge of math.
- For the children, the best moments to receive a reward are during the levels, and after the levels. Child 6 said: "Like whenever, when you get really confused so like in the middle". Child 6 seems to suggest that when the player is not doing well in the game, they should receive something (e.g. reward) to encourage them to keep playing.
- Regarding the reward format, the children said that they prefer: "Physical rewards" – for instance, something printed from the game. Moreover, they prefer to receive resources that they can use in the game instead of rewards just for collection. Also, for them, a reward is more fun when it is an item, rather than a score.

Limitations of the data collection

The primary purpose of this experiment was to identify possible methodological problems in the data collection approach used in this study. The following is a list of the problems identified.

- The children's reaction and the difficulties they had in articulating their responses, suggest that many of the questions need to be reformulated. Yes or

no questions should be avoided, and open questions which allow the children to better express their opinions should be used instead (e.g. Why?).

- Due to time limitations, the profile script and the game element script were applied together. This proved to be inappropriate. The children did not have enough time to answer all the questions comfortably, and as a result some of their answers were rather brief. Thus, the scripts will be revised and the number of questions reduced. Shorter scripts will allow the children to provide more detailed answers and to better justify their choices.
- Experiment 2 showed that although the children know what they prefer, it is not always easy for them to justify their answers. Thus, the interviews will now take a more conversational tone in order to help the children to express their ideas and preferences more freely.
- Due to the need to conduct the interviews as a conversation, more time will be needed with each child. Moreover, the children should be allowed some time to acquaint themselves with the researcher before the interviews, e.g. through playing a quick and simple board game. Otherwise, they will be shy and have more difficulty in expressing themselves.
- Although permission was given to make audio-recordings of the interviews, the interviewer recorded the information by taking notes. This proved to have a negative impact on the interaction with the users, because it constrained the interviewer's performance. For that reason, in further interviews the interviewer will no longer be taking notes during the interaction with the children. Instead, the interviewer will make audio-recordings of the interviews, and/or another researcher will observe the session (without interacting with the children) and take notes.
- This experiment tested the effectiveness of interviewing the children in pairs. Interviewing the children in pairs optimized the time. Also, the children felt more confident to speak and express their opinions after listening to one another, at times even complementing each other's responses. On the other hand, when the children were confused by the question or were shy, they tended to repeat what the other child said. One strategy used to prevent this from happening was to ask the less talkative child to speak first.
- The user verification in experiment 2 made use of a semi-structured interview. This, however, was not always effectively conducted. In future interviews, it is essential that the interviewer takes into account the fact that in semi-structured interviews new questions will emerge during the interaction with the children. Thus the interviewer should be flexible and allow for changes to be made, based on the conversation with the participants.

Figure 50 summarizes the main data gathered in experiment 2.

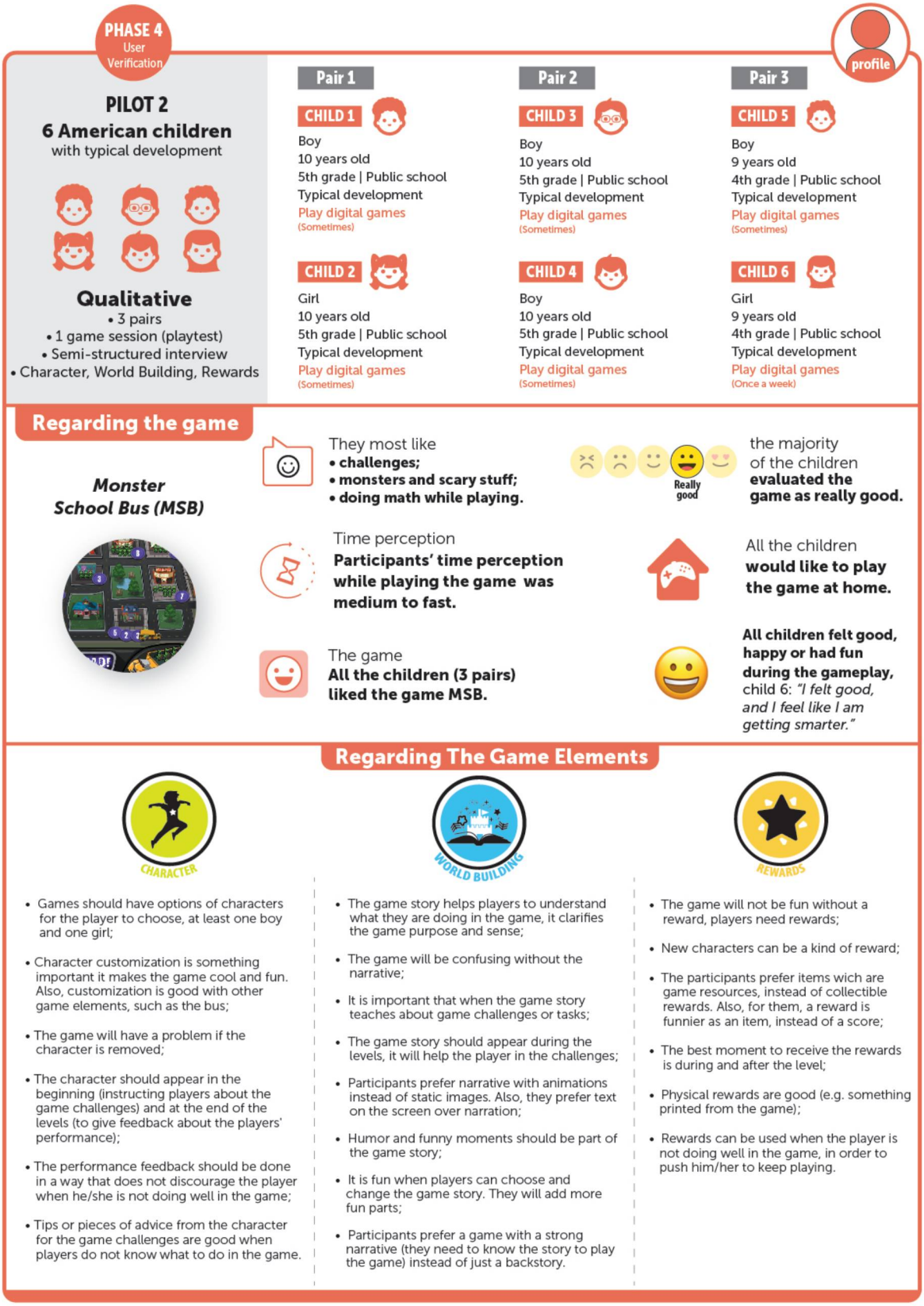

Figure 50: Summary of experiment 2 data.
Source: the author.

7.3 Final user verification

The aim of this final user verification was to gather information on the children's preferences with regards to educational games. More data was collected in this final user verification. This was because there were more sessions - one session per week over a period of three weeks. Also, each child was interviewed three times: before, during and after the gameplay. In addition to being interviewed, this time the children were also observed during the game sessions. This enabled the researcher to verify how the children behaved during the sessions, for instance how they interacted and how they communicated with the interviewer, as well as their level of engagement. Each game session focused on one of the three dramatic elements considered, namely character, world building, and rewards.

Four Brazilian children with dyscalculia took part in this user verification[30]. Some of the participants, however, were not able to attend all three game sessions. Table 40 provides a brief description of the sessions.

Table 40: Final user verification sessions with Brazilian children.
Source: the author.

CHILD (#)	Session 1	Session 2	Session 3
(#1) PJ	Profile + Character	World Building	Rewards
(#2) MJ	Profile + Character	World Building	Rewards
(#3) BJ	Profile + Character	World Building + Rewards	X
(#4) AJ	Profile + Character + World Building + rewards	X	X
(#5) X	Profile + Character	This child withdrew from the research.	X

The methodology and the materials used in this final user verification are described in chapter 4. The following is a summary of its main aspects.

- **Goal:** To verify with children with dyscalculia their motivational preferences with regard to the game elements character, world building and rewards.
- **Sampling:** Four Brazilian children diagnosed with dyscalculia, aged 9 to 13.
- **Mediators:** The author of this dissertation
- **Selected game:** An adapted version of Monster School Bus (translated into Portuguese) (see figure 51).

[30] Participants were from Brazil therefore the questions were in Portuguese. Questions and answers were later translated into English.

- **Recommendations regarding the elements:** Character, World Building, and Rewards.
- **Place:** Developmental Neuropsychology Laboratory (UFMG – Brazil).
- **When:** March 2019.
- **Number of sessions:** Three sessions of game interaction (1 session per week).
- **Technical procedure:** A semi-structured interview and observation.

Figure 51: An adapted version of Monster School Bus.
Source: the author based on mathsnacks.com/monster-school-bus.html

The results of this final user verification are presented in the following sections. Four categories were distinguished according to content (see figure 52):

- **Part A:** children's profile; previous experience with games in general and with educational games; their feelings towards the learning of math.
- **Part B:** children's motivation and preferences with regard to the game played and other educational games.
- **Part C:** information gathered through observations.
- **Part D:** summary of the children's preferences.

The data analysis followed the same main structure for all four children. The amount and nature of the data, however, differed slightly from one child to another, which is to be expected when semi-structured interviews are used.

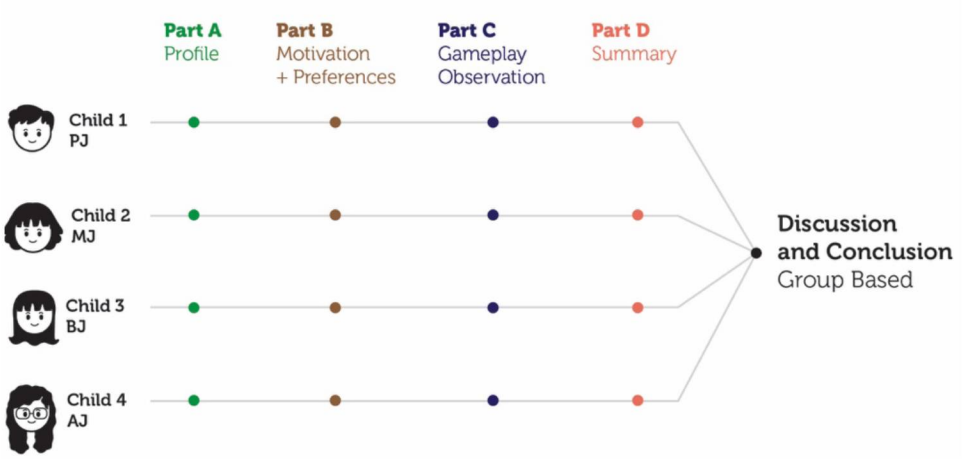

Figure 52: Data analysis structure.
Source: the author.

7.3.1 Child 1 - PJ

7.3.1.1 Part A – Profile

PJ is a 13 years old boy. He is very calm, polite, and a little shy. He goes to a military school and is in the 8th grade. PJ was diagnosed with developmental dyscalculia and ADHD (attention deficit hyperactivity disorder) by the DNL (UFMG). He attended all three game sessions. PJ's profile is summarized below.

- **To have fun:** PJ uses mainly a cellphone because it is always with him making it easy to be used. He also plays videogames (pc and Ps3).
- **Digital artifacts at school:** PJ sometimes uses a computer in class to do research.
- **Frequency of playing games:** PJ plays digital games sometimes during the week.
- **Platform:** PJ prefers to play on PlayStation 3, because the quality is better, and he can play with his friends.
- **Preferred digital games:** PJ likes action games with levels to be explored. He also likes to play multiplayer games with his friends.
- **Favorite game:** PJ's favorite game is *Street Fighter* (Ps3), because of the quality of the game and because he can play it with his friends. Ryu (from *Street Fighter*) is his favorite game character.
- **To be fun a game must have:** A large variety of characters with different skills. He does not like characters that have only one skill.
- **Previous experience with educational digital games:** PJ thinks this kind of game is important for learning because children like them. He likes most educational digital games.
- **Learning mathematics:** PJ likes math, it is one of his favorite subjects.

7.3.1.2 Part B – Motivation and Preferences

About the game

As aforementioned, PJ attended all three game sessions. In each session, after the gameplay, he answered questions regarding his experience of playing the game Monster School Bus. The purpose was to check whether the child felt motivated to play the game and whether they stayed motivated throughout the sessions.

With regard to **how fast he felt the time went by during the gameplay,** PJ said the time went by fast in all three sessions:

[Session 1] PJ: It went fast, because it was very cool.

[Session 2] PJ: Fast, because everything that we like goes fast.

[Session 3] PJ: Fast, because everything that we like goes fast, right?

As for **how he felt while playing the game,** PJ said he felt curious, happy, and confident during the three sessions (table 41):

Table 41: How PJ felt while playing the game.
Source: the author.

Session 1	Session 2	Session 3
PJ: Ah I liked it. I was curious. Because in the second world there were other kids. I think in the other worlds there are new kids.	PJ: I was feeling happy, because I liked the game. Q: Did you feel confident during the game challenges? PJ: Yes, I always felt confident.	PJ: I felt happy because the game is cool and I can learn my favorite subject playing it. (speaking excitedly)

When asked **if he would play the game Monster School Bus at home,** in all three sessions, PJ said that he would like to play the game at home. His reasons for that are given in table 42 below.

Table 42: PJ's reasons for wanting to play the game Monster School Bus at home.
Source: the author.

Session 1	Session 2	Session 3
PJ: I would, because it was fun.	PJ: Uh-huh, I would. Because the game is fun and also, it teaches math, right? It is not only about having fun, but it also teaches, so it would not be a waste of time. Because we would be studying... and it is something that we like to do, and it is something that we are learning.	PJ: I would, because it can be a great way to study and still have fun, right?

In the second session, when asked **if the game would help him to learn math,** PJ said that it would. He also pointed out the following:

PJ: Uh-huh, also it would be great if we could have categories like: difficult, easy, and medium, you know? For people who are already in the 8th or 9th grade, who already find it easy. Thus, it would be much better if the game used the math from their grade, do you understand?

Q: So do you think that before the game starts, the player choose be able to choose the level of difficulty (easy, medium or difficult)?

PJ: Yes, because, for example, for someone in the 1st grade, this category would be difficult because they are still learning. But for someone like me, who is in the 8th grade, it is a little bit easy, because we already know how to use decimals...

Q: I see, but did you find this game too easy for your level?

PJ: Yes, it was easy to count. But it was a little harder with the slime, because we couldn't tell the quantity, only the size.

When asked **to evaluate the game using a smile scale (1 to 5),** PJ rated the game as really good (4) in all three sessions. See table below:

Table 43: PJ's overall assessment of the game.
Source: the author.

Session 1	Session 2	Session 3
Really good (4). PJ considered the level of difficulty of the game to be medium. For him the controllers were the hardest part.	Really good (4). For the game to be fantastic (5), it should allow the player to choose the level of difficulty.	Really good (4). For the game to be fantastic (5), it should allow the player to customize the design of the bus.

In session 1, it was noticed that PJ was not interested in the bonus potions, and in one occasion he did not even try to catch them. With that in mind, in session 2, the researcher asked PJ **what he thought about the potions. PJ's answers are** shown below.

PJ: Sometimes the children would not try to catch those potions because they wanted to pick up more kids in less time or in a better category, right? Because if we try to pick up more potions than kids, it would take a long time, wouldn't it?

Q: So you try to optimize your time by taking the kids and leaving the potions because they are not valuable enough to be a caught.

PJ: Yes, exactly. The kids would give more points, you know?

Q: Do you think that the time it takes to take the kids to school should be considered, so you would earn more points based on how fast you were?

PJ: Yes, and also the number of kids. If you take all the kids, you earn more "likes".

When asked **whether he liked learning math,** in the first and last sessions PJ said that he liked learning math, that it was his favorite subject.

PJ: I like math very much. So, if someone asks me to study math, I do.

Q: Cool. And what do you think about learning math while playing a game?

PJ: I think it is very cool, math and a game. There are many world games that are very famous math games, right?

Q: So, do you think that it would be cool if your school used games in some activities?

PJ: Yes, it would be cool.

Regarding the level of difficulty of the game, in the third session, the researcher asked PJ if he thought the game had become easier.

PJ: Yes, it has. Because at one level, if you do it again the number sequences do not change. So, we can memorize the level, then you already know.

Q: Did this help you? Was your strategy to memorize the number and keep trying?

PJ: Uh-huh, yes.

When asked what makes a math game fun and cool, PJ said:

PJ: Ah, for me it doesn't need to have anything. For me, the game is excellent the way it is.

Q: Okay. So can you tell me what makes this game cool?

PJ: Yeah, that we move the potion, I think it's pretty cool - the bonus that changes shape.

Q: So, do you think that catching the potions and transforming the buildings make the game cooler?

PJ: Uh-huh, and that makes us more curious - thinking about what that place will be like with the potion.

PJ was then asked what advice he would give a game developer who was developing the next game:

PJ: Ah, first it should focus on a story, right? Because a lot of games have a history, even if they do not have a story sequence. But most of them are good and have a story like that.

Q: I see. What else would be important to have in the game?

PJ: Also, you know... for example: we could customize our bus in the middle of the game. You know, it makes the game more dynamic.

Q: More dynamic, do you mean a game that does not always stay the same (presents different things)?

PJ: Uh-huh, with bonus levels, where there are different functions and other things. It's like, for example, one day it is like a bonus level and you get a kit to be part of your bus; Another example: now you need to go to a specific place.

Q: So, you think it's important that the game changes and have different things, that it does not always do the same thing.

PJ: Yes.

Session 1: Game Character

For PJ the game character from Monster School Bus is cool, mainly because the character is funny.

PJ: Ah, I think he is very cool.

Q: What is so cool about him?

PJ: Ah I don't know. He understands other things apart from words. It is cool. (smiling)

Q: So, did you think he was funny?

PJ: Uh-huh! (excited)

When PJ was asked what he thought would happen to the game if the character was removed, he said that the game would no longer be cool.

PJ: I think it's not going to be cool because it is like the character was the essence of the game. He is one of the main characters in the game. He is the driver, isn't he? And we're playing with the driver.

Q: So, what would the game be like without the character?

PJ: If you remove the character you would only have the other one (referring to the female character - Jenny). Then, it would be out of focus, because always in a game like that, most games have a man and a woman as options, right?

Q: But if we remove both characters? In this case, you wouldn't have any options to choose from.

PJ: Ah and where is the character? (puzzled) It has to have a character, right? It has a story, right? Then it should have a character.

Although PJ would not make any changes to the Monster School Bus Character, he had some ideas regarding **what a game character should do in the game:**

PJ: Hum, I don't know. In most games, there should be a boss right, a challenge. My idea would be another driver, who would try to take the kids.

Q: As a competition, to see who would take more monster kids?

PJ: Uh-huh. (excited)

Q: In this case, would you rather compete with other children (player) or with a NPCs (computer)?

PJ: hum, either.

When asked **when in the game the character should appear,** PJ said that he did not know. He, however, made some suggestions with regard to customizing the character.

Q: In the MSB, the character appears before and after the level. Do you think this is a good idea or would you prefer to control the character, for instance, taking the bus?

PJ: No, the focus is on math and we use the bus to take the kids. Then it would be a little out of focus. Also, in other levels, we could make changes to the bus, you know. An improved bus with more seats. We could buy one and customize it as a bonus, you know.

When asked **what he thought would make a game character cool**, PJ had difficulty verbalizing his preferences. However, when the researcher mentioned that he had said earlier that he liked characters with good skills, PJ confirmed.

As for **the type of character he would like to see in the game,** PJ said that it is important that the character has a connection with the game narrative/story. He gave the following example – PJ: this game had a zombie city, then it is better if the character is a monster, right? Because it is a monster city.

When asked **what he thought about the possibility to control the character during the game,** PJ said it would be good to have some bonus levels, where there are new things to do with the character (e.g. new skills or ways to interact with the character).

When asked if the character should give the player tips about the game challenges, PJ said that this would help:

PJ: Ah, this would be good because it helps.

Q: But, should it happen all the time or only in very difficult parts?

PJ: Only in a very difficult moment. Or advice like, in a challenge when you need to do something extra. For example, when you need to take all the flasks with the potions. It would be an instruction.

When asked what he thought about the possibility to choose or customized the game character, PJ explained:

PJ: It would be good, right? Because in this case the person would think "Really! I can customize him!" It would be more fun, he would design his own character and also the bus.

When asked **if the game character should talk (audio or text) about the game tasks,** PJ explained that he prefers to receive instructions from the character as part of the game story:

PJ: This is good. Because it is like a better instruction to teach us, it instructs us to do the level.

Q: Do you like it when it is the character who gives you the instructions?

PJ: It should be the character, because it is like a story, right? The character is the boss, so he would like to talk about it.

Q: Ok. So do you think it is better when the game instructions are part of the story?

PJ: Uh-huh. (excited)

In the last question, when asked if the character should tell the player when they did the right thing or made a mistake in the game, PJ said:

PJ: Yes, a compliment, you know - well done, you did it!

Q: Would you prefer this compliment to be in the form of a text on the screen or an audio?

PJ: An audio would be cool, but with some variety. If it was after the game, it could be the boss. But if it was in the middle of the game, it would be better through audio, like a "radio system" that every bus has. For that reason, it is good to have a variety of languages in the game.

Session 2: World Building

In session 2 of the game, after the gameplay, PJ answered questions about the element world building. Firstly, he was asked **what he thought about the game story (narrative).**

PJ: Ah I liked the story.

Q: What is cool about the story?

PJ: That he was looking for a job, and then he got this job.

Q: What do you think about the funny parts in the story?

PJ: It's always good to have funny things like this.

Q: Do you think that the game story is more interesting with funny parts?

PJ: Uh-huh, yes! (excited)

When PJ was asked to imagine **what the game would be like without the story,** he explained that the story is important because the game does not make sense without it. He also said that there should be a tutorial explaining how to play the game.

PJ: It won't make any sense, right? Because, there are some moments when he talks to the boss. So, that creates a little of... since when he has this job? How did he get into this job? It should have these things.

Q: Do you think the story makes it easier to understand the game?

PJ: Uh-huh, yes. Also, it is very good that the games always have a tutorial to explain how to play. Because if we don't have a tutorial, we just get confused, like in some of the games that I played that didn't have a tutorial.

PJ was then asked whether he thought a game should have a story:

PJ: It does because with no story... (gesticulating) it is like a story about the main character.

Q: So, do you think that the story is connected with the character?

PJ: Uh-huh!

Q: So, if the game has a character...

PJ: It should have a story.

PJ had difficulty to verbalize his preferences regarding the length of the game story (long or short) and what would make it cool. When asked **whether he would make any changes to the Monster School Bus story to make it better**, PJ said that he would not change anything. For him the story is good the way it is.

When asked if the game story should teach about the game challenges or tasks PJ said:

PJ: Like, the story saying what the game will have? It is good, right?

Q: In the MSB, the instruction (tutorial) was part of the story, did you like that?

PJ: It is better if it is part of the story, right? Because in this way I already know and will get some kids.

Q: Do you think you understand the game better when the instructions are part of the story?

PJ: Uh-huh, because the speaker is the boss, right? He tells you about the kids you are going to pick up and their characteristics. So, this is always good.

When asked **when in the game the story should appear,** PJ said that it should be before the levels, to explain if there are different missions in the level.

When asked **whether static images or short animation should be used to present the game story,** PJ said that he preferred static imagens, because, for him, if the character moves it can be confusing for the player. He also preferred a narration to a text on the screen. For him, the story should be told by a storyteller, but he did not justify his answer.

For PJ, **the possibility of choosing and changing the game story** would distract the player and affect his attention.

When asked **if to play the game the player needs to understand the story,** PJ said yes. He also explained the role of the story in games and movies:

PJ: It's good because if we understand the story, then we understand a little bit what we need to do, right? Because it is there, right?

Q: Do you think that the story makes you want to play the game more?

PJ: Uh-huh. People always like to play games that have a story because they want to find out about the ending, right? Like in the movies.

Finally, when asked **whether the game story should have funny moments,** PJ said: "it makes people laugh, and have fun, right? Funny things make people relax a little."

Session 3: Rewards

In the last interview with PJ, the focus was on the game element rewards. The first question was **whether PJ liked the Monster School Bus rewards:**

PJ: Yes, because it shows whether you have been good, more or less or very good. That shows whether we did well in math.

PJ was then asked to imagine what the game would be like without the rewards. He said:

PJ: Huh, it is because the car (referring to the final game reward) works as a way to make us curious. If we get all the stars, right? Then, it makes everyone curious.

PJ said that he would not change the game rewards. He, however, explained what kind of game rewards he likes. PJ said he likes rewards that he can use in the game, such as a resource that will help the player in some of the game challenges.

When asked what type of reward is more fun, physical rewards (e.g. a certificate in the real world) or virtual rewards (e.g. stars in the game), PJ said that he preferred virtual rewards because it shows that the character is winning something, assuming that the character represents the player in the game.

When asked whether he preferred to receive a reward that can be used in the game (resources) or a reward just for collecting, PJ said:

PJ: Like the stars...in many games if you collect a number of stars, it gets you a number of coins to open a chest. This chest would have another reward.

Q: So, the game would have two types of rewards. One to be collected, and another one that, based on the number of items in your collection, will allow you to earn other rewards.

PJ: Uh-huh (excited).

When asked about the best moment in the game to receive a reward, PJ said:

PJ: In the end, right? Because we have already completed the level.

Q: How about during the level? To receive a compliment - "well done".

PJ: Ah, if it is a speed bonus, it would be good, right?

Q: Do you mean, getting faster in the game?

PJ: No, like if we did it fast, we'd get more energy, you know?

Q: So, the player would earn an extra reward if he/she completed the level fast.

PJ: Uh-huh, yes.

When asked **what type of game reward he disliked the most,** PJ said that he liked all kinds of rewards:

> PJ: Ah, any type of reward is good. And any reward can be used, whether it is bad, good or more or less.
>
> Q: So, if you get "try again, you did badly", do you think it is important to receive this kind of feedback?
>
> PJ: Yes, it shows where we need to improve.

As for what kind of rewards is more fun (e.g. points, stars, potions), PJ said:

> PJ: Ah, stars...potions... it is better because it is more visible.
>
> Q: Do you mean, more visible in the game?
>
> PJ: Yes. Then we could use a type of coin with some trader who sells bus parts.
>
> Q: Okay. So, what would be the purpose of the stars?
>
> PJ: They would make the person try to get more potions and more stars.

7.3.1.3 Part C – Researcher's observations

Table 44: Summary of the researcher's observations - Child 1 – PJ (Brazilian boy with dyscalculia). Source: the author.

Session 1
• PJ was focused and engaged during the gameplay and interviews. • PJ completed two game worlds (6 levels) in this first session. • PJ had no problems understanding the game's instructions and story. • PJ learned how to use the game controls without any difficulty. However, PJ had some difficulty with the controllers when he needed to be faster. For instance, to pick up the flasks with the potion. He found the keyboard arrows a little difficult to use. • PJ avoided catching the flasks. He said that he was trying to take the kids faster, although this was not a requirement of the game. • In the first game world, PJ was able to strategically do full loads (find a group of number that equals 10), for instance, 7+3=10. • The second game world, where the player needs to add decimals (e.g. 3.5 + 6.5 = 10.0), was too difficult for PJ. He was engaged and kept trying, however, at this point his strategy was trial and error. • PJ could not do sums with decimals, and therefore he did not perform well. The game system, however, still allowed him to move to the next level. This kept PJ motivated. PJ said that he was curious to see and try the new game world and see the new monster kids. • At the end of this session, PJ said that he liked the game. He also said that the game was getting harder at each level.
Session 2
• PJ was more talkative and could verbalized his game preferences better. • During the gameplay he was engaged and excited about finishing the game. He made a few comments while playing. • PJ showed significant improvement in his use of the game controllers. • In the game world 3, the player needs to pick up a group of kids to equal 1 (e.g. .7 + .3 = 1.0). PJ planned a strategy to pick up the kids before moving the bus. This got him many full loads. The level of difficulty of the game was intermediate, which was appropriate for PJ. • In the game world 4, the player also needs to pick up a group of kids to equal 1 (e.g. .75 + .25 = 1.00). This time PJ struggled to complete the levels. He then used the strategy of trial and error. The activity was too difficult for PJ.

• PJ ended the game with few stars (13 out of 36). As a final reward, he got a Beetle, which is the worst reward in the game (1 of 3 types of cars). PJ still found it cool, and said that he got excited about trying to get more stars.
Session 3
• PJ played some of the levels where he had had a low score again. The idea was to get more stars to earn a better reward at the end of the game. • PJ was excited and engaged during the whole gameplay. He was very talkative and felt comfortable in the researcher's presence, which helped him to verbalize his preferences. • When PJ played some of the levels again, he got the highest score earning three stars. He was pleased and smiled. • PJ's improvement in the levels was representative. • PJ used a different strategy this time. He used the restart button several times, beginning the level as soon as he noticed that he had made a mistake (in some levels, more than 4 times). He said that his strategy was to memorize the group of numbers and keep restarting the level until he got the three stars. In some levels, he still used the trial and error strategy, mainly when it involved decimals and large numbers • PJ improved his performance and earned more stars (25 out of 36). He then got a better car as a final reward (2 of 3). He was very pleased with his final reward. • PJ said that he would like to use games in his treatment at the DNL. He also said that he had enjoyed taking part in the research.

7.3.1.4 Summary: Child 1 - PJ

Table 45: PJ (Brazilian boy with dyscalculia).
Source: the author.

About the game
• PJ felt motivated to play the game Monster School Bus during the game sessions. • PJ felt that the time went by fast while he was playing the game. He was curious and felt happy while playing the game. • PJ would like to play MSB at home because it combines learning with fun. • Some of the levels of the game were too difficult for PJ. Nevertheless, he remained motivated. Even when PJ did not perform well, the game system still allowed him to move forward. PJ was curious about the new game characters and narrative. • PJ thought the game was cool and rated it highly (very good). • PJ thought that the game should allow the player to choose the level of difficulty, and to customize the character and other elements. • In PJ's opinion, a math game should be funny, foster curiosity, focus on a story, allow design customizations, and be dynamic (e.g. a game with some bonus levels).
Character

- **For the game character to be cool:** It needs to be funny and customizable (other game elements should also be customizable); it should have more than one skill or power; the game should offer different character options.
- **A game with no character:** It is not going to be cool; the game needs to have a character; if it has a story it should have a character and vice versa.
- **Possible changes to the MSB character:** PJ said he liked the MSB characters as they are, however, competition would be good; a character (big boss) as a challenge would also be good.
- **Type of character:** It should follow the game story; the game should offer options to players, at least a male and a female character.
- **Possibility to control the character:** PJ would like to have bonus levels where the character could perform different actions or have different skills.
- **Whether the character should give tips during the game:** It would be good, but only in a very hard challenge; the game story could be used to inform players about the challenges and tasks.
- **Customization of the character:** Throughout the session PJ stressed that this would make the game more fun.
- **Talking with the player:** PJ likes the idea of the character giving some tip about the game challenge, as part of the game story; it would be good to receive a compliment "well done" as audio or screen text; negative feedback would also be good, because the player would then know where he/she needs to improve.

World Building

- **For a game story to be cool:** It should have funny parts, because this makes the story more interesting, makes people laugh, have fun, and relax.
- **A game with no story:** For PJ, it is great to have a story in a game; the story gives meaning to the game; the story helps the player to understand the game. For PJ, a tutorial explaining how to play the game should also be part of the story; the story is connected with the character.
- **Possible changes to the MSB story:** PJ liked the MSB story as it was.
- **Whether the story should teach about the game:** It is good when the story teaches about the game challenges, like an instruction saying what players will need to do.
- **When the story should appear:** For PJ, the story should appear before the level to explain the challenges and new things.
- **Story format:** PJ prefers static images to animations; and a story told by a storyteller to a text on the screen.
- **Customization of the story:** For PJ, the possibility of changing and choosing the game story would distract the player.
- **Role of the story:** The story can make the player want to play more, promoting curiosity; it can teach about the game challenges.

Rewards

- **For a game reward to be cool:** PJ likes rewards that can be used in the game as resources, new skills or powers. For him, a virtual reward is more fun, because it shows that the character is winning. He likes to collect rewards, but he also likes when a number of items can give him another reward. For PJ, all rewards are good.
- **A game with no reward:** For PJ rewards stimulate the players' curiosity and motivate them to play; rewards are important to show the player whether he/she is doing great or not.
- **Possible changes to the MSB rewards**: PJ liked all the MSB rewards and would not make any changes;
- **The best moment to earn a reward:** For PJ, the best moment to get a reward is at the end of the level; to earn a reward when the player completes the challenges fast. For PJ, bonus levels are also good rewards.
- **Reward types:** PJ likes virtual rewards and a mix of collectible items and resources. PJ prefers stars and items to points. For him these are more visible, and these items can be used to earn other rewards.

7.3.2 Child 2 – MJ

7.3.2.1 Part A – Profile

MJ is a 12 year old girl. She is calm, very polite, and spontaneous. She goes to a public school and is in the 7th grade. MJ was diagnosed with developmental dyscalculia and Communication disorder (language disorder) by the DNL (UFMG). She attended all three game sessions, one session per week over a period of three weeks. MJ's profile is summarized below.

- **To have fun:** MJ plays videogames on a console (Xbox). She also plays board games (e.g. detective), and games on her cellphone. She mostly uses the console - Xbox - because she likes it most and because the screen is bigger.

- **Digital artifacts at school:** MJ does not use a computer, tablet or cellphone in any school activity.

- **Frequency of playing games:** MJ plays digital games only at the weekends, when she has more free time.

- **Platform:** MJ prefers to play on the Xbox, because the screen is bigger.

- **Preferred digital games:** MJ likes sandbox games, such as *Minecraft* where she can build or customize things. She also prefers to compete with other players to cooperate with them.

- **Favorite game:** MJ's favorite game is *Five Night at Freddy's*, which is a survival game. What she likes most about the game is the story. In the game, the player is a nighttime security guard who needs to fight some creatures to survive.

- **To be fun a game must have:** A story about the characters. For MJ, the story helps the player to understand the game. The story also helps the player with the challenges. According to MJ, to be fun a game should also have good graphics.

- **Previous experience with educational digital games:** MJ likes educational games because they can stimulate the player. She has had good experiences with educational games.

- **Learning mathematics:** MJ feels good and very confident when learning math. She would like to play a math game because she believes it can grab her attention, stimulate and help her when she gets discouraged.

7.3.2.2 Part B – Motivation and Preferences

<u>About the game</u>

As aforementioned, MJ attended three game sessions. In each session, after the gameplay, she answered questions regarding her experience of playing the game Monster School Bus.

The purpose of this script was to check whether the child felt motivated to play the game and whether they stayed motivated throughout the sessions.

With regard to **how fast the time went by during the gameplay,** MJ thought the time went by fast in all three sessions:

[Session 1] MJ: It went fast, it is very easy to win.

[Session 2] MJ: Fast, because the goals were completed very quickly.

[Session 3] MJ: Fast, because you focus on something, then you don't notice how fast time passes.

When asked **how she felt while playing the game,** MJ said she felt confident, excited, cheerful and curious, during the three sessions (table 46):

Table 46: How the child felt while playing the game.
Source: the author.

Session 1	Session 2	Session 3
MJ: I was very confident. Q: But tell me what made you feel confident? MJ: Because sometimes the game is hard, but you need to win it. Q: Did you think that it was too hard? MJ: I did, but it gets easier with time. Q: Do you think that the game should have more levels in the first world? So that you understand it better and only then you move forward to the second world. MJ: I think it is better, because in the first level it is a little bit easier, and then it gets harder.	MJ: Cool, and it was much more fun. You need to check if the slime tank gets full... Q: Nice! Did you feel curious, confident, excited...? MJ: Excited to know how the other levels would be, what the goals would be. Q: Okay. So you were a little curious about the next levels? MJ: Uh-huh.	MJ: So cheerful, confident and curious to know what reward I could win, what happens if I complete all the stars. Q: Well, you will get a very special car. Do you want me to show it to you here or would you rather play the game at home and find out? MJ: I would like you to show it to me. I'm curious. Q: Cool beans. I will show it to you at the end of this interview. Is that OK? MJ: Uh-huh.

When asked **whether she would play the game Monster School Bus at home,** in all three sessions MJ said that she would like to play the game at home. The reasons she provided are given below in table 47:

Table 47: Reasons for wanting to play the game Monster School Bus at home.
Source: the author.

Session 1	Session 2	Session 3
MJ: I would, because things get easier. It is more like...what is it called...? (gesturing with her hands, trying to find the words) Q: So, do you think it would be more fun to play it at home? MJ: It would be.	MJ: I would, now I will get more stars to see what is going to happen. Q: You are thinking about the car that you can earn, aren't you? MJ: Yes, I am curious now. (smiling)	MJ: I would. To show it to my friends, parents, and sister. Q: Do you think they will like the game? MJ: They will because it has math problems, carnival park, and jokes. What is it called...it has those magic potions that can change the buildings.

MJ was then asked to say **how much she liked the game overall, using a smile scale (1 to 5).** MJ evaluated the game as really good (4) in the first session, and as fantastic (5) in the second and third sessions. The reasons she gave are presented in the table below:

Table 48: MJ's overall assessment of the game.
Source: the author.

Session 1	Session 2	Session 3
MJ: I thought the game was very good. Q: Cool. Can you tell me why the game is very good? MJ: I liked the graphics, and also, I liked the story. Q: Why isn't the game fantastic? What is lacking? MJ: Ah (thinking carefully before answering). It should be, it should tell a little bit more about the story. Q: Do you mean, more about the game content or the character in the story? MJ: The content. Q: So, do you think the game should have more explanations of the content in the story? MJ: Uh-huh. Q: Would you rather this was through a storyteller (audio) or a text on the screen (like in the MSB)? MJ: I liked the text.	MJ: Fantastic. Q: Wow! Why do you think the game is fantastic? MJ: Ah, because of the graphics and also the rewards (smiling and excited). Q: Are you talking about the stars or the car? MJ: The stars and the car, both together. Q: Do you think that the rewards make you want to play? MJ: Yeah, it makes you more curious about what it is going to happen. Q: So, what do you think about games with no rewards (stars and car)? MJ: Boring, because if it does not have a reward, it is not funny either. Q: Okay. So the rewards are very important? MJ: Yeah.	MJ: Fantastic (excited). Q: Wow! What makes this game fantastic? MJ: Because of the slimes, and because of the car that starts building with the little stars collected.

When asked **whether she liked learning math,** in the first session MJ said that she liked learning math, that she felt good and very confident when learning math. She also said that she would like to play a math game. After playing Monster School Bus for three weeks MJ still felt positive about learning math.

> Q: How do you feel about learning math after playing MSB?
>
> MJ: Now it gets easier, because if there is a game to teach math, the teaching gets better.
>
> Q: Do you think you learned something by playing the game? Has the game helped you in your math classes?
>
> MJ: Uh-huh, I remembered the game when I took a test.

MJ was then asked about **the level of difficulty of the game.** The researcher asked MJ if in the third session, the game had become easier or harder:

MJ: I thought it was hard because of the last level, you know? The slimes, there it got hard.

Q: But when the game was too hard, did you still want to play it?

MJ: I did.

Q: What made you want to keep playing?

MJ: Because of the prize that you need to get, more stars, to earn a better car.

Q: I see. So the stars and the final reward (car) motivate you to keep playing?

MJ: Yes, and I was curious.

MJ was then asked to imagine herself advising a game developer about how to develop the next game:

Q: What should the new design include?

MJ: Prizes, solving math problems to save a friend, and a story to learn more (biting her nails)

Q: What else would you like in a game?

MJ: Time and cars.

Q: Do you think that game challenges should have a time limit?

MJ: Uh-huh, like if you did the first activity very fast, you could get more time in the others.

Session 1: Game Character

MJ liked the game character from Monster School Bus. She thought the character was very colorful. She also liked her clothes and hair.

When MJ was asked what she thought would happen to the game if the character was removed, she said that the game would become boring.

MJ: It would be boring.

Q: Why do you think the character is so important?

MJ: Because you can create the story. You can choose or design your own character.

Q: So, do you think it would be cool to customize the character?

MJ: I do, customized the clothes, hair...

Q: Do you think that would make the game even cooler?

MJ: Uh-huh. (excited)

MJ would not change anything about the Monster School Bus Character. She likes the character (Jenny) the way she is. However, it would be cool if she could change the hair and the clothes of the character.

When asked what a game character should do in the game to be cool, MJ said:

MJ: It could help, such as giving tips.

Q: Do you mean tips for the game challenges?

MJ: Uh-huh.

As for when in the game (moments) she thought the character should appear, MJ said that it should appear during the game levels.

> MJ: During the levels.
>
> Q: Why do you think that?
>
> MJ: Ah, to start getting to know him, to know what he is like...

MJ had some difficulty explaining what she thought made a game character cool. For her, a cool character helps people. Also, the character should have a story, to tell players how things happen. In her opinion, that would help during the gameplay. MJ also said that she would like to have different character options to choose from.

Regarding **what type of game character she likes,** MJ said that she likes animal characters, such as, cats. In her opinion, they are cooler and more colorful.

As for **the possibility to control the character during the game,** MJ thinks this is cool, because she can interact with her chosen character and with other characters. She likes when there are other characters in the game besides her character.

When asked whether the character should give her tips about the game challenges, MJ said that this would help:

> MJ: I think it's a lot better to get through the game, to see how you do it.
>
> Q: But, should it happen all the time or only in very difficult parts?
>
> MJ: Only when I'm having difficulty, otherwise it gets too easy.

As for the possibility to choose or customize the game character, MJ said:

> MJ: I think it is very cool, to see how your imagination works, right?

When asked **whether the game character should talk (audio or text) about the game tasks,** MJ explained that she prefers to receive instructions from the character:

> MJ: To explain the story, and what we need to do.
>
> Q: So, do you prefer this explanation from the character to be part of the game story?
>
> MJ: Uh-huh, yes.
>
> Q: Why is it cooler with the character explaining?
>
> MJ: Ah, it is cooler and it would grab your attention.

Finally, the researcher asked MJ whether she thought the character should tell the player when they did the right thing and when they made a mistake in the game. MJ said:

> MJ: Cool, because it would explain things to you. Like, he (character) can tell you that you cannot go there, or only in the next level.

<u>Session 2: World Building</u>

In session 2, after the gameplay, MJ answered questions about the game element world building.

MJ liked the game story (narrative) from MSB. She had difficulty explaining why and gesticulated a lot with her hands while trying to do it. MJ was then asked **what she likes in a game story.** She said:

> MJ: A cool story, a story about a mystery.
>
> Q: By that you mean a mystery to solve or to be curious about?
>
> MJ: Yes.

When MJ was asked **to imagine what the game would be like without the story,** she said that people would get confused with some of the information from the game character. This confirmed that MJ believes that a game should have a story.

> MJ: It would be...no one would know how she took the bus if she really wanted the job.
>
> Q: Do you think the story helps you to understand the game?
>
> MJ: Uh-huh.
>
> Q: In your opinion, does a game need a story?
>
> MJ: It does, to know what will happen, like to have an idea about what happened.

As to making changes to the Monster School Bus story to make it better, MJ said she liked the story the way it was.

When asked **whether she thought the game story should teach about the game challenges and tasks,** MJ said: "it would be cool to receive some tips. Then it would be easier to get the kids. Also, it would be much easier to get the potions."

As to the moment in the game **when the story should appear,** MJ said that it should be during the levels:

> MJ: During (biting her nails. She found the question a little confusing).
>
> Q: For example, do you get a potion and then a part of the story appears?
>
> MJ: Yes.
>
> Q: In the MSB, did you see that the story appears before and after the game levels? What do you think about this organization?
>
> MJ: I liked it. In that way, it can happen that...because it is telling the story bit by bit
>
> Q: So, did you like that the story was being told bit by bit?
>
> MJ: I did.
>
> Q: Do you think the game story made you more curious about the next level and monsters?
>
> MJ: Yes.

When asked **whether static images or short animation should be used to present the game story,** MJ said that she prefers animation, because it looks more like a communication, and the images are shown better. As to whether a **narration (audio) or a text on the screen should be used,** MJ prefers audio to a text on screen, because in that way she does not need to read. She said that it would be better if the player could choose between these two options (audio or text).

MJ liked the idea of being able to choose and change the game story. She explained that if the player could decide what happens, or does not happen, in the game, this would increase his/her motivation to play.

When asked **whether to play the game the player needs to understand the story,** MJ said that it was necessary. In her opinion, the player needs to understand the story to know what is going on, and what will happen in the game.

Finally, when asked **whether she thought the game story should have funny moments,** MJ said: "Yes, because you can rest, also you can kind of forget the goals".

Session 3: Rewards

In the last interview with MJ, the focus was on the game element rewards. When asked whether she **liked the Monster School Bus rewards, MJ said:**

> MJ: Good to make the player stay more time playing, to devote himself more to the game.

MJ was then asked to imagine what the game would be like without the rewards:

> MJ: It would be boring because it would have nothing. Then you don't enjoy playing the game.
>
> Q: So, do the rewards make you want to play the game?
>
> MJ: Yes.
>
> Q: So, if at school, for example, you did an activity and earned a reward, would that be interesting?
>
> MJ: It would. Then I would do the activity.
>
> Q: What do you think the reward should be (at school)?
>
> MJ: An excursion.

MJ would not change anything in the game rewards. She thought the game rewards were good. She, however, explained what kind of game rewards she prefers.

> MJ: A ticket
>
> Q: What do you mean? A ticked to be used in the game world or in the real world?
>
> MJ: To exchange for a prize in the real world. You play and can get a ticket to exchange for a candy or a CD.

As to what type of reward she considered more fun, physical rewards (e.g. a printed certificate in the real world) or virtual rewards (e.g. stars in the game), MJ said she preferred physical rewards outside the game. She said that when it is physical, the player can see the thing that she/he worked hard to earn.

When asked whether she preferred to receive rewards that can be used in the game (resources) or rewards just for collection, MJ said:

> MJ: It is better if it is a skill to give more time in the game, then it gets cooler.
>
> Q: Why?
>
> MJ: Because if you earn more skills, more time... how can I say that?

Q: Do you think that with new skills you would like to spend more time playing?

MJ: Uh-huh. The more time I will play the game, the more I will want to play it.

As for when it would be the best moment in the game to receive a reward, MJ said:

MJ: During the level, because you may want to play more, or like, in the last level I earned a car, right? So, you go on collecting these things.

Q: For example, you collect things in each level, and then at the last level you earn a bigger reward. Something like that?

MJ: Yes.

When asked whether there was any game reward that she strongly disliked, MJ said that there was no reward that she would hate to receive. As to what kind of rewards she thought is more fun (e.g. points, starts, potions), MJ said:

MJ: Items. They can be more useful. For example, if you are battling, an item can be very useful.

MJ: It can be a bomb or a sword.

Q: By that do you mean something that can be used in the game, such as a power or a skill?

MJ: Uh-huh, yes.

7.3.2.3 Part C – Researcher's observations

Table 49: Summary of the researcher's observations - Child 2 – MJ (Brazilian girl with dyscalculia). Source: the author.

Session 1
• MJ said that she had fun during the session. She could easily understand the game instructions and story. • MJ learned how to use the game controls without any difficulty. However, she had some difficulty using the controllers when she needed to be faster (e.g. to pick up the potions). • MJ completed two game worlds in this session, which covers 6 levels. In each level, she only got one star. • MJ was engaged both when playing the game and during the interview. However, due to her language disorder, she had difficulty to verbalize her ideas. Several times during the interview, she was not able to finish her sentences, and she gesticulated a lot. The researcher helped her by giving examples, helping her to complete the sentences, or reformulating the question. • MJ performed well in world 1, with many full loads. However, she had difficulty getting the potions. When she managed to get a potion, MJ was excited about changing the buildings. When that happened, she smiled and celebrated. • In world 1, MJ understood the task and had a strategy to fill up the bus (e.g. 7+3=10). However, in world 2, the sum with decimals (e.g. 3.5 + 6.5 = 10.0) was too difficult for her, even after some additional explanation. At this point, she adopted the strategy trial and error, stopping at each group of kids trying to see if it was possible to get them inside the bus. • At the end of world 2, MJ said that it was too difficult: "because you need to count the kids, and there are more kids". Although she seemed to be a little demotivated by the challenges in world 2, she was interested in the game. Also, she was very excited to play the game at home. • Several times during the gameplay, MJ described what she was doing: "now I will turn here!"; "this game gets easier when you practice"; "I shouldn't go there"; "I will take this big group".
Session 2
• MJ was very enthusiastic about taking part in the research. According to hear mother, MJ got very excited before the sessions.

- MJ could finish the game in this session. She was more talkative and more comfortable with the researcher.
- She was very happy and smiled when she got all the potions and three stars (world 3, level 1).
- MJ's performance improved considerably. She could also use the game controllers better.
- MJ had difficulty with numbers such as 3.5; 1.5. It was explained to her that she could count the empty seats in the bus. This strategy helped her considerably. Her performance improved and she became more confident.
- In world 4 (slime kids) it was not possible to count the seats, and this was difficult for MJ. Again she used the trial and error strategy, in sums such as .75 + .66. However, in the second level of world 4, MJ had a 100% score. She said very happily: "Now it got easy".
- MJ ended the game with few stars (18 out of 36). As a final reward, she got a Beetle, which is the worst reward in the game (1 of 3 types of cars). She was happy and curious about the other cars she could earn.
- MJ considered the level of difficulty of the game as medium. However, it could be seen that in some levels the game proved to be too difficult for her, especially in the initial activities with new numbers or new group sizes.

Session 3

- MJ played some levels again. The idea was to get more stars to earn a better reward at the end of the game.
- She said that she was very excited, but also sad because it was the last session.
- MJ was very excited and engaged both during the game and the interview. She was now very comfortable with the researcher, and very talkative. However, due to her language disorder, she still found it difficult to express her opinions.
- The tips and the researcher's assistance helped MJ to improve her performance, and to stay engaged during the levels.
- MJ performed well in world 1. As a strategy, she used her fingers to count the empty seats. She was very excited when she changed all the city's buildings.
- At the end of the levels, she hopefully waited to see how many stars she had earned and if the character would give her a smile.
- Although she had played the game in two sessions, and at home, MJ had difficulties in world 2 and world 3. According to her, in those worlds there were no easy numbers, such as 5+5, only numbers like .3;.7;.4. It was too hard for her, and as a result, she did not perform well. However, the game system did not prevent her from finishing any of the levels, and this kept her motivated. Also, she was curious to see what her final reward (car) would be.
- In the last world (4), MJ had even more difficulty. It was too hard for her and she used the strategy of trial and error. Yet, she remained motivated. She tried several times to improve her score (restarting a couple of times), and at the end she got good scores.
- MJ said that she would like to use games in her treatment at the DNL. She also said that she enjoyed taking part in the research because she could play and talk. It was fun for her.
- MJ's performance improved and she earned more stars (25 out of 36). As a result, she got a better car as a final reward (2 of 3). She was very pleased with this final reward, but was still curious to see the other cars.

7.3.2.4 Summary: Child 2 – MJ

Table 50: MJ (Brazilian girl with dyscalculia).
Source: the author.

About the game
• MJ felt motivated to play the game Monster School Bus in all three sessions. • MJ thought that the time went by fast while she was playing. • She was excited and curious about the next levels, challenges, and rewards. She was confident and cheerful because sometimes the game got too hard and she needed to win it. • MJ liked the idea of playing MSB at home. She said she would show it to her parents and her friends. According to her, they would like it because the game has math, carnival parks, jokes, and the magic potions to change the buildings. • In the first two sessions MJ thought the game was really good (4), she highlighted the colorful graphics and the story. In the third session, she rated it as fantastic (5) mainly because of the rewards (stars and car), and the slime kids. • In some levels, mainly world 3 and world 4, the game was too difficult for MJ. Yet, the game system did not prevent her from moving forward or from finishing a level, which kept her motivated. MJ was curious and excited about the final game reward (car). • According to MJ, a math game should have prizes (rewards); have math problems that if you solve them you save a friend in the game; have a story you can learn from (content and instructions); have a limited time for the levels; have jokes and colorful graphics.
Character
• **For the game character to be cool:** It needs to be colorful, connect with the story, and be customizable (e.g. clothes, hair); there should be different characters to choose from; the character should give tips to help the player, and appear during the levels (connected with the story). • **A game with no character:** It is going to be boring because the game needs the character for the story (connection between character and story); the character makes the game cooler. • **Possible changes to the MSB character:** MJ liked the characters as they were, but customization would be cool. • **Type of character:** MJ would like animal characters (e.g. a cat) – they are more colorful; the game should offer options. • **Possibility to control the character:** it would be cool because it would allow the player to interact with the character; it would be cool to have more than only one character in the game world. • **Whether the character should give tips in the game:** This would help to overcome the challenges and understand how to do things. However, it will be good only in a very difficult challenge, otherwise, it would be too easy. • **Customization of the character:** it would make the game cooler and would allow the player to explore his/her imagination. • **Talking with the player:** it would be cool if the character explained the story and what the player needs to do; it would be cooler if the game instructions came from the character because it would grab the player's attention; it would be cool if the character told the player when they did something wrong or right.
World Building
• **For a game story to be cool:** it needs to have a mystery to be solved; make the players curious; have funny moments, when the players can relax and forget the goals. • **A game with no story:** Players would get confused because the story helps them to understand the purpose of the character and the game challenges; a game needs to have a story to make what happens clear (game sense). • **Possible changes to the MSB story:** MJ liked the MSB story as it was. • **Whether the story should teach about the game:** It would be cool and help with the game tasks, like an instruction explaining what the player needs to do.

- **When the story should appear:** For MJ, the story should appear during the levels, bit by bit, to make the player curious about it.
- **Story format:** MJ prefers animations because it looks more like a real communication, and the images are shown better; she prefers a story from a storyteller because the player does not need to read. It would be cool if the player could choose between text and audio.
- **Customization of the story:** MJ likes the idea of changing and choosing the game story. She thinks this would increase the player's motivation to play.
- **Role of the story:** To help the player understand the game challenges and the purpose of the character; to make the player curious about a mystery or about the game elements and levels.

Rewards

- **For a game reward to be cool:** it should please the player and make him/her want to spend more time playing the game; it should be something that the player can use in the real world; it should be a reward that allows the player to see what he/she worked hard to earn; it should be a virtual reward, a small reward that the player can exchange for something bigger at the end of the world or at the end of the game.
- **A game with no reward:** It would be boring; the player would not enjoy playing the game.
- **Possible changes to the MSB rewards:** MJ liked all the MSB rewards and would not make any changes;
- **The best moment to earn a reward:** The best moment to receive a reward is during the levels, to stimulate the player to keep playing; also, at the end of the level, when after collecting some small rewards the player can earn a better one.
- **Reward types:** Physical rewards in real life; MJ also prefers items which can be used in the game to points, for instance, extra power or skills.

7.3.3 Child 3 – BJ

7.3.3.1 Part A – Profile

BJ is a 9 year old girl. She is very spontaneous, talkative and energetic. She goes to a public school and is in the 5th grade. BJ was diagnosed with developmental dyscalculia, ADHD (attention deficit hyperactivity disorder), and Dyslexia by the DNL (UFMG). She attended two game sessions, one session per week. BJ's profile is summarized below.

- **To have fun:** BJ uses a cellphone, a computer, a tablet. She also watches television and likes to play games. She mostly uses the cellphone, because it is very easy to use. She likes to play games and watch videos on YouTube.
- **Digital artifacts at school:** BJ does not use a computer, a tablet or a cellphone in any of the school activities.
- **Frequency of playing games:** BJ plays digital games as often as she can.
- **Platform:** BJ prefers to play on the cellphone, because it is very practical.
- **Preferred digital games:** BJ likes games where she needs to look after pets, run restaurants or customize nails and hair. She likes creating and customizing things in games.
- **Favorite game:** BJ's favorite game is *Talking Tom Cat* because she can travel with the character, feed him, and take care of him. In the game the player is responsible for the pet.
- **What a game must have to be fun:** BJ likes games which have cute things.
- **Previous experience with educational digital games:** BJ played an educational game at DNL, and she liked it.
- **Learning mathematics:** BJ does not like math very much. She made a grimace when she was asked about math. She explained that math is a little bit cool and a little bit boring. Although her teacher has told her that we use numbers all the time in our everyday life, BJ said she could not see them so easily. She thinks that it would be easier to learn math using an educational game because the student would be playing and "feeding" the brain at the same time and he/she would learn almost everything through the game.

7.3.3.2 Part B – Motivation and Preferences

<u>About the game</u>

As aforementioned, BJ attended two game sessions. In each session, after the gameplay, she answered questions about her experience of playing the game Monster School Bus. The purpose of this script was to check if she felt motivated by the game and if she stayed motivated throughout the sessions.

When asked **how fast the time went by while she was playing the game,** BJ said that the time went by fast in both sessions:

> **[Session 1]** BJ: It went fast, because I didn't complete all the levels.
>
> **[Session 2]** BJ: It went fast because we were playing the other game, right? (referring to the board game she played as a rapport). Then, we stopped and started playing this one and it was the same thing, very quickly (she snapped her fingers).

As to **how she felt while playing the game,** BJ said she felt curious during the two game sessions (table 51):

Table 51: How the child felt while playing the game.
Source: the author.

Session 1	Session 2
BJ: Curious. Q: What were you curious about? BJ: If I was going to get the potions or lot of kids. Q: Ok. Did you get curious about new kids or the next levels? BJ: Uh-huh.	BJ: It was cool. I was curious about whether I was going to get more potions.

When asked **whether she would like to play the game Monster School Bus at home,** in both sessions, BJ said that she would like to play the game at home and explained why (see table 52 below):

Table 52: Reasons for wanting to play the game Monster School Bus at home.
Source: the author.

Session 1	Session 2
BJ: Yes, because there will be no buttons for me to press on the cellphone. Q: Ok. I am not sure you can play it on the cellphone. But, did you think the buttons/controllers on the laptop were not cool? BJ: No, but there is an arrow to go up and go down. You will not have to keep pressing all the time. Q: Ah, was it bad playing with the laptop keyboard arrows? BJ: No, it wasn't.	BJ: Uh-huh, yes. Because there, after I finish the game you will not ask any questions (laughing) Q: Ha Ha! My questions aren't that bad. Then, now it is your turn to ask me a question. BJ: Have you ever been to a factory that develops games, or a company? Q: Oh, this is a great question! I went to a university in the USA, which is similar to where we are today. There, they have a good laboratory that develops educational games. The lab is great fun. They always ask kids like you to test their new games. I bet you would like it there.

BJ was then asked **to assess the game using a smile scale (1 to 5).** She rated the game as really good (4) in the first session, and as fantastic (5) in the second session. Her reasons are presented in table 53 below.

Table 53: BJ's overall assessment of the game.
Source: the author.

Session 1	Session 2
BJ: Hum, really good, because I thought it was very cool. Q: Why isn't the game fantastic? What is lacking? BJ: It should give more time to get the potions, they should stay a little longer. Because when you take one the others have already disappeared.	BJ: I thought it was fantastic. Q: OMG! What makes the game fantastic? BJ: It is because today I got more potions and I played it very fast. The last time was great, wasn't it? Q: Last time you rated the game as really good.

When asked **whether she liked learning math,** in the first session, BJ said that math was a little bit cool and a little bit boring. She also said that she would like to play a math game. After playing the game Monster School Bus for two weeks, BJ still did not like talking about math. However, she admitted that she had learned something by playing the game, mainly to count how many kids were necessary to fill a bus.

With regard **to the level of difficulty of the game,** the researcher asked BJ whether she thought the game was too hard:

> BJ: Not so much, a little hard because the potions disappear.

When asked what advice she would give a game developer who is developing a new game, BJ said:

> BJ: Customization.
>
> Q: Okay, customization for the character?
>
> BJ: Yes, customize the character.
>
> Q: Why do you think the game should have customization?
>
> BJ: Because with customization you can choose how you want your character, if you would like a man, with hair or no hair.
>
> BJ: Do you think you would customize the character the whole time, or only at the beginning of the game?
>
> BJ: I would make changes to him during the whole game.
>
> Q: I got it. What else would be important to have in the game?
>
> BJ: What else? I don't know.

Session 1: Game Character

BJ liked the game character from Monster School Bus. She thought the character was cool:

> BJ: He (the boss) asked something and she (Jenny – game character) said something that didn't make any sense (smiling). I think she is cool, but what she says sometimes does not make any sense.

When BJ was asked to think about what would happen to the game if the character was removed, she explained:

BJ: Ah, no girl will want to play the game.

Q: Do you think that girls always like to play with a female character?

BJ: Uh-huh.

Q: But if we removed both characters?

BJ: Then no one will want to play. The game needs to have one, or two or three characters.

Q: Why is the character so important in the game?

BJ: Because without the character you cannot watch the cartoon or play. Because you need him to play, because the person will say what you need to do with the character. Then, you need the character.

BJ would like to make changes to the look of the Monster School Bus Character, to customize it:

BJ: To change the look.

Q: Do you mean her clothes or hair?

BJ: The hair. Her hair should be long and with small bangs.

Q: So, what would it be like if you could customize the game character? (e.g. clothes, hair).

BJ: It would be really cool.

When asked what a game character should do in the game to be cool, BJ said:

BJ: For the character to be cool? Nothing, he is already cool.

Q: Would you like to control the character in the game, or should he only appear in the story?

BJ: I like to control the character, moving him back and forth, and to one side or the other.

As to **when in the game (moments) the character should appear,** BJ thinks it should appear during the game levels. She explained that the character should open the bus door for the kids, because, according to her, a child will not know how to open it.

When asked **what makes a game character cool,** BJ said that a character should be cute and customizable. As to **the type of character that she prefers,** BJ likes animal characters, such as, cute cats that you can change the look and the hair.

When asked about **the possibility to control the character during the game,** BJ said she thinks it would be really cool:

BJ: It is really cool because it is you, you are controlling a character that you have chosen to play.

Q: Do you think that when you can control the character you relate more to the character?

BJ: Yes, because you are controlling it, not the application.

When asked whether the character should give her tips about the game challenges, BJ said that this would help:

BJ: It makes it easier (smiling).

Q: Would you rather receive this tip as audio or text on the screen?

BJ: Speaking on the audio.

Q: But, should it happen all the time or only in a very difficult part?

BJ: Only when you are not solving it.

Q: But if the character helps you all the time?

BJ: No. Then you won't be playing. You would be getting the answer from the game. This is like my teacher says, if you give the answer to a classmate during the test, the test will become meaningless.

When asked whether she would like to choose or customize the game character, BJ explained:

BJ: It is really cool, it is really cute. It can be any way you like. You can choose the colors, the looks, the clothes and the hair (excited)

Q: Why is it so cool to customize the character?

BJ: Because in real life you don't cut or stick a flower and so on. But with the game character, you will be able to remove, to cut and to stick things.

When asked **whether the game character should talk (audio or text) about the game tasks,** BJ explained that she prefers to receive the game instruction from the character:

BJ: Your work was well done!

Q: Ah, would you like that he tells you that? When you do the right thing?

BJ: Yes, and not like my math teacher.

Q: What does she do?

BJ: She does something like this – No, you did it wrong. Come here and bring a pencil and an eraser. You will do it again (doing an impression of the teacher).

Finally, the researcher asked BJ whether she thought the character should tell the player when they did the right thing or made a mistake in the game. BJ said:

BJ: It would not be nice, but it would be the truth, that you made a mistake. I would like the character to tell me when I made a mistake and when I did it right. Because if he doesn't tell me, I will not know, and then he is not being honest.

Q: So, do you like when the character is honest with you?

BJ: Yes.....not so much.

Session 2: World Building

In session 2, after the gameplay, BJ answered questions about the element world building. Firstly, she was asked **what she thought about the game story (narrative) from MSB.**

BJ: Cool.

Q: What is cool in the story? Do you remember any part that you really liked?

BJ: She (Jenny – the character) making no sense when she speaks.

Q: How was that?

BJ: He (the boss) asked something and she (Jenny) replied something that made no sense in the game.

When BJ was asked to imagine **what the game would be like without the story**, she explained that the story is important because without it the game does not make sense:

BJ: Then it would make no sense. Because it does not have a story. Then it is not possible to understand anything.

The next question aimed to confirm whether or not BJ thought that a game should have a story:

BJ: It should. Because if it doesn't, you won't understand anything and you won't be able to play. You will want to know how many kids you need to pick up, but you can't, then you won't understand the game.

BJ had difficulty to verbalize her preferences regarding **what makes a game story cool.** As to **whether she would make changes to the Monster School Bus story to make it better,** BJ said she would not make any changes to the story. However, she said that she would like to have more time when the potions appear, during the full load bonus.

When asked whether the game story should teach about the game challenges or tasks, BJ said:

BJ: It would be easier, right? Because then you would already be thinking about how you would do the challenges, right?

As to **when in the game the story should appear,** according to BJ it should be before the levels. She did not justify her answer.

When asked whether static images or short animation should be used to present the game story, BJ said that she prefers animations, because it would be more fun, cooler and funnier. As for whether she preferred a narration (audio) or a text on the screen, she said that she prefers audio to a text on screen, because in that way she does not need to read.

When asked **whether she would like to choose or change the game story,** BJ said that she would like to change the end, to avoid earning an old beetle. As a final reward in the game, BJ earned an old beetle (the worst reward), based on her performance in the game, and she hated that.

As to **whether to play the game the player needs to understand the story,** for BJ it is important that the player understands the game story. Otherwise, it would be horrible because the player would not understand anything and would not be able to play. Finally, BJ was asked **whether she thought the story should have funny moments**:

BJ: Yes, it should have funny moments to entertain.

Session 3: Rewards

In the same session, after answering the questions about world building, BJ answered questions about rewards. The first question asked **BJ if she liked the Monster School Bus rewards:**

BJ: I only liked the potions and stars, not the car (serious and a little upset because she had earned a bad car).

Q: Why did you not like the car?

BJ: Because it was a little beetle. The beetle had a flat tire and it was dirty. If it was clean and with a good tire, it would be okay. But it had a flat tire and it was all dirty (angry).

Q: But did it not make you want to play and get more stars to earn a better car?

BJ: It did, but I don't want to play.

When asked **if she would make any changes to the game rewards**, BJ said that she would and explained what kind of game rewards she likes:

BJ: Even if you didn't get many stars, it could be a better car, right? (laughing).

Q: And thinking about other games, what would be a cool reward?

BJ: It would be a bunch of stars and potions. More new looks, new hairs, and nail polish.

As to what type of reward is more fun, physical rewards (e.g. a printed certificate in the real world) or virtual rewards (e.g. stars in the game), BJ said she preferred physical rewards outside the game:

BJ: Something for me to paint, or color or write on.

When asked whether she preferred to receive rewards that can be used in the game (resources) or rewards just for collection, BJ said:

BJ: To collect, because then you will have them for a long time. If the computer or the cellphone breaks down, the game will be gone. You will need to start everything again.

Regarding the best moment in the game to receive a reward, BJ said:

BJ: At the end, because you would be curious.

Q: Do you mean at the end of the level or at the end of the game?

BJ: At the end of the whole game, then you would be curious to know about it.

When asked what type of game reward she dislikes the most, BJ said old beetles. As to what kind of reward is more fun (e.g. points, starts, potions), BJ said:

BJ: Items, because then you can put the stars there when you got one or two stars. But I didn't like the little beetle.

7.3.3.3 Part C – Researcher's observations

Table 54: Summary of the researcher's observations - Child 3 – BJ (Brazilian girl with dyscalculia).
Source: the author.

Session 1
• BJ learned to use the game controls without difficulty. However, she showed some difficulty with the controllers when she needed to be fast (e.g. to pick up the potions). • BJ completed two game worlds in this session, which covers 6 levels. With the exception of the first level, where she got two stars, BJ only got one star in all the other levels. • During the game BJ was engaged most of the time. She was less engaged during the interviews. • BJ enjoyed playing the board games. She wanted to play them with her mother at the end of the session. • During the first 5 minutes of playing the game, BJ said that "there is too much math". • BJ complained many times about how little time she had for the potions. In her opinion, the potions should stay a little bit longer, especially if there are more than one or two. After some attempts, she became a little frustrated and said that she would not be able to catch the potions. • BJ performed well in world 1. Her strategy was to count on her fingers how many kids were still available and how many seats there were in the bus. • In world 2, BJ had difficulty with the sum with decimals (e.g. 3.5 + 6.5 = 10.0). It was too hard for her, even after some additional explanation. At this point, she adopted the strategy trial and error, stopping at each group of kids trying to see if it was possible to get them on the bus. • During the explanation, she became nervous and worried. She started biting her nails during the levels. • BJ always preferred to go forward and move to new levels to redoing a level to improve her score. • BJ was concerned about how the game character would react to her performance if she smiled or made an angry face at the end of the level.
Session 2
• BJ could only attend two sessions because she had hurt her foot playing at home. For that reason, in session 2 she answered questions about World Building as well as Rewards. The long duration of the session proved to be too tiring for BJ and consequently had a negative impact on her engagement during the activities. • BJ finished the game completing the remaining worlds 3 and 4 (20 minutes of gameplay). Because she did not have a third session, BJ could not play the game again in order to improve her scores. • During the first level of world 3, BJ had a good score, getting many full loads. However, she had difficulty catching the potions, which demotivated her. She also had difficulty with the game controllers. In the last level of world 3, she seemed tired, mainly because she kept losing the potions. • In session 2, BJ's mother stayed in the room. This had a negative impact on BJ's behavior and ability to focus during the activities. • During the gameplay, BJ remembered some funny parts from the game narrative and happily shared them with her mother. Her mother became interested in the game and its learning aspects. • BJ was tired during the last interview. She yawned, talked with her mother, and wanted to know how long it would take to finish the interview. • BJ enjoyed the board game she played before the gameplay. She wanted to play it again at the end of the session. She played it with her mother and had lots of fun. • BJ complained many times about how little time she had for the potions: "I will stop trying to catch the potions"; I will not be able to catch any potions. They are already gone"; "I will not be able to catch the potions, I will not even try". • BJ was bored in world 3. This could be seen in her bad posture and negative comments. The new elements from world 4 (slime kids), however, renew her interest in the game. BJ changed her posture and made positive comments about the kids from this world: "That little slime there is alone"; "This one will not even make a difference in the bus, he is still growing up". The level of

difficulty of this world, however, was too high for BJ, and she did not perform well. Her method of problem solving was trial and error.

- BJ ended the game with only a few stars (15 out of 36). As a final reward, she got a beetle, which is the worst reward in the game. She did not like the reward. She was upset and said she was tired of playing. During the interview, BJ mentioned several times how disappointed she was with the reward. This reward made her lose interest in the game.
- The level of difficulty of world 1 was medium and covered basic additions (e.g. 7+3=10). This was appropriate for BJ. The level of difficulty of the other worlds proved to be too high for her.
- BJ would like to use games in her treatment at the DNL – "I think it is cool because then it would be put in your head in a fun way". Although somewhat tiring for her, BJ enjoyed taking part in the study.
- BJ was happy at the end of the sessions. She hugged the researcher and gave him chocolate.

7.3.3.4 Summary: Child 3 – BJ

Table 55: BJ (Brazilian girl with dyscalculia).
Source: the author.

About the game
• BJ felt motivated and was excited about playing MSB during the whole first gameplay. In the second one, however, there were times when she felt less excited about playing the game. • In both sessions, BJ felt that the time went by fast while she was playing the game. • BJ was curious about the potions, the kids, and the different levels. • BJ would like to play MSB at home, mainly because she will try to play it on her cellphone, and there she will not need to answer questions about the game after the gameplay. • BJ rated the game as really good (4) in the first session. She said the game was cool, but the potions disappeared too fast. In the second session, BJ rated the game as fantastic (5) because she got more stars and potions. • With the exception of world 1, the game was too difficult for BJ. In world 3, she was not able to catch the potions, and this made her lose interest in the game. Her interest was restored in world 4 (slime kids) where the new monster kids made her engage again with the game, even though the game was too difficult for her. The game system did not prevent her from moving forward or from finishing a level, and this kept her motivated to play. • The game was too difficult for BJ, and as a result, her final reward was not very good. This demotivated her. She was clearly disappointed with the reward and lost interest in the game because of that. • According to BJ, a math game should let players customize their characters. It should be fun.
Character
• **For the game character to be cool:** The character should be funny; there should be different characters to choose from, at least a boy and a girl; the character should be customizable (e.g. clothes, hair); the character should be cute. • **A game with no character:** The game needs to have at least one character; the player cannot play or understand the story without the character; • **Possible change to the MSB character:** BJ would like to customize the MSB character's hair. • **Type of character:** BJ would like cute animals that she could customize (e.g. hair, clothes). • **Possibility to control the character:** BJ thinks it would be very cool to control the character. According to BJ, the player is represented by the character, so if the player can control the character (chosen or customized) he/she will feel more connected with the character. • **Whether the character should give tips during the game:** This would make the game easier. However, it should only occur in a very difficult challenge, otherwise, it would be too easy, and the game would be meaningless. BJ prefers to receive the tips as audio rather than text. • **Customization of the character:** It is really cool and cute because the player can do things in his/her own way. Also, according to BJ, this would allow the player to do things that he/she would not do in real life. • **Talking with the player:** BJ would like to receive compliments from the character (e.g. well done!). She likes when the character is honest and tells the player when they did something wrong, otherwise the player would not know they had made a mistake.
World Building
• **For a game story to be cool:** It should have funny moments to entertain the player; it needs to give meaning to the game; • **A game with no story:** Players would become confused because it is the story that makes it possible for them to understand the game; the game will not make sense without the story. Players will not understand anything in the game. It will be impossible to play the game, because it is the story that gives information about the game challenges (e.g. how many kids to pick up). • **Possible changes to the MSB story:** BJ liked the MSB story, and the only change she would make would be to have more time to catch the potions. • **Whether the story should teach about the game:** It would make it easier (in a good way) because the player could start thinking about how to deal with the game challenges.

- **When the story should appear: BJ** said she prefers the story before the levels, but did not justify her answer.
- **Story format:** BJ prefers animation because it is more fun, cooler and funnier. She prefers the story in audio format instead of a text on the screen, because in that way she does not need to read.
- **Customization of the story:** BJ would like to change the end of the story to avoid earning an old beetle.
- **Role of the story:** To help players understand the game, otherwise they will not be able to play.

Rewards

- **For a game reward to be cool:** A cool reward would be a bunch of stars or potions; or new items to customize the game character (e.g. clothes, hairs); or items that the player can collect and which show his/her progress in the game.
- **A game with no reward:** BJ did not answer this question.
- **Possible changes to the MSB's game rewards:** BJ strongly disliked the final game reward that she received (an old beetle). She thought the player should at least receive a car in good condition (e.g. no flat tire, clean), even if they had a low score.
- **The best moment to earn a reward:** The best moment to receive a reward is at the end of the whole game because the player will be curious about it and keep playing.
- **Reward types:** BJ prefers physical rewards in real life, something to paint, color or write on. She prefers items to points. BJ also prefers rewards that can be collected in the game, something that shows the player's progress in the game.

7.3.4 Child 4 – AJ

7.3.4.1 Part A – Profile

AJ is an 11 years old girl. She is very polite, extroverted and spontaneous. She goes to a public school and is in the 6th grade. AJ was diagnosed with developmental dyscalculia, ADHD (attention deficit hyperactivity disorder), and dyslexia by the DNL (UFMG). AJ only attended one game session in which all three topics were covered. AJ's profile is summarized below.

- **To have fun:** AJ plays with her dog Luna. She also plays games on her cellphone, and she plays board games sometimes. She has the most fun when she plays with Luna.

- **Digital artifacts at school:** AJ does not use a computer, a tablet or a cellphone in any of her school activities. She would like to use them.

- **Frequency of playing games:** AJ plays digital games on the cellphone as often as she can.

- **Platform:** Cellphone.

- **Favorite game:** AJ did not mention a favorite game. However, she said that when she played on her cellphone a game that her mom used to play years ago, she felt very excited. She did not remember the name of the game.

- **What a game should have to be fun:** Cool things like a character teaching how to play the game and giving feedback. It should also be fun and have new things.

- **Previous experience with educational digital games:** BJ played math and Portuguese language games when she was little, and enjoyed it. However, according to her, not all educational games are fun, it depends on the game.

- **Learning mathematics:** AJ thinks that learning math is hard because it is always getting harder and she gets confused. She feels very nervous and "crazy" when she is learning math.

7.3.4.2 Part B – Motivation and Preferences

<u>About the game</u>

As aforementioned, AJ only attended one game session. In the session, after the gameplay, she answered questions about her experience of playing the game Monster School Bus. The purpose of this script was to check if the child felt motivated by the game in this session.

When asked about **how fast time went by during the gameplay,** AJ said that the time went by fast:

AJ: Fast. Because you had to take a bunch of kids, then you did not know what to do, then you had to see how many kids you had, then you had to pick up some potions quickly, because if you did not pick up all the potions...

As to **how she felt while playing the game,** AJ said that she felt stressed:

AJ: I was a little stressed because I had to rush to one side and then to another to pick up the potions and take the kids to school.

Q: But were you having fun?

AJ: Yes, I was.

When asked whether she would like to play the game Monster School Bus at home, AJ said that she would:

AJ: Uh-huh. Because I have already played it, I have experience. I will know how the game works, right? Then, I will play it a little bit faster.

Q: So, do you think that you will play better at home because you have some experience of playing it?

AJ: Yes!

AJ was then asked to say **how much she liked the game using a smile scale (1 to 5).** She rated the game as really good (4):

AJ: Really good, because it is different from other games. It teaches you that you need to know how many kids are inside the bus, if not it would be hard, right?

Regarding the level of difficulty of the game, AJ considered it difficult in some moments, mainly at the beginning when she had not understood it properly yet.

When asked what advice she would give a game developer who was developing a new game, she said:

AJ: It has to have cool things, right? The character teaching how to play the game, and speaking when you did right or wrong (players performance).

Q: Nice! But what would these cool things be?

AJ: Cool things that promote fun. It would have a serious thing, many things. Like, for example, you are in one area, then in another one and then another one.

Q: So, do you like novelties in a game?

AJ: Yeah.

Session 1: Game Character

AJ liked the game character from Monster School Bus because it was different from the characters in other games:

AJ: I liked it. It is different, right? Because it is a zombie. Because in most of the games they are humans, right?

When AJ was asked what she thought would happen to the game if the character was removed, she said:

AJ: It would be boring. Because without it the game is boring. He (referring to the game character) changes everything. He drives and picks up the things, he speaks.

AJ would not make any changes to the Monster School Bus Character. **As to what a game character should do in the game to be cool,** AJ said:

> AJ: Hmm, the character of that game (referring to Monster School Bus) is different. He is not like the characters in all the games that you see; and you need to do things fast, if not you will lose.

When asked **when in the game (moments) the character should appear,** AJ said that it should appear after the game levels:

> Q: What will the character do after the level?
>
> AJ: He (the character) will know if it was good or bad.
>
> Q: Do you mean that the character will inform players about their performance in the level?
>
> AJ: Yeah.

When asked **what makes a game character cool,** AJ said the character needs to be powerful and funny. She described her favorite character:

> Q: Do you have a favorite character (from games or cartoons)?
>
> AJ: I do. Naruto (very excited).
>
> Q: Nice! What is the coolest thing about Naruto?
>
> AJ: Besides being addle-headed, he has very incredible powers.
>
> Q: So, do you think for a character to be cool he/she needs to have powers?
>
> AJ: Not only power. To be funny as well, like him (referring to Naruto - laughing)
>
> Q: Ah, so do you like powerful and funny characters?
>
> AJ: Yeah!
>
> Q: Why should a character be funny?
>
> AJ: Because sometimes it gets boring, they get all serious, then everything gets serious. But sometimes it is also cool when everything is serious, and suddenly it starts to be exciting, then it is funny. So, I think "Wasn't it weird?" But suddenly, everything is very exciting (laughing).

When asked about **the possibility to control the character during the game,** AJ said that she thinks it is important, and explained why:

> AJ: Because I already see the difference between this player and the other player.
>
> Q: Do you think that it would be cool to control the character?
>
> AJ: I do.
>
> Q: Did you miss controlling the character in this game?
>
> AJ: No. There is already a game called Naruto where you can control the character.
>
> Q: Did you like it?
>
> AJ: Hu-huh. At the beginning I thought it was strange, then I got used to it.

When asked whether she thought the character should give her tips about the game challenges, AJ said that this would make the game easier:

> AJ: Ah, it would make it a little easier

Q: Would that be cool?

AJ: Yeah.

Q: But should it happen all the time or only in a very difficult part?

AJ: So, for example, you are doing very badly, then he (the character) goes there and gives you a tip, then you do better.

When asked what she thought about the possibility to choose or customize the game character, AJ said that it was a good idea:

Q: Do you think that it is cool when you can customize the game character?

AJ: I do (excited), because if you keep it the same, then you have the same thing, and it gets boring.

Q: Okay. So would you change the character during the levels?

AJ: Uh-huh. Sometimes I would play with the same one in two levels, and then in the other two levels I would choose another one (referring to the character).

As to whether the game character should talk (audio or text) about the game tasks, AJ said it should and that she preferred a narration to a text:

AJ: A narration (audio) because it is easier.

Q: Do you mean easier to understand?

AJ: Uh-huh.

Finally, AJ was asked whether she thought the character should tell the player when they did the right thing or made a mistake in the game. AJ said:

AJ: I would like that because then I could correct the mistake.

Session 1: World Building

Still in game session 1, after the gameplay, AJ answered questions regarding the element world building. Firstly, she was asked **what she thought about the game story (narrative) in MSB.**

AJ: Different, right? She (referring to the game character) was thinking about eating a lot. What is that!

Q: Did you think these parts about food were funny?

AJ: I did.

When AJ was asked **what the game would be like without the story**, she said it would be confusing:

AJ: Ah, you would not know what you were doing in the game.

Q: Do you think the game story helps you to understand the game challenges?

AJ: Yeah, uh-huh.

AJ did not answer the question about **whether she thinks a game should have a story.** However, she had mentioned before that a game without a story can be confusing and difficult to play. When asked **what makes a game story cool,** AJ explained:

AJ: It has to be fun. There are many things in a cool story, craziness too. As Naruto, in one episode he has a power, then in another episode, he has a different power.

Q: So, do you like when things change in the story?

AJ: Uh-huh.

Q: In your opinion, what should a game story have?

AJ: Someone speaking, telling you things.

When asked **about the Naruto's story,** AJ got very excited and explained what she likes about this story:

AJ: Naruto's story? I think it is really cool! (very excited and speaking more loudly). Because there is a sad part, there is a cool part, there is a part with a fight. It is all together (very excited and smiling).

AJ liked the Monster School Bus story and would not make any changes. When asked **if the game story should teach about the game challenges or tasks,** AJ said:

AJ: It would be better, but it is also good that we go on learning, right? Playing the game and learning.

Q: Do you think it is important to keep trying until you learn?

AJ: Uh-huh.

Q: Do you not lose interest in the game when this happens?

AJ: No, because then we see what we did, and then we fix it.

As to **what moment in the game the story should appear,** AJ thinks it should be at the beginning of the game:

AJ: In the beginning, because we will know what we need to do and we will choose our characters.

When asked **whether static images or short animation should be used to present the game story**, AJ said that she preferred animation because it is less boring for the player. As to whether she preferred a narration (audio) or a text on the screen, AJ said that she preferred audio to a text.

When asked what she thought about the possibility of choosing and changing the game story, AJ said that it would be cool:

AJ: It would be cool! (excited). Because then you could say what you had learned.

Q: How would that be?

AJ: Like you are playing then you start to understand the game. Then at the end, you kind of teach the person who made a mistake. Then you say: Ah, you did well, then it was kind of bad, then it was good.

AJ did not answer the question about **whether to play the game the player needs to understand the story.** However, she had mentioned previously that a game without a story would be confusing for the player.

Finally, AJ was asked if she liked funny moments in the game story:

Q: Do you like funny parts in the game story? Or should the story be serious because you are learning?

AJ: No, it should be funny, because if it is all serious, it is boring.

Session 1: Rewards

In the last part of session 1 AJ answered questions about the game element rewards. Firstly, AJ was asked **whether she liked the Monster School Bus rewards:**

AJ: Yes, it shows whether you have done well or not.

AJ was then asked to imagine what the game would be like without the rewards:

AJ: You would not know if you did well. Because in most of the games you need to get the stars, because sometimes when you do not get these stars, you do not know how many points you scored.

AJ would only make one small change to the game rewards. She explained what that would be and also what kind of game reward she likes:

AJ: I would only change the potions, to give like speed and stuff like that.

Q: Ah! Would you like to gain new skills or powers with the potions?

AJ: Yeah.

Q: Cool! And, for you, what is a cool game reward?

AJ: That we could earn money, then we could buy another bus.

Regarding what type of reward is more fun, a physical one (e.g. a printed certificate in the real world) or a virtual one (e.g. stars in the game), AJ prefers virtual ones:

AJ: Just in the game because then you will be playing and using it.

As to whether she prefers rewards that can be used in the game (resources) or rewards just for collection, AJ prefers rewards that she can use in the game:

Q: So, do you prefer to receive rewards that you can use in the game (resources) or rewards just for collection?

AJ: In order for us to buy other items. Because in some games, you earn the stars, then you can buy another type of monster, or uniform, or clothes.

Q: Do you think that makes you want to play the game more? For example, you want to get more stars to buy new game items.

AJ: Uh-huh. The game that I play, you need to get the stars, then I had a character, then I changed my character. When I got two stars, then I said – "Come on, I will win this game". Then, I am in a different type of level that is harder, every time it gets worse (referring to the level of difficulty).

Q: Wow! And even when the game is that hard you still want to play it. Why?

AJ: Uh-huh. To know what happens in the end, after.

Regarding the best moment in the game to receive a reward, AJ said:

AJ: Like, in the first level you earn money, then at the other level you earn money.

Q: Do you mean that each level gives you a larger amounts of money or better rewards?

AJ: Like this, in this one you earn 30, then in the next you earn 60 and in the other you earn 120.

Q: Do you mean that the game levels will be harder, but the rewards will become better?

AJ: Yeah.

When asked about what type of game reward she disliked the most, and what type of game reward is more fun (e.g. points, starts, potions), AJ said:

Q: Is there some game reward that you dislike strongly?

AJ: The reward that is bad, like you earn a potion that instead of making you faster it makes you go more slowly. Then, for instance, depending on the game, the levels have limited time and you must walk fast, but the thing makes you walk slowly.

Q: What is more fun as a reward: numbers (e.g. points, scores) or items (e.g. potions, stars)?

AJ: Items because you can change (things in the game) so that you don't get bored with what you are, right?

7.3.4.3 Part C – Researcher's observations

Table 56: Summary of the researcher's observations - Child 4 – AJ (Brazilian girl with dyscalculia). Source: the author.

Session 1
• AJ was very sociable and extroverted. • AJ attended only one session. The session lasted one hour and a half, and covered all three topics. So that the session was not too tiring for AJ, the profile interview was conducted while she was playing the board game Uno Stacko. This made her less aware of the fact that she was being interviewed, and kept her from getting bored. • AJ played two game worlds (1 and 2) covering 6 levels (20 minutes of gameplay). Due to time constraints, she did not play worlds 3 and 4 and therefore did not complete the game. • AJ enjoyed playing the board game Uno Stacko, the game used before the digital game. She wanted to play it again at the end of the session. • During the session, AJ talked enthusiastically about her favorite anime, Naruto, her dog Luna, and her grandmother. • During the gameplay AJ was determined to get the potions, however, she had difficulties with the game controllers. • AJ enjoyed playing the game and had fun during the gameplay. • In world 1, AJ performed well in level 1, where she had many full loads. Although she had difficulty catching the potions, she was very focused on the game. AJ did not perform so well in level 2, although this level also works with simple sums (e.g. 7+3=10). She tried to obtain 10 by doing 6 + 5 and 7 + 9. AJ also had difficulties in level 3, where she tried to obtain 10 by doing 5 + 8 and 5 + 7. At this point, she adopted the strategy trial and error, stopping at each group of kids to see if it was possible to get them on the bus. • World 2, where the player needs to add decimals (e.g. 3.5 + 6.5 = 10.0), was too hard for AJ, and consequently she did not perform well in this world. She repeatedly used the trial and error strategy. Yet, the game system did not prevent her from finishing any of the levels, and this kept her motivated. • As she played, AJ commented on what she was doing: "And now?; "It will not work"; "Now on the other side"; "Oh, what's that?"; "Oh my goodness! It is over. I have lost (laughing)"; "I cannot drive by the front of the school"; "Ah, now I get it why we have these little circles. It is to know how many kids are in there, right?". This showed how focused on the game she was. • AJ said that she would like to use games in her treatment at the DNL – "It would be cool!"

7.3.4.4 Summary: Child 4 – AJ

Table 57: AJ (Brazilian girl with dyscalculia).
Source: the author.

About the game
• AJ only played MSB in one session, and she felt motivated to play it throughout the session. • AJ felt that the time went by fast while she was playing, mainly because the many tasks in the game kept her busy. • AJ felt stressed while playing the game because she had to complete the game tasks quickly. Yet, she had fun. • AJ would like to play MSB at home. She is confident that having played the game in the session, she will play it better at home. • AJ thinks the game is really good (4) because it is different from other games. It is different because it teaches math using kids and a school bus, which makes it easier to learn math. • It could be observed that even the first game world was too hard for AJ. In most of the levels, she used the strategy trial and error and did not perform well. Although the game proved to be too difficult, AJ remained engaged during the session and had fun playing the game. She was curious about the story and the monsters and this may have been what kept her interested in the game. The fact that the game system did not prevent her from finishing any of the levels, also kept her motivated. • According to AJ a cool game should have: cool things that promote fun; a character teaching how to play and giving feedback on the player's performance; serious and funny moments, and novelties.
Character
• **For the game character to be cool:** It should be different from other game characters; give feedback about on player's performance; be powerful and funny. • **A game with no character:** It would be boring. The character changes everything, he does the things in the game. • **Possible changes to the MSB character:** AJ liked the way the MSB characters are. • **Type of character:** AJ likes different characters. She liked the fact that in the MSB game the character was a zombie, because according to her in most games the characters are usually humans. • **Possibility to control the character:** It is important that the player knows with whom he/she is playing. It is cool when the character can be controlled. • **If the character should give tips in the game:** It would make the game easier. However, it would be good only in a very difficult challenge, where the tips would help the player progress in the game. • **Customization of the character:** It is very cool because if the player keeps the same character it will be the same thing, then it will be boring. AJ would like to change the character during the levels, to avoid getting bored. • **Talking with the player:** AJ would like to receive performance feedback and tips from the character through audio because it is easier to understand. She would like the character to tell her if her performance was bad, so she can improve it.
World Building
• **For a game story to be cool:** It should have both serious and funny moments to surprise the player; novelty in the story with different moments (e.g. sad, funny); someone telling the story. • **A game with no story:** Players would not know what they were doing. The story helps players to understand the game tasks. • **Possible changes to the MSB story:** AJ would not make any changes to the story. • **If the story should teach about the game:** It would be good, however, it is also good to learn by doing; • **When the story should appear:** AJ prefers the story at the beginning, to inform the players of what they need to do in the game. Also, players would be able to choose their character.

- **Story format:** AJ prefers animation because the player will not get bored. She prefers audio to a text on the screen.
- **Customization of the story:** For AJ it would be cool because the players could tell what they had learned.
- **Role of the story:** To help players understand what they need to do in the game; to introduce the game characters; to surprise the player with novelties; to make the player curious about the end.

Rewards

- **For a game reward to be cool:** It should reflect the player's performance; give the player new skills or powers; be something that the player can collect (e.g. items) and exchange for new game items (e.g. new cars, characters).
- **A game with no reward:** Players would not know how well they performed, because the rewards are connected with the player's score.
- **Possible changes to the MSB rewards:** AJ would allow more time for the game potions, and give the player some power (e.g. extra speed).
- **The best moment to earn a reward:** AJ would like to receive rewards after each level, and the value of the rewards should increase as the levels increase.
- **Reward types:** AJ prefers virtual rewards because the player will be playing and already using them. She prefers items to points, especially items that the player can collect and exchange for other game resources. It makes the player interested in the game because it allows the player to change things. AJ dislikes bad rewards, for instance, when the player picks up a potion that makes him go slowly for a while.

7.3.5 Discussion & Conclusion

This section presents a summary of the user verification presented in this chapter, focusing on a group-based perspective (see also figure 53). It discusses the following aspects: **Motivational aspects of the game played; Children's preferences regarding the elements Character, World building and Rewards.**

Participants' motivational aspects regarding the game played

- **Motivation:** Both PJ and MJ felt motivated to play the Monster School Bus game during all three game sessions. AJ also felt motivated to play the game throughout her single session. As for BJ, although she initially felt motivated to play the game, in the second session she sometimes felt bored. BJ is 9 years old and is the youngest participant.
- **Level of difficulty:** Based on the participants' performances in the game and the research observations it could be concluded that the game was too difficult for all four participants. This was more evident in the second game world, where the players needed to add decimals (e.g. 3.5 + 6.5 = 10.0). At this point, the participants started using the trial and error strategy. Although the game proved to be too hard for the participants, they all remained engaged in the game. PJ remained engaged because he was curious about the new monsters kids (characters) from the other game levels, and about the game story. MJ remained engaged because she was very curious about the final game rewards, and was determined to improve her performance to earn a better final reward. BJ, although she lost interest in the game at times, was usually engaged when the game presented some novelty (e.g. new characters). Also, she wanted to find out how many potions and kids she would be able to take. AJ was curious about the end of the game story and the new monsters. The fact that the game system did not prevent any of the participants from moving forward or finishing a level also contributed to keeping them engaged. In addition, the participants who attended all three sessions (PJ and MJ), showed a significant improvement in their performances. Thus it is possible to infer that when learning math, children with dyscalculia need more time and practice in order to understand the activities and to progress.
- **Playing the game at home:** All the participants would like to play MSB at home.
- **How fast time went by:** All the participants felt the time went by fast while they were playing the game.
- **How participants felt while playing:** On the whole they felt happy, excited, confident and cheerful. PJ, MJ and BJ also felt curious about the next levels and monsters. AJ had fun playing the game, although she felt stressed because she had to complete many challenges and tasks.
- **Monster School bus ratings:** Participants rated MSN as really good or fantastic. The main reasons for these ratings were: the game is cool; the colorful graphics and story; the rewards (stars and car); the slime kids; it is different from other games, it teaches math in a way that is easy to understand (with kids and a school bus).

- **What participants would like to see in the MSB game:** the player should be given more time to catch the potions; the game should let players choose the level of difficulty, and allow customization of the character and other game elements (bus).

<u>Participants' preferences with regard to the Character</u>

- **What the game character needs to be cool:** It needs to be funny, powerful (have more than one skill or power) and customizable (e.g. clothes, hair); it needs to be different, colorful and cute; it needs to be connected with the story; it should teach the player about the game challenges and give feedback on the player's performance; there should be different characters to choose from (at least one male and one female).
- **A game with no character:** It would be boring; the story and the character are connected so if there is a story the game should have a character and vice-versa; the game needs to have one or more characters; the character makes the game cooler; the player cannot play or understand the story if there is no character; the character changes everything, he/she does the things in the game.
- **Possible changes to the MSB character:** The participants liked the character. However, character customizations would be cool. PJ would also like to have competition in the game, for instance, a big boss to play against.
- **Type of character:** The character should fit with the game story; the game should offer different characters to choose from, at least a male and a female character; the character should be colorful and customizable; the character should be different from the characters in other games; animal characters (e.g. cats) are cool.
- **Possibility to control the character:** This was considered cool by all the participants. Players will relate better to the character if they can control it. Players will also connect better with the character if they can choose or customized it. It would be good to have bonus levels where the character could perform different actions or have different skills in the game.
- **If the character should give tips in the game:** Participants thought this would make the game easier, it would allow players to progress when they were stuck and help them with a new task. However, the participants stressed that this should only occur in very hard challenges, otherwise, it would be too easy and the game would become meaningless.
- **Customization of the character:** All four participants highlighted that customization makes the game funnier and cooler. Customization allows players to explore their imagination and do things in their own way; customizing is a form of expression and allows players to do things that they would not do in real life; customization allows players to change things during the game levels, and keeps them from getting bored.
- **Talking with the player:** Participants thought it would be better to receive performance feedback from the character. It would also be cool to receive

instructions on how to play the game from the character as part of the story; the game instructions are cooler when they come from the character because it grabs the attention of the player. Participants would also like to receive compliments from the game characters (e.g. well done!), but the character should be honest and tell players when they performed poorly, so that they can improve it.

Participants' preferences with regard to World Building

- **For a game story to be cool:** It should have both serious and funny moments to surprise the player with novelty; an interesting story would make people laugh, have fun and relax, and not worry about the goals of the game; a cool story should have a mystery for the players to solve, and make them curious about it; it should give meaning to the game challenges, and purpose to the characters in the game; it should have a narrator, mainly the game characters; the game should have a tutorial to teach players how to play.
- **A game with no story:** The game would not make sense; players would become confused because the story helps them to understand the game, the purpose of the character and the game challenges; A game needs to have a story to make it clear what happens (game sense); it would be impossible to play the game because it is through the story that information about the game challenges and tasks (e.g. how many kids to pick up) are given.
- **Possible changes to the MSB story:** All four participants liked the MSB story and would not make any changes to it.
- **If the story should teach about the game:** It would be good if the story taught about the game challenges and tasks, and instructed players about what they need to do; it would be easier because players could start thinking about how to deal with the game challenges; it would be good, but it is also good to learn by doing.
- **When the story should appear:** PJ, BJ and AJ prefer the story before the levels, because in this way the players would know what they need to do in the game (challenges and new things). Also, players can use the information from the story when choosing their character. MJ, on the other hand, would like the story to appear during the levels gradually, to make players curious about it.
- **Story format:** MJ, BJ, and AJ prefer animation because it is more like real communication, the images are shown better, it is more fun, cooler and funnier. Also, animations keep the player from getting bored. In contrast, PJ (the boy) prefers static images. All four participants think the story should be presented through a storyteller. This is mainly because in that way players would not need to read, as they would if the story was presented as a text on the screen.
- **Customization of the story:** MJ, BJ, and AJ think this would be cool because it would increase players' motivation to play, and players could tell what they had learned. PJ (the boy), on the other hand, thinks this would not be a good idea because it would distract the player.
- **Role of the story:** To keep the players motivated to play the game, and make them curious about the game elements from the next levels or about a mystery;

to teach about the game challenges and what players need to do in the game; to introduce new game characters; to surprise the players with novelties; to make players curious about the end.

Participants' preferences with regard to Rewards

- **For a game reward to be cool:** A cool reward is one that can be used in the game as a resource, giving the player new skills or powers; it should be something that the player can collect (e.g. stars) and later exchange for new game items (e.g. new cars, characters, new clothes); the value of the rewards should increase according to the levels - the more difficult the level the better the reward; a cool reward should reflect the player's performance and progress in the game. All four participants like virtual rewards, i.e. game resources. BJ and MJ also like rewards that the player can use in the real world (e.g. something to paint, color or write on); a good reward should make the player want to spend more time playing because it gives them pleasure. Also, a cool reward should foster curiosity and motivation, and encourage the player to perform well;
- **A game with no reward:** It would be boring; players would not enjoy playing the game; players would not know how well they were performing, because the rewards are connected with the player's score.
- **Possible changes to the MSB rewards:** PJ and MJ would not make any changes to the MSB rewards. BJ, on the other hand, strongly disliked the final game reward that she received (an old beetle). She thought the player should receive a car in good condition (e.g. no flat tire, clean) even if they had a low score. AJ would give players more time to catch the potions, and it would give them some power (e.g. extra speed).
- **The best moment to earn a reward:** During the levels, to encourage the player to keep playing; at the end of the levels to make the player curious and eager to keep playing; after the player has collected some small rewards they should earn a better one; when players complete the challenges fast they should earn extra rewards; bonus levels could be a kind of reward.
- **Reward types:** All participants prefer items (e.g. stars, potions, coins) to points. For them, items are more visible and can be used to earn other game resources (e.g. extra power, skills; new characters). Also, items keep players interested in the game because they allow players to change things.

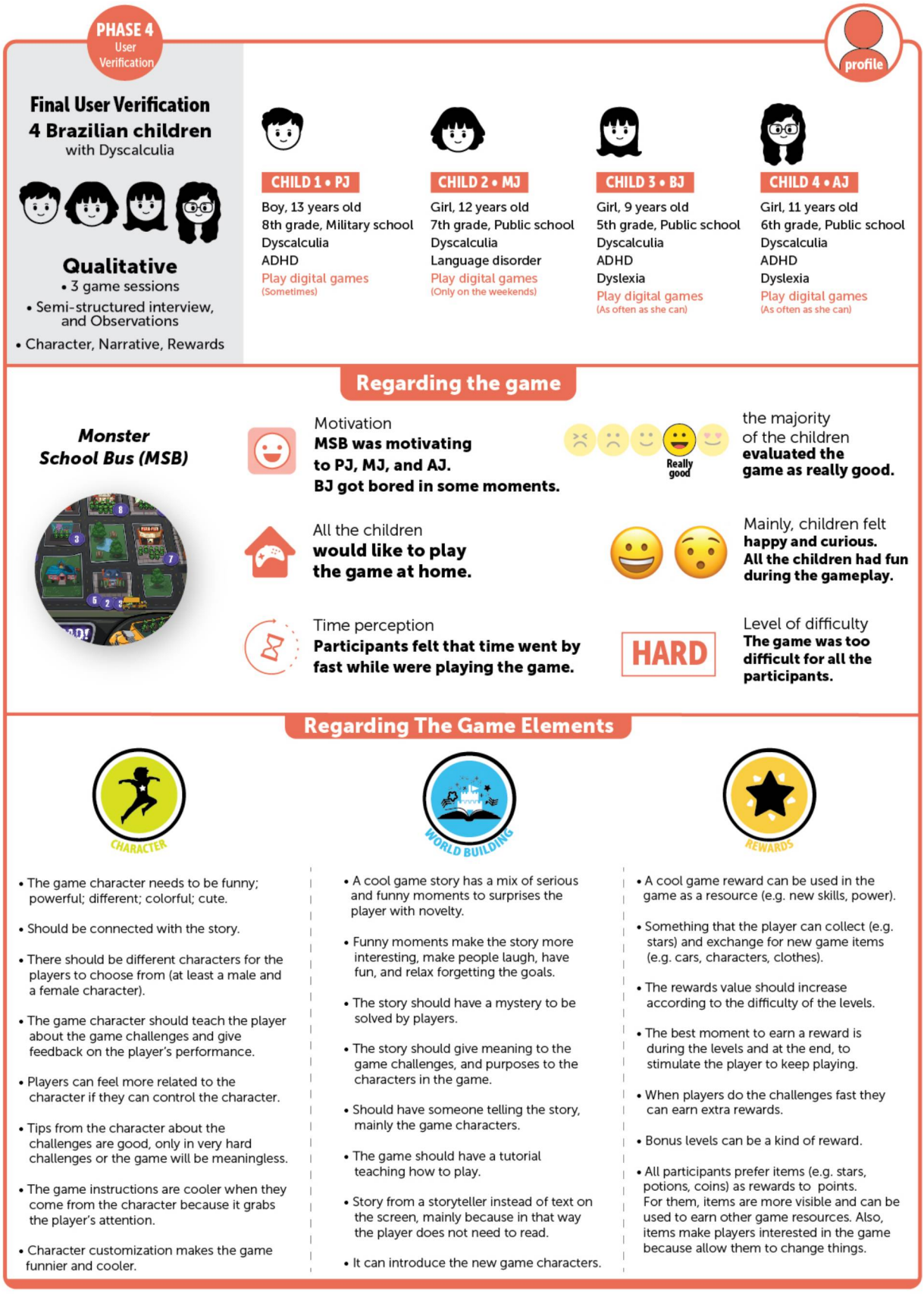

Figure 53: Final user verification visual summary.
Source: the author.

7.4 Summing up

This chapter discussed the results of the user verification: experiment 1, experiment 2, and the final user verification. In so doing, it fulfilled the 5th specific goal of this dissertation, namely: **To verify, with children with dyscalculia, the game design recommendations made by this research, and explore how these recommendations contribute to increasing the motivational element in educational digital games.**

In **experiment 1**, four Brazilian children (aged 10 to 13) with dyscalculia interacted with a game for 6 weeks and were interviewed about their preferences and motivations. This experiment focused on on the game character recommendations, and the game used was implemented specifically for this user verification. Based on the results obtained in this experiment, the semi-structured interview was revised, and the game design experience approach was modified. Thus, instead of using a game with two different versions (e.g. one with a character and another without a character), the following user verification used only one pre-existent and well-developed game.

In **experiment 2**, six American children (aged 9 to 10) with typical development interacted with the game Monster School Bus, during one afternoon in the Learning Games Lab (NMSU). These children were interviewed about their preferences and motivational aspects regarding the game. This experiment used the final versions of the scripted interview, mainly to check the quality of the responses given by the users. This experiment was conducted during the researcher's exchange program at the Learning Games Lab (NMSU).

The final user verification was not entirely similar to either experiment 1 or experiment 2. Nevertheless, both experiments were useful as they helped to improve the interview questions, the process of data collection, and consequently the data quality of this dissertation's user verification.

The final user verification took place at the Developmental Neuropsychology Laboratory (LND-UFGM), Brazil. Four Brazilian children (aged 9 to 13) diagnosed with dyscalculia took part in the study. These children attended a three-week game session, in which they played the math game Monster School Bus. Semi-structured interviews were used, and the participants answered questions about their motivational game preferences before, during and after the gameplay. In addition, participants were observed by the researcher. The user verification showed that the game Monster School Bus was able to promote and sustain participants' motivation. Although the game proved to be too difficult for the participants, they remained engaged in the game, mainly because they were curious about the new characters (monster kids), the new challenges, and about the end of the game story. Participants were also curious and excited about the final game reward. The fact that the game system did not prevent any of the participants from moving forward or from finishing a level also contributed to keeping participants engaged in the game. In addition, the final user verification identified several player's preferences with regard to the game elements character, world building and rewards.

It is important to clarify that during the recommendation process, only the data from the user verification with the 4 Brazilian children with dyscalculia were considered. Despite the methodological contributions of experiments 1 and 2, the data gathered during these experiments were not suitable for the purposes of this study and were therefore not used. The methodological findings provided by these experiments are discussed in chapter 9.

In an overall perspective, some qualitative observations can be made based on the data from all the user verifications conducted in this research. These observations are discussed below.

First, when comparing the data from experiment 2 (6 American children with typical development, aged 9-10) with the data from the final user verification (4 Brazilian children with dyscalculia, aged 9-13), it can be seen that children with dyscalculia had more difficulty with the game (Monster School Bus), mainly in the levels where they needed to work with decimals (e.g. 3.5 + 6.5 = 10.0), which was to be expected. However, it was also noticed that the performance of these children improved considerably in the second session, some of them achieving high scores. This shows that children with dyscalculia need more exposure to and further practice in math in order to progress, compared to children with typical development. Therefore, educational games focusing on children with dyscalculia, should provide an environment where they can practice and learn, and where they can feel confident and ready for the next level. With regard to game preferences, the research results indicate that in general, children with dyscalculia and children with typical development share the same preferences, which means that the game design recommendations of this research could potentially benefit both groups of users.

Second, it was noticed that one of the children with dyscalculia used memorization as a strategy to succeed in the game levels which were too difficult for him (sums with decimals). He realized that the numbers never changed in the game levels, so he memorized them and used the restart button until he got a high score. This suggests that children with dyscalculia instinctively use their general preserved cognitive domains (e.g. intelligence, working memory) to compensate for their limitations in the math-specific cognitive domains. This can be seen as qualitative evidence of the efficacy of the compensation approach used in neuropsychological rehabilitation, highlighted by authors such as Wilson (2008), Antunes et al. (2013), and used by the DNL (UFMG) (for further discussion see section 3.2 Neuropsychological Rehabilitation).

Finally, four children, three girls and one boy, all diagnosed with dyscalculia, took part in the final user verification. This gender imbalance in the sample can be seen as a limitation of this research. Preferences regarding motivational aspects in educational games may be influenced by gender, this however, falls outside the scope of this study.

8 DETAILED RECOMMENDATIONS

This chapter details the game design recommendations which resulted from the data triangulation (YIN, 2001; MINAYO, 2005). This triangulation comprises data from (1) theoretical information on game design recommendations (chapter 2); (2) the field research with game developers (chapter 5); (3) the field research with specialists in rehabilitation (chapter 5); (4) the final user verification with children with dyscalculia (chapter 7). These data were discussed in chapters 2, 5 and 7.

This chapter represents the last phase of this research methodology, and aims to fulfill the main goal of this dissertation: to make detailed game design recommendations on how to promote and sustain the motivation of children with dyscalculia in educational digital games, during neuropsychological rehabilitation.

The data from the literature review and from the field research (both stakeholders mentioned) are discussed in chapter 6. Thus, the main purpose of this chapter is to consider the motivational preferences of children with dyscalculia. This chapter is divided into 5 sections. The first three sections discuss the game elements investigated in this dissertation, namely **Character; World Building; Rewards,** respectively. The contributions made by these recommendations are presented in section 4. Finally, section 5 provides a summary of the main points presented in this chapter.

The game design recommendations made here have as their starting point the recommendations found in the literature, and those made based on the results of the field research (chapter 6). These recommendations have been further developed based on the preferences of children with dyscalculia which were identified in the final user verification (chapter 7).

8.1 Character

The recommendations made in this section concern the game element character. The recommendations identified in the literature regarding this element are presented in table 58 below.

Table 58: Character recommendations.
Source: the author based on the indicated references.

Character
a) **Main recommendation:** An emotional connection between the player and the game character should be established. This connection, based on the player's level of identification with the character (e.g. motivation, skills) brings new experiences to the player. Thus, the game character can draw the player's attention to the game's activities.
b) Stimulate the player's imagination through the game environment (MALONE and LEPPER, 1987; DESURVIRE and WIBER, 2009, ALFADHLI and ALSUMAIT, 2015).
c) Use humor to create entertaining and remarkable characters (DESURVIRE and WIBER, 2009).

d) For each game character, create a backstory which can catch the player's curiosity (ALFADHLI and ALSUMAIT, 2015; DICKEY, 2015).

e) Develop ethical and interesting characters whose movements can be controlled by the player. Moreover, allow the game character to become more powerful as the game progresses (ALFADHLI and ALSUMAIT, 2015).

f) Make it clear to the player what the character's role in the game is, especially its connection to the game conflict. Also, detail the visual appearance, movements, and dialogues of the game character according to its role (DICKEY, 2015).

g) Involve the player in the creation of the character. The creation of a well-developed character requires user participation. Players like to control and take part in creative activities, such as designing or customizing the character. Moreover, developers should use familiar elements based on the player's earlier experiences, but also surprise the player with new things (CHAMBERLIN, 2003).

The following are the recommendations based on the preferences of the children with dyscalculia who participated in this study.

a) **An emotional connection between the player and the game character should be established. This connection, based on the player's level of identification with the character (e.g. motivation, skills) brings new experiences to the player. Thus, the game character can draw the player's attention to the game's activities.**

- An educational game should have a character, who carries out the game actions and represents the player. Players prefer games with a character.
- Game characters should foster empathy and curiosity in the player. The connection between player and character has the potential to sustain the player's engagement in the game, particularly when the challenges are outside of their optimal experience.
- So that players can identify themselves with the game characters, the game should allow players to control, customize or choose the characters. Players consider a game funnier and cooler when they can customize the game characters (e.g. hair, clothes, add new powers or skills).
- To prevent players from losing interest during the gameplay, use character customization during the game levels, not only at the beginning. For instance, new characters or new features/items for the character that are unlocked during the levels are good game rewards to sustain players' motivation.
- Provide a variety of characters. Players expect to have different character to choose from in educational games, at least one male and a female option. Gender representation allows players to relate better with the character.
- Games for the rehabilitation of children with dyscalculia should have a ludic environment that comprises at least one character with a backstory, rather than simply being a digital place to solve math problems.

b) **Stimulate the player's imagination through the game environment (MALONE and LEPPER, 1987; DESURVIRE and WIBER, 2009, ALFADHLI and ALSUMAIT, 2015).**

- Use character customization to allow players to explore their imagination. Customization allows players to do things that they would not do in real life, and this keeps them motivated.
- Create a backstory to feed players' imagination during the game challenges.
- The imaginary world of the game should make sense in the game environment. Players relate to the imaginary elements in the game environment, provided that these make sense to them. Thus the backstory should make it clear to players why the character is doing something or why it ended that way.
- Besides providing players with fantasy through the game environment, the game should offer novelty and surprises to keep players motivated. For instance, new characters should appear in new levels or the narrative should contain unexpected events.

c) **Use humor to create entertaining and remarkable characters (DESURVIRE and WIBER, 2009).**

- The game character should be funny. Also, the game should have funny moments as they make players relax and forget about the goals for a while. Funny parts make players more comfortable to face the learning challenges (less tense).
- Use funny character and funny moments in the narrative as game novelties to surprise and make players curious about the narrative, as this can help to sustain players' motivation.

d) **For each game character, create a backstory which can catch the player's curiosity (ALFADHLI and ALSUMAIT, 2015; DICKEY, 2015).**

- The story and the character are connected. So if the game has a character, the game should also have a story, and vice-versa.
- A character backstory should be a central element in the game, as it is the story that gives sense to the game. A coherent story helps players to sustain their engagement in the game.

e) **Develop ethical and interesting characters whose movements can be controlled by the player. Moreover, allow the game character to become more powerful as the game progresses (ALFADHLI and ALSUMAIT, 2015).**

- Use heroic characters. Players like characters that save something or someone. For instance, a hero archetype who becomes powerful after overcoming some game challenges to save a friend.
- Use unusual characters to catch players' attention. Players prefer unusual characters. For instance, a zombie character can be more interesting than a human one, because it will surprise the players. However, these characters also need to have a story and a purpose in the game.

- Create characters with remarkable skills or powers which can be improved or combined with extra powers during the game levels. For instance, the character can gain a new power as a reward after overcoming some game challenges. This will open up new possibilities in the game, bringing novelty to the gameplay, which helps to sustain players' motivation.
- Use bonus levels which are related to the game content, where players need to perform different actions (mechanics) with the character, through the game possibility spaces. This brings novelty to the game challenges and helps to sustain players' motivation.

f) **Make it clear to the player what the character's role in the game is, especially its connection to the game conflict. Also, detail the visual appearance, movements, and dialogues of the game character according to its role (DICKEY, 2015).**

- The game should make it clear to the players the purpose of the character and the backstory. Players expect to understand what is happening in the game, for instance, why the character is fighting or looking for a job. This will help players make sense of the game, and consequently help them connect with the game.
- Use the character backstory to foster players' curiosity about the game narrative and the game levels, as this will keep players motivated to play the game.

g) **Involve the player in the creation of the character. The creation of a well-developed character requires user participation. Players like to control and take part in creative activities, such as designing or customizing the character. Moreover, developers should use familiar elements based on the player's earlier experiences, but also surprise the player with new things (CHAMBERLIN, 2003).**

- Players with dyscalculia differ in their preferences regarding the game character (e.g. powerful, cute, different, colorful). However, they all believe that the character should be funny, customizable and relevant to the story.
- Users should participate in the creation of the game character, or at least, their preferences should be taken into account during the creation of the game character for an educational game.
- Use different characters in different levels or different game worlds, in order to foster players' curiosity and maintain players' motivation. Players like when new characters appear during the levels and become curious about the new characters.

h) **Use game characters to give players tips about the game challenges or to communicate instructions about how to play.** This is a new recommendation based on the findings of this research.

- Use the characters to communicate with the player. Players prefer when instructions about the game challenges and on how to play the game, as well as feedback on their performance are given by the characters.

- Characters should be honest but kind when providing negative feedback on players' performance. This will help players to know where they need to improve without discouraging them.
- Use characters to help with the game challenges, particularly when players are having difficulty with a task and are not progressing. Players prefer to receive tips only in very difficult challenges, otherwise it would be too easy and the game would be meaningless.

8.2 World Building

The recommendations made in this section concern the game element world building. The recommendations identified in the literature regarding this element are presented in table 59 below.

Table 59: World building recommendations.
Source: the author based on the indicated references.

World Building:
a) **Main recommendation:** Both a narrative and a story should be used as the base for creating the game's world building and ludic context (e.g. character, rewards, mechanics). It is through the narrative and the fictional world that the player immerses himself in the game. Both the player's imagination and curiosity are stimulated by the different and engaging experiences provided by the narrative and the fictional world of the game. The game should not simply be a digital environment to solve math problems.
b) Use visual and sound effects to stimulate the player's curiosity about the game world (MALONE and LEPPER, 1987; FEDEROFF, 2002).
c) Create a game world that works either with or without the character, and which is based on an interesting storyline (FEDEROFF, 2002).
d) Allow players to create content in the game world, to give them a customized experience (FEDEROFF, 2002; CHAMBERLIN, 2003). Additionally, allow players to have a sense of control over the game world, in other words, allow them to make choices in the game world (DESURVIRE and WIBER, 2009).
e) Allow players to participate in the creation of the game world. In the game world, elements such as characters, sounds, humor, surprise, and fantasy are important for the player's experience. Thus, the creation of an interesting and engaging game world requires players' participation (CHAMBERLIN, 2003).
f) Run the game through an engaging, clear and fast storyline. The story should consider the player's earlier experiences with both the real world and the non-real world (ALFADHLI and ALSUMAIT, 2015).
g) An attractive game narrative should follow the three-act structure (i.e. beginning, middle and end), and include the following three main elements: function (exogenous or endogenous); type (linear or nonlinear); the quest (plot, character, setting, conflict) (DICKEY, 2015).
h) A narrative for game-based learning should contain at least the following elements: setting, characters with their roles, the conflict of the story and how it relates to the learning goals, obstacles, backstory, and plot integration (DICKEY, 2015).

a) Both a narrative and a story should be used as the base for creating the game's world building and ludic context (e.g. character, rewards, mechanics). It is through the narrative and the fictional world that the player immerses himself in the game. Both the player's imagination and curiosity are stimulated by the different and engaging

experiences provided by the narrative and the fictional world of the game. The game should not simply be a digital environment to solve math problems.

- Use a narrative to create the game sense. Players enjoy fantasy in the game narrative, provided that the narrative makes sense to them. The narrative should make it clear to players what happens to the character, why the character is fighting and what for.
- Use the game sense from the narrative to help players understand the purpose of the character and the game challenges. Players expect that from the game. However, players also appreciate learning by doing.
- Create a game narrative that fosters curiosity about the game levels, characters, and challenges. Players become curious when they need to solve a mystery; they are also curious about the end of the story. A narrative that fosters curiosity in the player makes players want to continue to play the game.
- The game characters should be the narrators. Players become more engaged in the game when the characters are the storytellers. This also makes the communication more personal and informal, and as a result, players can relate more with the character, story, and game tasks.
- Create a tutorial teaching players how to play the game and make it part of the narrative. Players feel more confident when they understand the goals of the game.

b) **Use visual and sound effects to stimulate the player's curiosity about the game world (MALONE and LEPPER, 1987; FEDEROFF, 2002).**

- The game narrative should be creative and surprise the player with the design of the characters and scenery. These should be revealed gradually, as the player progresses in the game. Players are curious about the different elements of the narrative, and this keeps them motivated to play the game.

c) **Create a game world that works either with or without the character, and which is based on an interesting storyline (FEDEROFF, 2002).**

- Players expect a character if the game has a narrative, and vice-versa. Although games can work without a narrative or a character, when both these elements are well-developed and well connected, the game can more easily foster curiosity in the player and maintain their motivation to play the game.

d) **Allow players to create content in the game world, to give them a customized experience (FEDEROFF, 2002; CHAMBERLIN, 2003). Additionally, allow players to have a sense of control over the game world, in other words, allow them to make choices in the game world (DESURVIRE and WIBER, 2009).**

- Allow players to choose or customize the game world elements (e.g. character, items, vehicles), mainly during the levels. This brings novelty to the game and keeps the player interested in the game. For instance, when starting a new level the player should be

allowed to change characters or make changes to the character they are already playing with.

- Allow players to select the level they would like to play in the game world, provided that the level chosen has already been unlocked. Players prefer to choose the levels to being assigned one by the game.
- Allow players to restart a level or re-do it, to improve their performance. This gives players some control in the game world.
- Allow players to control the presentation of the game narrative, that is, allow players to skip parts of the narrative, or the whole narrative, and to see it again if they wish.

e) **Allow players to participate in the creation of the game world. In the game world, elements such as characters, sounds, humor, surprise, and fantasy are important for the player's experience. Thus, the creation of an interesting and engaging game world requires players' participation (CHAMBERLIN, 2003).**

- Players with dyscalculia differ in their preferences with regard to how the game narrative should be (e.g. customizable or not, animations or static imagens). However, they all agree that a story should have both serious and funny moments to surprise the player. This makes the story more interesting and funnier for the player. This way players can have more fun, they can relax and not think about the goals of the game for a while.
- Use a storyteller instead of a text on the screen to present the story, mainly because players prefer not to have to read this kind of information.
- Funny moments catch the player's attention and players tend to remember narrative moments that have humor more easily.
- Users should participate in the creation of the game world building, or at least their preferences should be taken into account during the creation of the game world building for an educational game.

f) **Run the game through an engaging, clear and fast storyline. The story should consider the players' earlier experiences with both the real world and the non-real world (ALFADHLI and ALSUMAIT, 2015).**

- The elements of surprise and novelty should be used in strategic moments in the game story as a way of preventing players from losing interest in the game.
- Use familiar elements from the player's universe to build the narrative. Also surprise the player with new things, provided that these fit in with the game world building.

g) **An attractive game narrative should follow the three-act structure (i.e. beginning, middle and end), and include the following three main elements: Function (exogenous or endogenous); Type (linear or nonlinear); The quest (plot, character, setting, conflict) (DICKEY, 2015).**

- Present the game narrative before and between the levels. Before the levels, in order to explain to the players what they need to do in the game (explain the challenges and introduce the new elements). Players also use the information from the story to choose their characters. Between the levels, present the story gradually, to make players curious about it, as this helps to maintain the player engaged in the game.

h) **A narrative for game-based learning should contain at least the following elements: setting, characters with their roles, the conflict of the story and how it relates to the learning goals, obstacles, backstory, and plot integration (DICKEY, 2015).**

- The game narrative should be creative. Players expect the character and the story in educational games to be connected.
- Provide ways in which players can relate to the characters through a narrative and backstory. This flourishes players curiosity about the game narrative, and motivates them to keep playing even when they are out of the optimal experience (game challenges too easy or too hard).

8.3 Rewards

The recommendations made in this section concern the game element rewards. The recommendations identified in the literature regarding this element are presented in table 60 below.

Table 60: Rewards recommendations.
Source: the author based on the indicated references.

Rewards
a) **Main recommendation:** Players should be provided with rewards as these contribute to the development of their skills, and also increase their engagement and level of immersion during the game activities. In addition, rewards can increase players' self-efficacy as the game system gives them feedback according to their efforts. This feedback (e.g. scores, badges, rewards) helps the player to progress in the game, since it works as a stimulus for facing the challenges. Moreover, in educational games, feedback can reflect the player's learning strategy. Thus, rewards should be seen as a form of feedback on the game challenges, goals, and objectives.
b) The game should consider the acquisition of knowledge as a type of reward (FEDEROFF, 2002).
c) Use several types of rewards. These rewards need to be systematically designed to increase players' engagement. Provide both small and big rewards based on the difficulty of the challenges completed (CEZAROTTO and BATTAIOLA, 2016).
d) Use elements such as feedback on their progress, scores and badges as rewards to stimulate players' self-efficacy in the game tasks (CEZAROTTO and BATTAIOLA, 2016).

a) **Players should be provided with rewards as these contribute to the development of their skills, and also increase their engagement and level of immersion during the game activities. In addition, rewards can increase players' self-efficacy as the game system gives them feedback according to their efforts. This feedback (e.g. scores, badges, rewards) helps the player to progress in the game, since it works as a stimulus for facing the challenges. Moreover, in educational games, feedback can reflect the player's**

learning strategy. Thus, rewards should be seen as a form of feedback on the game challenges, goals, and objectives.

- Educational digital games should have different types of rewards. For instance, small rewards after a completed level, and a bigger final game reward at the end of the game. Players expect rewards and consider a game with no reward uninteresting. Rewards affect how much pleasure players have in playing the game. Rewards also provide players with feedback on their performance, since they reflect the player's score.
- Give players rewards that can be used in the game as resources. For instance, a reward that gives a new power/skill to the game character, or a reward that players can collect (e.g. stars) and exchange for new game items (e.g. new cars, characters, new clothes) later in the game. This type of reward helps sustain the player's motivation during the game tasks. Physical rewards in the real world (e.g. something printable to color, or a certificate) should also be given.

b) **The game should consider the acquisition of knowledge as a type of reward (FEDEROFF, 2002).**

- Create a connection between the acquisition of knowledge and the game rewards.
- Use rewards strategically to show players their progress, highlighting what they have done (learned) and what they can still earn (learn). Players like to know that they are learning, and that playing the game is worth their efforts.

c) **Use several types of rewards. These rewards need to be systematically designed to increase players' engagement. Provide both small and big rewards based on the difficulty of the challenges completed (CEZAROTTO and BATTAIOLA, 2016).**

- The value of the reward should increase according to the difficulty of the levels. Players expect to earn rewards that reflect their efforts in the challenge/task.
- Give players rewards after a completed level, provided that they had a good performance. This will encourage them to keep playing. Players should not be prevented from progressing in the game, even if they do not earn a reward. In this case, show players how they can improve and earn the reward.
- Design game rewards that can flourish curiosity in the player. Players become more engaged and motivated, and are more likely to perform well in educational games when they are curious about the game.
- Extra rewards can be given to players when they complete some challenges fast, provided that these are connected with the purpose of the educational game. For instance, to unlock a bonus level, or new game items. Players expect such rewards during the gameplay.

d) **Use elements such as feedback on their progress, scores and badges as rewards to stimulate players' self-efficacy in the game tasks (CEZAROTTO and BATTAIOLA, 2016).**

- Use rewards as a way of showing the player their progress, highlighting what they have earned based on their efforts. This can increase players' self-efficacy and motivation.
- Use items (e.g. stars, potions, coins) as rewards instead of points. Players consider items more visible and useful, provided that they can use them to earn other game resources (e.g. extra power, new characters, items) and to change things in the game (e.g. character clothes, vehicle).

8.4 Contributions made by the recommendations

This section discusses the contributions made by the recommendations proposed in this research. Besides fulfilling this dissertation's main goal, which will be discussed in chapter 9, the detailed game design recommendations made here will benefit the flow theory (CSIKSZENTMIHALYI, 1990).

As described in chapter 2, the flow theory is one of the main theories used to investigate players' motivation in games. In brief, the flow experience is an autotelic experience to be reached, and which reflects players' intrinsic motivation. According to this theory, in a game, the player reaches the optimal experience when the level of difficulty of the game challenges is intermediate in relation to the player's skills, oscillating from boredom (too easy – A2, figure 54 below) to anxiety (too hard – A3, figure 54 below) during the flow experience.

Although a number of studies[31] on educational games have used the flow theory, one aspect which is yet to be investigated is how the game elements can affect players' intrinsic motivation during this period of oscillation between boredom and anxiety.

Based on data from this research, it can be inferred that the dramatic game elements character, world building, and rewards play an important role in keeping players motivated in the game challenges, especially when the game tasks are outside of the players' optimal experience (e.g. too high - leading to anxiety). In other words, when players leave the flow experience or have not achieved it yet, these game elements can help to keep players motivated to achieve it.

The detailed game design recommendations provided by this research can help game development teams with the design of math games for children with dyscalculia. These recommendations focus on the importance of fostering players' imagination and curiosity about the game elements. They show that these elements can motivate and sustain players' motivation in educational games, and that this contributes to the flow experience. Based on a study by Cezarotto and Alves (2019), this research highlights the relevance of **players' emotional and cognitive aspects, and of players' sensory curiosity** to the flow experience of the player, as can be seen in the figure 54 below.

[31] These studies were identified in the systematic literature review of this research. See chapter 1, section 1.7 (p. 16) for a summary.

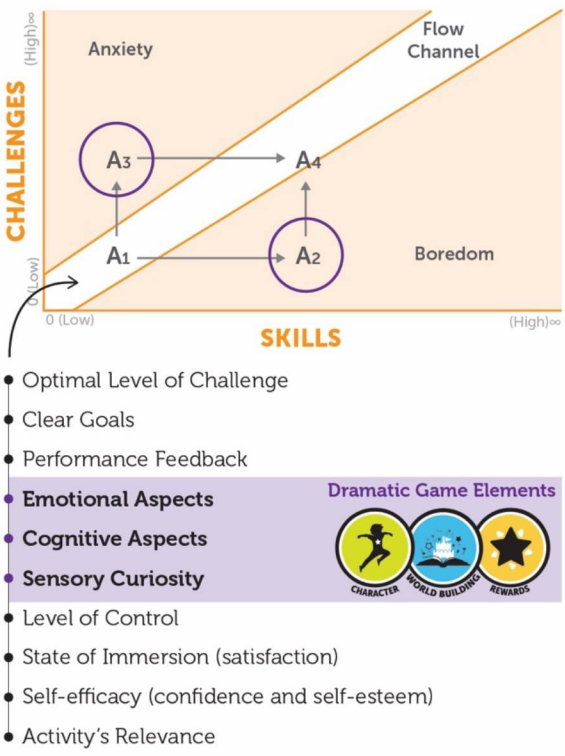

Figure 54: Recommendations on the flow experience.
Source: based on Csikszentmihalyi (1990), Cezarotto and Alves (2019).

8.5 Summing up

This chapter has presented detailed game design recommendations on how to foster and sustain the motivation of children with dyscalculia in educational digital games. These recommendations fulfill the main goal of this dissertation, namely: **to make detailed game design recommendations on how to promote and sustain the motivation of children with dyscalculia in educational digital games, during neuropsychological rehabilitation.** These recommendations focus on three dramatic game elements: character, world building, and rewards.

In the first section, **eight recommendations about the game character were detailed. In these recommendations the following was considered:** character type and roles in the educational game; features of a remarkable character and possible actions in the game; ways to foster an emotional connection between players and characters; ways to flourish players' imagination in the game environment through the character.

The second section detailed **nine recommendations about the game world building. In these recommendations the following was considered:** features of an attractive narrative, and its roles in the educational game; ways to foster players' imagination and curiosity through the world building environment; the basic elements to build a narrative for game-based learning.

The third section detailed four **recommendations about the game rewards. In these recommendations the following was considered:** features of a cool reward and its role in the educational game; types of rewards and strategies to use it in an educational game.

Finally, **the contributions made by these recommendations were discussed.** The main contribution of these recommendations is that as a whole they will help players to achieve a flow experience in educational games. The findings of this research have shown that the dramatic game elements investigated, namely character, world building and rewards, play a significant role in helping players to achieve flow experience and sustain this experience throughout the gameplay. This is because these dramatic elements have an impact on players' emotional and cognitive states, and sensory curiosity in educational games.

9 CONCLUSIONS

This final chapter presents the findings of this dissertation. First, the achieved **results are discussed** considering the research problem and the defined goals. Second, **the methodological process used in this dissertation is discussed**. Furthermore, the **methodological findings from the user verification with children and games are also considered**. These findings can be seen as one of the contributions made by this research. Finally, based on the findings of this dissertation, some recommendations for further research are made. Section 9.5 provides a summary of the chapter.

9.1 Summary of results

This dissertation started with a theoretical investigation, based on the research context and scope, which made it possible to formulate the **research question**: "**how should developers design motivational elements of the educational digital game to best promote and sustain motivation of children with dyscalculia in neuropsychological rehabilitation?".**

To address this question, the main goal was defined: "To make detailed game design recommendations on how to promote and sustain the motivation of children with dyscalculia in educational digital games, during neuropsychological rehabilitation.

Due to the complexity of the main goal, **five specific goals were defined**. Each one of these specific goals addresses some theoretical or practical knowledge that is required to fulfil the main goal, and to, ultimately, answer the research question. The specific goals and their outcomes are presented below.

The first specific goal was "to identify recommendations, guidelines, and principles for the design of educational games which apply to the neuropsychological rehabilitation of children with dyscalculia". These recommendations were identified through a systematic literature review, which included papers (primarily from journals), masters theses, and doctoral dissertations from a variety of fields. The literature review allowed to identify gaps in the educational game design field, which led to the delimitation of the scope of this research. This literature review represents the first phase of this dissertation's methodology, and through it a set of recommendations, guidelines and heuristics were identified, selected, and organized according to the focus of this research, which is player experience in digital games.

The second specific goal was "to investigate, from the perspective of specialists in rehabilitation, what the requirements to develop educational digital games for children with dyscalculia in neuropsychological rehabilitation are". In this second phase of the methodological process, data were collected through field research. The twelve specialists who took part in the study answered an online questionnaire composed mainly of open-ended questions. The information gathered provided insights into the game set up, regarding content and children motivation.

The third specific goal was "to investigate what motivational game elements are used by game developers to promote player motivation, and how these elements are set up during an educational game project. Also, to contrast this information with the data from the literature review". Field research was again the chosen method of data collection. 41 game developers took part in the study. Data was gathered through a questionnaire containing mostly closed-ended questions and which was applied during the SBGames[32] 2017 held in Curitiba-Brazil. Participants provided information with regard to their experiences with the design of educational digital games, and the configuration of the game elements in this media. This field research made it was possible to identify the game elements that game developers consider essential to foster player motivation. Furthermore, this field research also revealed that more than half of the sample does not use a user-centered design approach in the development of educational games.

The fourth specific goal was "to propose a set of game design recommendations for educational games capable of fostering and sustaining motivation in dyscalculic children during neuropsychological rehabilitation". Whereas the first three specific goals concern data collection, this goal concerns data analysis. The method of data analysis used was triangulation. The different sets of collected data (literature review + field research with specialists in rehabilitation + field research with game developers) were organized and analyzed separately, and then converged. As a result, a set of game design recommendations on how to foster player motivation was proposed. These recommendations focus on the dramatic game elements character, world building, and rewards.

The fifth and last specific goal of this dissertation was "to verify, with children with dyscalculia, the game design recommendations made by this research, and explore how these recommendations contribute to increasing the motivational element in educational digital games". Experimental game design was the method used for this user verification, which comprised two experiments and the final verification. Four Brazilian children (aged 9 to 13) diagnosed with dyscalculia took part in the user verification. This verification involved attending three game sessions over a period of three weeks (one session per week), during which participants had to play the game Monster School Bus. As part of the user verification, participants had to respond to a semi-structured interview before, during and after the gameplay. Behavioral observations were also conducted, during which participants' verbalizations were recorded in writing. This made it possible to analyze participants' motivational experience during the gameplay, and to gain an insight into their preferences with regard to the educational game elements.

The fulfillment of the five specific goals led to the fulfilment of the main goal of this dissertation, and, consequently, to successfully answering the research question. By providing a set of detailed recommendations this research has fully achieved its proposed goals.

The set of detailed game design recommendations provided by this research can help game development teams, especially in the design of math games for children with dyscalculia. These recommendations rest on the belief that players' imagination and curiosity are key to motivate and sustain player motivation in educational games, and as

[32]SBGames (Brazilian Symposium on Computer Games and Digital Entertainment) is the largest academic event on games and digital entertainment in Latin America. The Brazilian Computer Society has been responsible for organizing the event since 2004. The 2017 edition was held at PUC (Pontifical Catholic University) in Curitiba. Available at: <http://www.sbgames.org/sbgames2017/> (Accessed on March 1, 2018).

such they contribute to the flow experience. Thus, these recommendations greatly benefit the game design field.

These detailed recommendations will benefit the academic community and society as a whole. The academic community will benefit from this research in that this research's findings will generate publications in both the design and the neuropsychology fields. This will stimulate the interdisciplinary discussion that the design of educational games for children with dyscalculia demands. Also, this research fostered a connection between the Federal University of Paraná, Federal University of Minas Gerais and the New Mexico State University. Moreover, the findings of this research will be available online for free, allowing game developers and researchers around the world to access this knowledge and make use of these recommendations to improve the quality of educational games for children with dyscalculia.

The recommendations made here should not be seen as a blueprint ready to be followed, but rather as directions. The effectiveness of these recommendations in fostering player motivation will largely depend, among other factors, on how the team will interpret and apply (creatively) the recommendations during the design project, and on how the game will be used. In addition, it is essential that players participate and/or are consulted during the design process.

9.2 Methodological limitations

This dissertation's methodology was suitable for the dissertation's goals and research question. Thus, hereinafter all the stages of the methodological process are discussed considering their strengths and limitations.

The **systematic literature review** constituted the basis of this dissertation and the studies cited provided the theoretical foundations for the research question. Due to the vast amount of data, this stage of the research took a long time to be completed, approximately one year. Also, some papers which were relevant to this research were not available to the researcher and therefore were not included in the research sample. However, it is believed that the studies in the game design field which are most relevant for this research were included in this review.

The **field research,** with both stakeholders, has provided information. The field research with game developers was conducted during the game symposium SBGames, which proved to be very effective as it gave direct access to a large number of experts in the field. The questionnaire was administered face-to-face with most of the 41 game developers who took part in the study (four developers answered the questionnaire online). In the field research with specialists in rehabilitation, an online questionnaire was used. So as to ensure a good response rate, the questionnaire was sent to members of a network of professionals in neuropsychology. This proved to be a successful strategy and 12 mediators completed the questionnaire.

Triangulation was used in three different moments of the research methodology to analyze data from different sources: data organization, data categorization and proposing process. This method of data analysis proved to be suitable for this dissertation's goals. Due to the vast amount of data, a high level of organization was required in order to establish a

clear and logical connection between the different sets of data. To this end, several excel sheets, textual discussions, and visual synthesis from each data source were created.

The next stage of this research's methodology was the user verification. **The experimental game design method** was used in the user verification and proved to be suitable for the purposes of this dissertation. The user verification required by this investigation could not be done by way of a classic experiment as it required more rigor than a regular playtest can provide. Thus a set of formal steps related to the methodology have been established and incorporated into the structure of the experimental game design. This formalization helps to understand the methodological path of this dissertation. It also fosters scientific rigor, and allows other researchers to apply the structure put forward here in other research contexts.

In the **user verification**, the use of experiments was essential to accurately configure the experimental game design. Although the two experiments did not entirely replicate the final user verification, they were nevertheless very useful. In **experiment 1,** through the experimental game design, variations of the investigated element (character) were created in a simple game. However, this approach proved to be unsuitable to measure the children's motivation because when a game element was disabled, it affected the gameplay experience, and consequently the player's motivation. This happened because games are complex and connected systems. Moreover, the semi-structured interview script applied individually after the gameplay contained flaws. In **experiment 2,** the improved interview scripts were used. Also, in this experiment, only one pre-existing and well-developed game (Monster School Bus) was used. After the game session, the players were interviewed in pairs and answered questions about their motivation and preferences with regard to the game elements. This method of interviewing aimed to verify whether interviewing the children in pairs would increase the data quality. This, however, proved not to be the case.

Adjustments were made based on the results from both experiments so that **the final user verification** could be a success. Four Brazilian children with dyscalculia took part in this verification. The data collection took place at the DNL (UFMG) during the first semester of 2019, and had the support of the researchers from the laboratory. In this final user verification, once a week over a period of three weeks, each child played a game under the researcher's supervision for approximately twenty minutes. Each session lasted one hour and was composed mainly of three activities: rapport, gameplay and interview. Although this research's approach is qualitative, the sample size can be seen as a limitation in the final user verification. The task of identifying children diagnosed with dyscalculia is not an easy one. The researches from DNL (UFMG) helped with the recruitment of participants as the lab has a large database of children diagnosed with dyscalculia. Although the vast majority of the children in the database were outside the target age for this study (i.e. 16 or 17 years old), the four children who took part in the user verification had all been diagnosed with dyscalculia by DNL (UFMG). It is important to acknowledge this limitation, to highlight the need for further studies so that generalizations about these users' preferences can be drawn. Nevertheless, it is believed that the sample used here, although small, produce relevant data which can be used as a starting point in studies using a larger sample.

This dissertation's methodology also included the use of **visual synthesis.** Visual representations were used to summarize ideas and complement the textual information, and were presented at the end of most chapters. These visual representations helped the researcher to connect ideas and highlight the main aspects of the data in each phase of the research. They are also a clear and concise way of presenting information to the readers of this dissertation.

Overall in this dissertation, two aspects need to be highlighted as the main limitations: **self-disclose of bias**, and **leading questions**. The **self-disclose of bias** could have influenced the data interpretation and conclusions, considering that only the researcher processed the information. Once this limitation was identified, as a strategy to reduce it, the full data collected from the participants were presented on this document, so the researcher's interpretations can be checked by any reader. As regards the **leading questions** after the data analyses, especially in the user verification, it was noticed that some questions were too leading. It is important to clarify that the leading questions were not intended. To reduce this limitation, all the players' interviews were presented integrally in this document. Based on the whole interview, it is possible to see that the interview process covered several and different questions and did not manipulate the participants' responses. These limitations do not invalidate this dissertation findings, however, it is something to be acknowledged.

9.3 The findings of the user verification

During the design and application of the user verification, a set of methodological issues were identified. These led to exploratory orientations to help researchers who intend to conduct scientific research on digital games with children. There is little available on this topic in the game design literature, thus these orientations represent one of the contributions of this study to the field of game design. Several of these orientations were outlined during the work conducted at the Learning Games Lab (New Mexico State University). These orientations are described below:

- **Formulating the questions:** create questions which appeal to children. Avoid yes-or-no questions as these do not encourage children to verbalize their ideas or preferences. For instance, the yes-or-no question "Do you like math?", can be reformulated as "If you were to tell a friend how much you like math, what would you say?".
- **Vocabulary:** make sure that the vocabulary used in the questions is suitable for the age of the target children. Provide examples in the questions as these help children understand the question. Likert scale with emojis help children verbalize their ideas and make the interview more dynamic.
- **Interview style:** use an informal and conversational style when interviewing children. This will make them feel more comfortable and more willing to share their ideas.
- **Interview strategy**: when planning the interviews, take into account the other activities the children will need to do in the session. Think about how much time each activity will take, and find ways to make them interesting to the children. Avoid long interviews as children are prone to boredom and tend to lose interest easily.
- **Testing the materials and the data collection strategy**: according to Professor Dr. Barbara Chamberlin, this dissertation's co-advisor (personal communication), to test the materials and the strategy that will be used to collect data with users is vital to the research, as this will help identify flaws and anticipate possible problems in the data collection, before the start of the final user verification.
- **Interaction with users:** use ludic language to explain to children their roles in the user verification. The children need to fully understand why they are there and what they need to do. Also, make it clear to them that they are the experts in games (design

consultants), and the researchers are there to learn from them. This will help foster and maintain their engagement during the research.

- **The use of incentives:** provided that it has been approved by the University Ethics committee, use incentives (e.g. $50 gift card) to show appreciation to the children and their parents for participating in the research. This will also help to keep the children motivated to take part in the activities, particularly in those that take more than one day to be completed.
- **Rapport:** use brief and straightforward board games to initiate interaction with the children, and as a way of introducing them to the other children and to the researchers. Rapport is a technique used by psychologists to develop a connection with the patient, make them feel comfortable before starting the treatment. In research with children, rapport will allow the children to feel more comfortable with the researcher and the environment.
- **Collecting users game preferences:** make it clear to the children that they are not being evaluated, that you are interested in their opinions and that there are no right or wrong answers. Also, create a friendly environment, where the children feel that they can ask any questions about the research at any time during the session.
- **Interviewing the children in pairs:** interview the children in pairs to optimize research time. Also, children tend to express themselves more freely and are more willing to share their opinions when in the company of other children. However, it was noticed that when the children are shy, or do not fully understand the question, they tend to repeat what the other child said. One strategy that can be used to avoid this is to ask the less talkative or shier child to speak first.
- **Note-taking:** while one researcher interacts with the children during the gameplay, another researcher should take notes. This will ensure that all the relevant information is recorded. It will also make the interaction with the children more natural and flow better.
- **Game debriefing:** after the user verification, researchers should meet to discuss their observations. One of the researchers should take notes.

9.4 Recommendations for future research

This dissertation makes contributions to the design of educational digital games for children with dyscalculia. Further research on the development and use of this artifact, however, is still necessary. The following have been identified as opportunities for future research which follow from the findings of this research:

- The recommendations proposed in this research can be validated quantitatively, using a representative sample of children with dyscalculia.
- The recommendations made by this dissertation considered only three dramatic game elements. Future studies should consider other dramatic elements (e.g. play, challenge).
- Development teams can test the applicability of the recommendations by applying them to an existing game design model.

- The proposed recommendations can be used in a study which aims to verify whether the level of motivation of the player has an impact on their learning when they are playing an educational digital game.
- Formalize the contributions to the method experimental game design in a journal, covering all the methodological protocols outlined in this research.
- Investigate if the recommendations detailed in this dissertation can be applied to educational games for children with typical development.
- Investigate whether children's self-efficacy for math improves when they play an educational game which has been developd according to the recommendations made in this study.
- Verify in an international sample and in a national sample of math educational digital games, if the recommendations outlined in this study have been followed and how.
- Investigate whether and how the graphical style of an educational digital game can affect player motivation.
- Investigate whether gender affects players' preferences.

9.5 Summing up

Each one of the four sections in this chapter presented the final discussions of this dissertation's main aspects: (1) results discussions; (2) the research methodology; (3) the findings of the user verification; (4) recommendations for further research.

In the first section, **the results were discussed** considering the research goals. So the findings from each specific goal were related to how they contributed to fulfilling the dissertation's main goal. As a foremost result, a set of detailed game design recommendations was presented. These recommendations focus on the design of motivational math games for children with dyscalculia. Moreover, the section emphasized the recommendations' contributions to the academic community and society as a whole.

Regarding **the research methodology**, section two detailed each method and technique used to achieve the dissertation's goals. Each methodological phase was discussed considering its strengths and limitations. Thus, this section fosters methodological contributions, mainly to research in the game design field.

As for section three, **users verification findings** were discussed. These findings led to orientations to help researchers who intend to conduct scientific research on digital games with children. The user verification findings can be seen as one of the contributions made by this research.

In section four, recommendations for **future research** were made based on this research's findings. A set of opportunities and questions to be addressed in the design of math games for children with dyscalculia were outlined.

This dissertation was completed in three years and eight months. This period was challenging but at the same time very gratifying for the researcher. The author evaluates the findings of this research satisfactory, and with methodological contributions to the game design area. As with most studies, there are still questions which need to be

addressed in future studies. It is believed that the findings of this dissertation have driven forward the academic knowledge about the design of educational digital games and dyscalculia.

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APPENDIX

TABLE OF CONTENT

APPENDIX A - Publications

This dissertation findings provided several academic publications between 2016 to 2019, and in this period the researcher also contributed to colleagues' researches. The following list presents these publications.

Journals

- CEZAROTTO, M. A.; BATTAIOLA, A. L. Design de jogo educacionais: estudo sobre tendências e limitações dos modelos de game design (in Portuguese). **Educação gráfica**, v. 21, p. 67-86, 2018.
- CEZAROTTO, M. A.; BATTAIOLA, A. L. Contribuições do aprendizado multimídia para jogos com foco nas dificuldades da matemática (in Portuguese). **Cibertextualidades** (PORTO), v. 08, p. 79-92, 2017.
- ALVES, M. M. ; BATTAIOLA, A. L. ; CEZAROTTO, M. A. Representação gráfica para a inserção de elementos da narrativa na animação educacional (in Portuguese). **Infodesign** (SBDI. Online), v. 13, p. 1-21, 2016.

Book Chapters

- AGUIAR, M. P.; WINN, B.; CEZAROTTO, M. A.; BATTAIOLA, A. L.; VARELLA, P. G. Educational Digital Games: A Theoretical Framework About Design Models, Learning Theories and User Experience. In: Marcus A., Wang W. (Org.). **Lecture Notes in Computer Science**. 1ed.: Springer International Publishing, 2018, v. 10918, p. 165-184.
- CEZAROTTO, M. A.; BATTAIOLA, A. L. Jogabilidade em jogos educacionais para crianças com discalculia (in Portuguese). In: Vania Ribas Ulbricht, Luciane Maria Fadel, Claudia Regina Batista. (Org.). **Design para acessibilidade e inclusão**. 1ed. São Paulo, SP: Editora Edgard Blücher Ltda., 2017, v. 1, p. 250-266.
- BATTAIOLA, A. L.; CEZAROTTO, M. A. Estudos Exploratórios em Design de Jogos Educacionais (in Portuguese). In: Eliane Pozzebon; Paulo João Martins; Robson Rodrigues Lemos; Luciana Bolan Frigo. (Org.). **Jogos Digitais e Analógicos: Novas Perspectiva em Computação, Design, Educação e Arte**. 1ed.Jundiaí: Paco Editorial, 2017, v. 1, p. 9-22.

Conference papers

- CEZAROTTO, M. A.; ALVES, M. M. Design de jogos digitais educacionais e a motivação do aprendiz, p. 1033-1047. In: **Anais do 13º Congresso Pesquisa e Desenvolvimento em Design.** São Paulo: Blucher, 2019. ISSN 2318-6968, DOI 10.5151/ped2018-2.3_ACO_06
- DUDCOSCHI JUNIOR, A.; BATTAIOLA, A. L.; CEZAROTTO, M. A. Design de Audiogames Acessíveis. (in Portuguese) In: **10ª Conferência de Ciências e Artes dos Videojogos**, 2018, Lisboa. Livros de Actas da Videojogos 2017. Lisboa: Publicações Universitárias Lusófona, 2018. v. 10. p. 48-60.
- CEZAROTTO, M. A.; BATTAIOLA, A. L. Avaliação de jogabilidade em jogos para crianças com discalculia: proposta de heurísticas (in Portuguese). In. **Anais do 16° ERGODESIGN & USIHC e CINAHPA**. Florianópolis: UFSC, 2017.

- CEZAROTTO, M. A.; BATTAIOLA, A. L.; KISTMANN, V. B. The design of educational games and innovation: a case study based on design management. In: Brazilian Symposium on Computer Games and Digital Entertainment (SBGames), XVI. 2017. **Proceedings of SBGames 2017**. Curitiba: SBC, 2017. p.1195-1203.
- CEZAROTTO, M. A.; BATTAIOLA, A. L. Estudo comparativo entre modelos de game design para jogos educacionais (in Portuguese). In: Brazilian Symposium on Computer Games and Digital Entertainment (SBGames), XVI., 2017, Curitiba. **Proceedings of SBGames 2017**. Curitiba: SBC, 2017. p. 174-181.
- BATTAIOLA, A. L; CEZAROTTO, M. A. Métodos científicos em pesquisas sobre Jogos: Mapeamento no SBGames trilha de arte e design (2004-2016) (in Portuguese). In: Brazilian Symposium on Computer Games and Digital Entertainment (SBGames), XVI., 2017, Curitiba. **Proceedings of SBGames 2017**. Curitiba: SBC, 2017. p.149-157
- CEZAROTTO, M. A.; BATTAIOLA, A. L. Recomendações para o design de jogos, enquanto intervenções motivadoras para crianças com discalculia do desenvolvimento (in Portuguese). In: Brazilian Symposium on Computer Games and Digital Entertainment (SBGames), XVI. 2017. **Proceedings of SBGames 2017**. Curitiba: SBC, 2017. Master and Doctoral Thesis SBGames Award, 2017. p 1358-1361.
- CEZAROTTO, M. A.; RUCKL, B. F. N.; BRITO, G. S. A percepção dos professores em relação ao termo tecnologia (in Portuguese). In: XIII Congresso Nacional de Educação, 2017, Curitiba. **Anais do XIII Educere**. Eixo educação, tecnologia e comunicação, 2017. p. 2540-2553.

APPENDIX B - Systematic literature review (journal and conference papers)

This protocol describes the procedures outlined for the systematic literature review, which covered two categories of publications: journals and conference papers. The focus was on the design of educational digital games. This protocol also presents the review results.

As the first step of this systematic literature review, information from a narrative review (COOK, MULROW and HAYNES, 1997) was considered. Through this first review, the research question and goal of the systematic review were defined. These definitions are listed below. Moreover, based on the narrative review results the initial search strings and their combinations were organized (see table 1).

- **Research question:** How is the project of educational digital games accomplished?
- **Main goal:** To outline the state-of-the art in the design of educational digital games, mainly regarding the knowledge available to assist in the design process.
- **Specific goals:** To identify recommendations, guidelines, and principles for the design of educational games that apply to the neuropsychological rehabilitation of children with dyscalculia; To identify research that covers the development of educational digital games for children with some learning disability.

Table 1: search strings.
Source: The author.

Strings (Cycle 1)	Strings (Cycle 2)
"game design" AND "framework"	*"educational games" AND "model"*
"games" AND "recommendations"	*"game design" AND "learning"*
"games" AND "guidelines"	*"game-based learning " AND "mathematics"*
"game design" AND "model"	

Search source

The systematic review of journals and conference papers accessed the following databases: **ScienceDirect, Scopus, and IEEE Xplore Digital Library**. These databases were selected based on the researcher possibilities of access through the *Portal Periódicos CAPES/MEC*, which is a Brazilian platform where researchers can access academic papers - provided by the Brazilian Federal Agency for Support and Evaluation of Graduate Education (CAPES) and the Brazilian Ministry of Education (MEC).

The **Scopus** database was selected based on its worldwide coverage and interdisciplinarity. Scopus[33] platform has approximately 70 million items revised and selected by an independent committee, which increases the quality of the database.

The **Science Direct**[34] database also was selected due to its worldwide coverage, which has more than 14 million publications carefully selected from different fields

[33] Scopus. Available at: <https://www.elsevier.com/solutions/scopus/content> (Accessed on September 7, 2018).
[34] Science Direct. Available at: <https://www.elsevier.com/solutions/sciencedirect/content> (Accessed on November 25, 2017).

At least, the **IEEE Xplore Digital Library**[35] was selected due to worldwide coverage with 4 million publications, primarily of highlight studies from computer science. Based on the interdisciplinarity of the design of the digital games, this field has a significant contribution to this artifact development that can be useful for this review.

Inclusion criteria

During the search process, the papers were selected based on a set of inclusion criteria defined by this protocol, which are listed below:

- Papers that were written in English or Portuguese;
- Papers published in Brazilian or international journals;
- Full papers published in Brazilian or international conferences;
- Papers published from 1990 until 2017.

Exclusion criteria

As well as the approach defined for the inclusion, exclusion criteria were defined for this review, which are:

- Studies that do not address about games;
- Materials without access to the researcher (based on the Portal CAPES/MEC);
- Materials such as a report or a review;
- Short papers or expanded abstracts;

Search filters

To work with the significant amount of material, during the review filters were used as steps to select the papers (figure 1). In **step 1,** the papers have their title, keywords and abstract revised. Additionally, in step 1 the inclusion and exclusion criteria were used. In **step 2,** based on a reading of the paper introduction, method and conclusions, it was possible to select those that contribute to the goals of this review. In **step 3,** the selected papers were evaluated following some criteria (it is described in the next item), which were elaborated based on Kitchenham et al. (2009). The evaluation provided an operationalization in the process of selecting the final sample of papers for the review. As final step, the papers with higher scores (from step 3) were selected for a complete reading. Also, the papers were archived as the base (sample) of this review, which represent **steps 4 and 5**.

[35] IEEE Xplore Digital Library. Available at: <http://ieeexplore.ieee.org/Xplorehelp/#/overview-of-ieee-xplore/about-ieee-xplore> (Accessed on November 25, 2017).

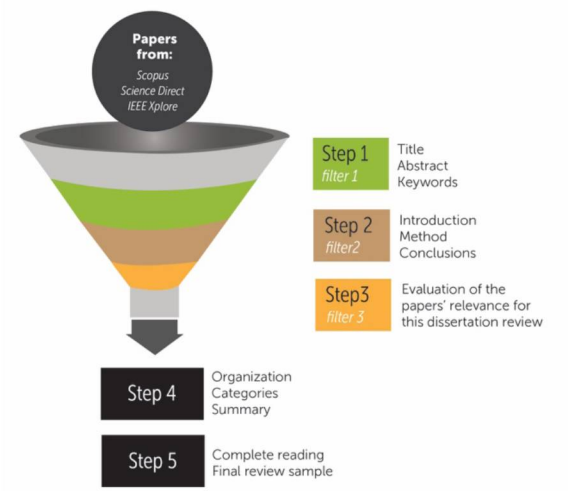

Figure 1: steps for the paper's selection during the review process.
Source: the author.

Relevance assessment for selected papers

Aiming to provide an operationalization in the selection of the papers, a set of questions were elaborated. These questions follow the review research question and goals. This procedure has as reference the study of Kitchenham et al. (2009) from the software engineering field. However, rather than measure the quality of the papers, this review measures the paper's relevance for the dissertation that provides this review. The assessment questions are listed below:

- Q1. Does the paper propose some framework, recommendations, guidelines for the design of digital games?
- Q2. Does the paper focus on educational games?
- Q3. Is the paper published in a journal?

Based on Kitchenham et al. (2009) this assessment follows a pattern for the evaluation (listed below). Thus, papers with a higher score are more relevant for this dissertation review. In that perspective, this review protocol defined that a paper should have a score equal to or higher than 2,5 to be selected as relevant for this review. The paper that does not achieve the defined score will not go to the next step (complete reading). Moreover, papers that the researcher could not access were excluded in this step.

- Yes = 1 (S)
- Partly = 0,5 (P)
- No = 0 (N)

Simplified results

Firstly, table 2 presents the data from the first search cycle. Based on the search of the three databases, this cycle found 663 papers, from this amount 182 were selected by filter 1, and 34 were selected by filter 2. Moreover, as part of the result, this search cycle identified new search strings.

Table 2: first search cycle.
Source: the author.

Search cycle 1 • July 8 and 9, 2016				
Source	**Strings**	**Results**	**Filter 1**	**Filter 2**
Science Direct	"game design" AND "framework"	29	22	7
	"games" AND "recommendations"	58	15	2
	"games" AND "guidelines"	45	13	2
	"game design" AND "model"	46	19	1
Scopus	"game design" AND "framework"	82	19	7
	"game design" AND "recommendations"	41	10	1
	"games" AND "guidelines"	73	15	4
	"game design" AND "model"	146	26	3
IEEE Xplore	"game design" AND "framework"	58	20	4
	"games" AND "recommendations"	7	3	1
	"games" AND "guidelines"	27	12	1
	"game design" AND "model"	21	8	1
Total		633	182	**34**

On the second search cycle (table 3) 689 papers were found, out of which 198 were selected by filter 1, and ending with 32 papers selected by filter 2.

Table 3: second search cycle.
Source: the author.

Search cycle 2 • July 12 and 13, 2016				
Source	**Strings**	**Results**	**Filter 1**	**Filter 2**
Science Direct	"educational games" AND "model"	34	21	2
	"game design" AND "learning"	100	44	5
	"game-based learning " AND "mathematics"	31	9	3
Scopus	"educational games" AND "model"	109	52	4
	"game design" AND "learning"	225	32	6
	"game-based learning " AND "mathematics"	83	12	5
IEEE Xplore	"educational games" AND "model"	25	11	3
	"game design" AND "learning"	43	9	3
	"game-based learning " AND "mathematics"	39	8	1
Total		689	198	**32**

Therefore, with a total sample of 66 papers selected, filter 3 was applied. Hence, through the reading of the abstract, introduction, research method and conclusions of each paper, their relevance was evaluated for this dissertation review. This evaluation was based on a set of questions from the review protocol (previously described). The result of this evaluation is listed in table 4. The papers with a star (equal to or higher than 2,5) were the ones selected for the final base of this review, which comprise a total of **28 papers total (see table 6).**

Table 4: the filter 3, evaluation of the papers' relevance for this dissertation review.
Source: the author.

ID	Paper reference	Q1	Q2	Q3	Score	
1	De Freitas et al. (2012)	1 (Y)	1 (Y)	1 (Y)	3	★
2	Manero et al. (2016)	1 (Y)	0 (N)	1 (Y)	2	
3	Kiili et al. (2012)	1 (Y)	1 (Y)	1 (Y)	3	★
4	Kiili et al. (2014)	1 (Y)	1 (Y)	1 (Y)	3	★
5	Kiili (2005)	1 (Y)	1 (Y)	1 (Y)	3	★
6	Carvalho et al. (2015)	1 (Y)	1 (Y)	1 (Y)	3	★
7	Alves et al. (2015)	1 (Y)	1 (Y)	1 (Y)	3	★
8	Khenissi et al. (2016)	0 (N)	1 (Y)	1 (Y)	2	
9	Frase et al. (2014)	0,5 (P)	0 (N)	1 (Y)	1,5	
10	Goh et al. (2008)	1 (Y)	0 (N)	1 (Y)	2	
11	All, Castelar, and Looy (2016)	0 (N)	1 (Y)	1 (Y)	2	
12	Rijnbout et al. (2016)	1 (Y)	0 (N)	1 (Y)	2	
13	Ak (2012)	1 (Y)	1 (Y)	1 (Y)	3	★
14	Echeverría et al. (2011)	1 (Y)	1 (Y)	1 (Y)	3	★
15	Ahmad and Jaafar (2012)	0 (N)	1 (Y)	1 (Y)	2	
16	Law and Sun (2012)	0,5 (P)	1 (Y)	1 (Y)	2,5	★
17	Aponte, Levieux, and Natkin (2011)	0,5 (P)	0 (N)	1 (Y)	1,5	
18	Alaribe (2015)	0 (N)	1 (Y)	1 (Y)	2	
19	Qian and Clark (2016)	0,5 (P)	1 (Y)	1 (Y)	2,5	★
20	Curatelli and Martinengo (2012)	0,5 (P)	1 (Y)	1 (Y)	2,5	★
21	Kucian et al. (2011)	1 (Y)	1 (Y)	1 (Y)	3	★
22	Waiyakoon et al. (2015)	1 (Y)	1 (Y)	1 (Y)	3	★
23	Brito, Vieira, and Duran (2015)	1 (Y)	0 (N)	0 (N)	1	
24	Aleven et al. (2010)	1 (Y)	1 (Y)	0 (N)	2	
25	Mora et al. (2015)	1 (Y)	0,5 (P)	0 (N)	1,5	
26	Mettler and Pinto (2015)	0,5 (P)	0 (N)	1 (Y)	1,5	
27	Bringula et al. (2014)	1 (Y)	0 (N)	0 (N)	1	
28	Marklund et al. (2014)	1 (Y)	1 (Y)	0 (N)	2	
29	Bennis and Benhlima (2015)	1 (Y)	1 (Y)	1 (Y)	3	★
30	Wilkinson (2013)	1 (Y)	1 (Y)	0 (N)	2	
31	Zhang, Fan and Xing (2010)	1 (Y)	1 (Y)	0 (N)	2	
32	Monodic et al. (2009)	1 (Y)	1 (Y)	0 (N)	2	
33	Franzwa, Tang,and Johnson (2013)	1 (Y)	1 (Y)	0 (N)	2	
				Selected	14	

ID	Paper reference	Q1	Q2	Q3	Score	
34	Jovanovic et al. (2011)	1 (Y)	1 (Y)	1 (Y)	3	★
35	Letra, Paiva, and Nunes (2015)	1 (Y)	1 (Y)	0 (N)	2	
36	Pirker, Gütl, and Astatke (2015)	1 (Y)	1 (Y)	0 (N)	2	
37	Ahmad and Jaafar (2013)	1 (Y)	1 (Y)	1 (Y)	3	★
38	Hall, Wyeth, and Johson (2014)	1 (Y)	1 (Y)	0 (N)	2	
39	Starks (2014)	0,5 (P)	1 (Y)	1 (Y)	2,5	★
40	Hunicke, LeBlanc, and Zubek (2004)	1 (Y)	1 (Y)	0 (N)	2	
41	Rooney (2012)	1 (Y)	1 (Y)	1 (Y)	3	★
42	Ahmad, Rahim, and Arshad (2014)	1 (Y)	1 (Y)	0 (N)	2	
43	Ibrahim and Jaafar (2009)	1 (Y)	1 (Y)	0 (N)	2	
44	Lameras et al., (2016)	1 (Y)	1 (Y)	1 (Y)	3	★
45	Yusof and Rias (2014)	1 (Y)	1 (Y)	0 (N)	2	
46	Sommeregger and Kellner (2012)	1 (Y)	1 (Y)	0 (N)	2	
47	Fang and Strobel (2011)	1 (Y)	1 (Y)	1 (Y)	3	★
48	Alfadhli and Alsumait (2015)	1 (Y)	1 (Y)	0 (N)	2	
49	Ma, Williams and Prejean (2012)	With no access				
50	Grünvogel (2004)	1 (Y)	0 (N)	1 (Y)	2	
51	Qian (2014)	1 (Y)	1 (Y)	1 (Y)	3	★
52	Rodkroh et al. (2013)	1 (Y)	1 (Y)	1 (Y)	3	★
53	Amory (2007)	1 (Y)	1 (Y)	1 (Y)	3	★
54	Kickmeieir-Rust et al. (2011)	1 (Y)	1 (Y)	1 (Y)	3	★
55	Bjoerner and Hansen (2010)	With no access				
56	Catalá and Jaen (2008)	1 (Y)	1 (Y)	0 (N)	2	
57	Khaled et al., (2014)	1 (Y)	1 (Y)	0 (N)	2	
58	Masuch and Rueger (2005)	1 (Y)	1 (Y)	0 (N)	2	
59	Chamberlin et al. (2012)	1 (Y)	1 (Y)	1 (Y)	3	★
60	Frossard et al. (2012)	0,5 (P)	1 (Y)	1 (Y)	2.5	★
61	Huang, Wu, and Huang (2013)	1 (Y)	1 (Y)	0 (N)	2	
62	Drigas and Pappas (2015)	0 (N)	1 (Y)	1 (Y)	2	
63	Brown et al. (2011)	1 (Y)	1 (Y)	0 (N)	2	
64	Erickson (2015)	With no access				
65	Khan and Reed (2011)	1 (Y)	1 (Y)	1 (Y)	3	★
66	Farrell and Muffat (2014)	0,5 (P)	1 (Y)	1 (Y)	2.5	★
				Selected	14	

Yes = 1 (Y) Partly = 0,5 (P) No = 0 (N) ★ Selected

Questions
Q1. Does the paper propose some framework, recommendations, guidelines for the design of digital games?
Q2. Does the paper focus on educational games?
Q3. Is the paper published in a journal?

Table 5 organizes an overview of the systematic literature review search cycles and the results. This table also lists the number of papers selected for this review.

Table 5: an overview of the search cycles and the results.
Source: the author.

Results overview from the search cycles				
Source	**Results**	**Filter 1**	**Filter 2**	**Selected**
Science	343	143	22	**Complete reading**
Scopus	759	166	30	
IEEE Xplore	220	71	14	
Total	**1322**	**380**	**66**	**28**

Finally, through this systematic review in journal and conference papers, a set of observations could be made and gaps in the researches regarding the design of educational digital games could be identified. This information was elementary for the scope delimitation of this dissertation. Nevertheless, as any other literature review, this systematic review has limitations based on the defined scope coverage and the researcher interpretation. Limitations refer, for instance, to the strings, the database sources, and the inclusion and exclusion criteria used for the review. However, during the process, an operationalization in the review decisions was used as much as was possible, in order to allow traceability from the data presented in this document.

Table 6: the selected papers in this review.
Source: the author.

Author	Title	
De Freitas et al. (2012)	Hot Issues in Game Enhanced Learning: the GEL Viewpoint.	★
Kiili et al. (2012)	The Design Principles for Flow Experience in Educational Games.	★
Kiili et al. (2014)	Flow framework for analyzing the quality of educational games.	★
Kiili (2005)	Digital game-based learning: Towards an experiential gaming model.	★
Carvalho et al. (2015)	An activity theory-based model for serious games analysis and conceptual design.	★
Alves et al. (2015)	Exploring Technological Innovation towards Inclusive Education: Building Digital Games – An Interdisciplinary Challenge.	★
Ak (2012)	A Game Scale to Evaluate Educational Computer Games.	★
Echeverría et al. (2011)	A framework for the design and integration of collaborative classroom games.	★
Law and Sun (2012)	Evaluating user experience of adaptive digital educational games with Activity Theory.	★
Qian and Clark (2016)	Game-based Learning and 21st century skills: A review of recent research.	★
Curatelli and Martinengo (2012)	Design criteria for educational tools to overcome mathematics learning difficulties.	★
Kucian et al. (2011)	Mental number line training in children with developmental dyscalculia.	★
Waiyakoon et al. (2015)	Development of an Instructional Learning Object Design Model for Tablets Using Game-based Learning with Scaffolding to Enhance Mathematical Concepts for Mathematic Learning Disability Students.	★
Bennis and Benhlima (2015)	Comparative study of the process model of Serious Game Design through the generic model DICE.	★
Jovanovic et al. (2011)	Motivation and multimodal interaction in model-driven educational game design.	★
Ahmad and Jaafar (2013)	Game design framework: A pilot study on users' perceptions.	★
Starks (2014)	Cognitive behavioral game design: A unified model for designing serious games.	★
Rooney (2012)	A theoretical framework for serious game design: Exploring pedagogy, play and fidelity and their implications for the design process.	★
Lameras et al., (2016)	Essential features of serious games design in higher education: Linking learning attributes to game mechanics.	★
Fang and Strobel (2011)	How ID models help with game-based learning: An examination of the gentry model in a participatory design project.	★
Qian (2014)	Construction and application of an educational game based on the ARCS model.	★
Rodkroh et al. (2013)	Problem-based educational game becomes student-centered learning environment.	★
Amory (2007)	Game object model version II: A theoretical framework for educational game development.	★
Kickmeieir-Rust et al. (2011)	A psycho-pedagogical framework for multi-adaptive educational games.	★
Chamberlin et al. (2012)	The learning games design model: Immersion, collaboration, and outcomes-driven development.	★
Frossard et al. (2012)	A learner-centred game-design approach: Impacts on teachers' creativity.	★
Khan and Reed (2011)	An evaluation of Neurogames®: A collection of computer games designed to improve literacy and numeracy.	★
Farrell and Muffat (2014)	Adapting cognitive walkthrough to support game based learning design.	★

APPENDIX C - Systematic literature review (theses and dissertations)

This protocol describes the procedures outlined for the systematic literature review, which covered theses and dissertations. The focus was on the design of educational digital games. Also, this protocol presents the review results.

As the first step of this systematic literature review, information from a narrative review (COOK, MULROW and HAYNES, 1997) was considered. Through this first review, the research question and goal of the systematic review were defined. These definitions are listed below. Moreover, based on the narrative study results the initial search strings and their combinations were organized (see table 7).

- **Research question:** How is the project of educational digital games project accomplished?
- **Mains goal:** To outline the state-of-the art in the design of educational digital games based on theses and dissertations, mainly regarding the knowledge available to assist in the design process.

Table 7: search strings.
Source: The author.

Strings (Cycle 1)	Strings (Cycle 2)
"jogos educacionais"	*"educational games"*
"jogos educativos"	*"game design"*
"game design"	*"game-based learning " AND "framework"*

Search source

In this review, three databases were accessed, which are listed below. These databases were selected based on their popularity, and their wide range of coverage both nationally and internationally.

- ***Biblioteca digital de teses e dissertações*** **(BDTD-IBICT)** [36]**.** This is a Brazilian virtual library that comprises all the theses and dissertations developed in the country, organized by IBICT (Brazilian Institute of Information in Science and Technology);
- ***Catálogo de teses e dissertações*** [37]**.** This is a Brazilian catalog that comprises all the theses and dissertations developed in the country, organized by CAPES (the Brazilian Federal Agency for Support and Evaluation of Graduate Education) and MEC (the Brazilian Ministry of Education);
- **OpenThesis** [38]**.** This is a free online repository of theses and dissertation.

[36] Biblioteca digital de teses e dissertações. Available at: <http://bdtd.ibict.br/vufind/> (Accessed on July 26, 2016)
[37] Catálogo de teses e dissertações CAPES. Available at: <http://catalogodeteses.capes.gov.br/catalogo-teses/> (Accessed on July 26, 2016)
[38] OpenThesis. Available at: <http://www.openthesis.org/> (Accessed on July 26, 2016)

Inclusion criteria

During the search process, the theses and dissertations were selected based on a set of inclusion criteria defined by this protocol, which are listed below:

- The theses and dissertations should be written in English or Portuguese;
- The researches should be published from 1990 to current days.

Exclusion criteria

As well as the approach defined for the inclusion, exclusion criteria were defined for this review, which are:

- Studies that do not address about games;
- Materials without access to the researcher (based on the Portal CAPES/MEC);

Search filters

During the search and selection of theses and dissertations, a process of four steps was used (figure 2). In **step 1** (filter 1), besides considering the inclusion and exclusion criteria, the researches title, abstract and keywords were read. Based on this initial analysis, the relevant researches to this review scope were selected.

In **step 2** (filter 2) the theses and dissertations were filtered based on the reading of their introduction, research method, and conclusions. Through this filter, the researches to be included in the final sample of this review were selected.

Step 3, finally, organized the selected theses and dissertations in categories. To do this, the software Mendeley, tables, and graphic representations were used. These categories are listed below:

- Type (theses or dissertation);
- Research field (e.g. design, computer science);
- Research goal (e.g. exploratory, descriptive, explanatory);
- Main research method (e.g. survey, case study);
- Similarity to this dissertation (e.g. the same object of study, method).
- Data approach (e.g. quantitative, qualitative, mixed).

After the categorization process the researches were selected based on how much they approach this dissertation, with regard to features such as method, study object and theoretical base. In **step 4** the selected researches were read and had summarized their main points. This summary covered three main questions, which are listed below:

- Q1. What is the main contribution of the research?
- Q2. Despite the research contribution, what gaps remain?
- Q3. How does this dissertation in development benefit/differ from the research analyzed research item?

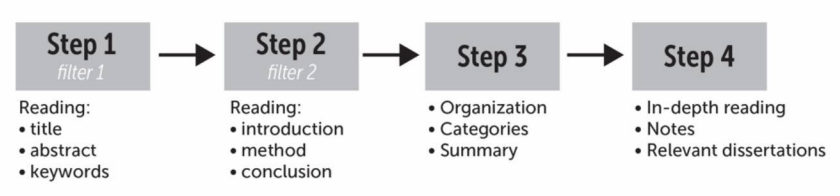

Figure 2: the theses and dissertation selection process.
Source: the author.

Integrate researches

During this systematic literature review other relevant materials, such as suggestions by academics and new materials from references from papers, are also alluded to in the review.

Output

As results, based on the processing of the selected researches, this systematic literature review provides an overview, which provides:

- The placement of this dissertation between the studies already carried out;
- Identification of the most used methods;
- Demonstration of the gaps and allowance of delineating studied required in the educational games;
- Allowance of outlining and refining the goal of this dissertation.

Results

This review search was carried out in two days: July 26, 2016 and February 1, 2017. As a result, 35 research were selected to compound the review sample (table 8 and table 9).

Table 8: result from the first search cycle (2016).
Source: the author.

Search • July 26, 2016				
Source	**Strings**	**Results**	**Filter 1**	**Filter 2**
Biblioteca digital de teses e dissertações	"jogos educacionais"	222	6	5
	"games educativos"	241	14	6
Teses e Dissertações Capes	"jogos educacionais"	104	11	5
	"jogos educativos"	141	10	1
	"game design"	70	7	2
OpenThesis (*Title; English* 2000-2016)	"game learning" AND "design"	60	3	1
	"games for learning"	56	7	4
Total				**24**

Table 9: results from the second search cycle (2017).
Source: the author.

Search • February 1, 2017				
Source	**Strings**	**Results**	**Filter 1**	**Filter 2**
Biblioteca digital de teses e dissertações	"educational games" AND "model"	202	16	3
	"game design" AND "learning"	28	6	2
	"game-based learning" AND "framework"	0	0	0
Teses e Dissertações Capes	"educational games"	85	8	2
	"game design"	70	5	3
	"game-based learning" AND "framework"	4	1	0
OpenThesis *(Title; English 1990-2017)*	"educational games" AND "model"	148	7	1
	"game design" AND "learning"	152	3	0
	"game-based learning" AND "framework"	17	2	0
Total				**11**

The filtering researches are listed chronologically, organized in theses and dissertations (table 10 and table 11). After a dynamic reading of each research, those that are closer to this dissertation and could somehow contribute were selected (identified with a star). It should be stressed out that eight researches were integrated into the final sample (7 dissertations and 1 thesis), due to their contribution to the educational digital game field.

Table 10: dissertations identified in the research.
Source: the author.

Dissertations

	Author/Year	Title	Field + University	Goal	Method	
1	Alves, 2017	*Design de animações educacionais: Modelo para a concepção colaborativa de animações educacionais para o Ensino Fundamental*	Design. Federal University of Paraná	Descriptive-exploratory	Field research	★
2	Assis, 2015	*Neuroreabilitação com jogos eletrônicos controlados por movimento corporal em idosos portadores de comprometimento cognitivo leve*	Biomedicine. Pontifical Catholic University of RS	Explanatory	Experiment	
3	Käser, 2014	Modeling and Optimizing Computer-Assisted Mathematics Learning in Children	Computer Science. ETH Zurich	Descriptive-Explanatory	Experiment	★
4	Vargas, 2014	*Un Modelo Conceptual Para El Diseño De Videojuegos Educativos*	Science and Technology. Universidad Carlos III de Madrid	Descriptive-exploratory	Case study	★
5	Jappur, 2014	*Modelo conceitual para criação, aplicação e avaliação de jogos educativos digitais*	Knowledge Engineering. Federal University of Santa Catarina	Exploratory Descriptive Explanatory	Design Science	★
6	Braghirolli, 2014	*Aprendizagem por jogo computacional na engenharia de produção*	Production Engineering. Federal University of Rio Grande do Sul	Descriptive	Field research	
7	Ferreira, 2012	*Um modelo semântico de busca e recuperação de jogos educacionais para ambientes de aprendizagem*	Electrical engineering. Aeronautics Institute of Technology	Exploratory	Case study	
8	De Lima, 2012	*Ambiente virtual para auxiliar a aprendizagem de meninas com dificuldade de leitura*	Engenharia biomédica. Universidade de Mogi das Cruzes	Explanatory	Experiment	
9	Savi, 2011	*Avaliação de jogos voltados para a disseminação do conhecimento*	Knowledge Engineering. Federal University of Santa Catarina	Exploratory	Case study	★
10	Neto, 2011	*Desenvolvimento de um jogo educativo/terapêutico no auxilio ao tratamento da dermatite atópica*	Children health. Federal University of Rio Grande do Sul	Explanatory	Experiment	
11	De Castro, 2011	*Ambiente virtual para auxiliar crianças com dificuldade de aprendizagem em matemática*	Biomedice engineering. University of Mogi das Cruzes	Descripitive	Experiment	★
12	Portugal, 2009	*Design em Situações de Ensino-aprendizagem: Um diálogo interdisciplinar*	Design. Pontifical Catholic University of Rio	Descriptive	Case study	★
13	Chagas, 2009	*A Inserção do Designer de Games na Indústria Brasileira de Jogos Eletrônicos*	Design. Pontifical Catholic University of Rio	Exploratory	Case study	★
14	Rosa, 2009	*Jogos educativos sobre sustentabilidade na educação ambiental crítica*	Ciências Biológicas e da Saúde. Universidade Federal de São Carlos	Exploratory	Case study	
15	Järvinen, 2008	Games without frontiers: Theories and Methods for Game Studies and Design	Media Culture. University of Tampere, Finland	Descriptive-exploratory	Case study	★
16	Zagal, 2008	Supporting learning about games	College of Computing. Georgia Institute of Technology	Exploratory	Field research	★
17	Barendregt, 2006	Evaluating fun and usability in computer games with children	Design. Eindhoven University of Technology	Descriptive-Explanatory	Experiment	★
18	Chamberlin, 2003	Creating entertaining game with educational content: case studies of user experiences with the children's website, food detectives fight bac!®	Education. University of Virginia	Descriptive	Case study	★
19	Moser, 2000	A Methodology for the Design of Educational Computer Adventure Games	Computer Science. University of New South Wales	Exploratory	Action research	★
20	Palermo,1993	*Intervenção pedagógica, via jogos Quilles e cilada, para favorecer a construção de estruturas operatórias e noções aritméticas em crianças com dificuldades de aprendizagem*	Education. University of Campinas	Explanatory	Experiment	
					TOTAL	13

★ = close to the dissertation in development

Integrated in the review sample based on its relevance

Table 11: theses identified in the research.
Source: the author.

Theses

	Author/Year	Title	Field + University	Goal	Method	
1	Cezarotto, 2016	*Recomendações para o design de jogos, enquanto intervenções motivadoras para crianças com discalculia do desenvolvimento*	Design. Federal University of Paraná	Exploratory	Case study	★
2	Vargas, 2015	*Uma extensão do Design Thinking Canvas com foco em Modelos de Negócios para a Indústria de Games*	Design. Federal University of Pernambuco	Exploratory	Literature review	
3	Dorneles, 2015	*UCHALLENGE: Uma Proposta de Modelo para Construção de Jogos Sérios Ubíquos, com Foco em Aprendizagem Baseada em Problemas*	Computer Science. University of Vale do Rio dos Sinos	Exploratory	Case study	★
4	Santos, 2015	*Qualidades dos Jogos que Influenciam positivamente o Processo de Aprendizado: uma análise crítica*	Computer Science. Federal University of Pernambuco	Exploratory	Literature review	
5	Trindade, 2015	Video game development ontology	Computing engineering. University of Rio de Janeiro	Exploratory-Descriptive	Literature review	★
6	Todor, 2015	*Taxonomia de Games Educativos*	Design. Pontifical Catholic University of Rio	Exploratory	Literature review	★
7	Brito, 2014	*Modelo de recomendação de jogos baseado em seleção de conteúdo no ensino da matemática*	Informatics Federal University of Rio	Exploratory	Case study	
8	Canteri, 2014	*Diretrizes para o design de aplicações de jogos eletrônicos para educação infantil de Surdos*	Informatics. Federal University of Paraná	Exploratory	Case study	★
9	Cardenas, 2014	*Modelo de ontologia para representação de jogos digitais de disseminação do conhecimento*	Knowledge management. Federal University of Santa Catarina	Exploratory	Systematic literature review and ontology	
10	Martins, 2014	*BROAD-PLG: Modelo Computacional para Construção de Jogos Educacionais*	Computer science. Federal University of Juiz de Fora	Exploratory	Literature review	
11	Barbosa Neto, 2013	*Uma metodologia de desenvolvimento de jogos educativos em dispositivos móveis para ambientes virtuais de aprendizagem*	Computer science. Federal University of Pernambuco	Exploratory	Literature review	
12	Lealdino Filho, 2013	*Jogo digital educativo para o ensino de matemática*	Science teaching. Federal University of Technology	Explanatory	Experiment	★
13	Trois, 2013	*Proposta de heurísticas para adaptação de conteúdo instrucional a game educativos*	Design. Federal University of Rio Grande do Sul	Exploratory	Case study	
14	Mendes, 2012	*Games e educação: Diretrizes de Projeto para Jogos Digitais Voltados à Aprendizagem*	Design. Federal University of Rio Grande do Sul	Descriptive	Systematic literature review and Benchmark	★
15	Ferraz Junior, 2012	*Métodos ágeis, dilema e rerroupagem no desenvolvimento de jogos educacionais em sala de aula*	Computer science. Federal University of São Carlos	Exploratory	Field research	
16	Aguiar, 2010	*Jogos eletrônicos educativos: instrumento de avaliação focado as fases iniciais do processo de design*	Design. Federal University of Paraná	Exploratory-Descriptive	Field research	★
17	Batista, 2010	*Design e Educação: o jogo no desenvolvimento de competências e habilidades do educando.*	Design. Pontifical Catholic University of Rio	Exploratory	Case study	
18	De Oliveira, 2010	*Cards Persona: Aplicação da técnica de personas na criação de jogos digitais*	Design. Federal University of Pernambuco	Exploratory	Literature review	
19	Costa, 2008	*O que os jogos de entretenimento têm que os jogos com fins pedagógicos não têm. Princípios para projetos de jogos com fins pedagógicos*	Design. Pontifical Catholic University of Rio	Exploratory	Literature review	★
20	Gerosa, 2008	*Um Framework para Criação Cooperativa de Jogos*	Informatics. Federal Univeristy of Espirito Santo	Exploratory	Case study	
21	Long, 2006	Game Theoretic and Machine Learning Techniques for Balancing Games	Computer Science University of Saskatchewan Saskatoon	Descriptive	Survey	★
22	Akili, 2005	A proposal of instructional design/development model for game-like learning environments: the FID2GE Model	Computer education and instructional technology. The Middle East Technical University	Exploratory	Case study	
23	Ching-yin, 2003	The new possibilities computer games offer for learning	Information Technology in Education. The University of Hong Kong.	Exploratory	Case study	
					TOTAL	10

★ = close to the dissertation in development

Integrated in the review sample based on its relevance

Initial analysis (an overview)

In this initial analysis, the researches (theses and dissertations) were organized in five categories (type; research field; research goal; research method; similarity to this dissertation; data approach). As a result, this analysis made an overview (figure 3), which helped in the enhancement of the dissertation in development. Below is presented a textual synthesis of the information outlined in this analysis.

The selected dissertations and theses are **from a wide range of fields.** The theses are mainly from the fields of design (9) and computer science (7), whilst, the dissertations are mostly from the field of engineering (6), although a few come from the field of design (4). This shows that a number of fields have interest in and produce research on games. This is due to the complexity of developing educational digital games, which demands interdisciplinary knowledge.

Most of the theses and dissertations have an **exploratory goal**. It is assumed that the educational game field has already outlined a set of variables and information, which allows further research with descriptive or explanatory goals. Additionally, many of these studies seem to combine different types of research goals (e.g. descriptive-exploratory; explanatory-descriptive; explanatory-descriptive-exploratory).

Regarding the research method, most of the theses and dissertations use the method of **case study.** Also, the theses frequently use a literature review with additional critical analysis, for instance, the analysis of games or design frameworks. In contrast, in the dissertations, the second most used method is the experiment one. Something causing concern was the fact that several researches from the sample, including dissertations, do not contain a methodological chapter that formalizes and explains the research method in detail.

Figure 3 illustrates, besides the previous categories, those researches to approach the dissertation in development. The identification of this research was based on a dynamic reading, which resulted in the selection of 10 theses and 13 dissertations. These researches stand as the final sample of this systematic literature review.

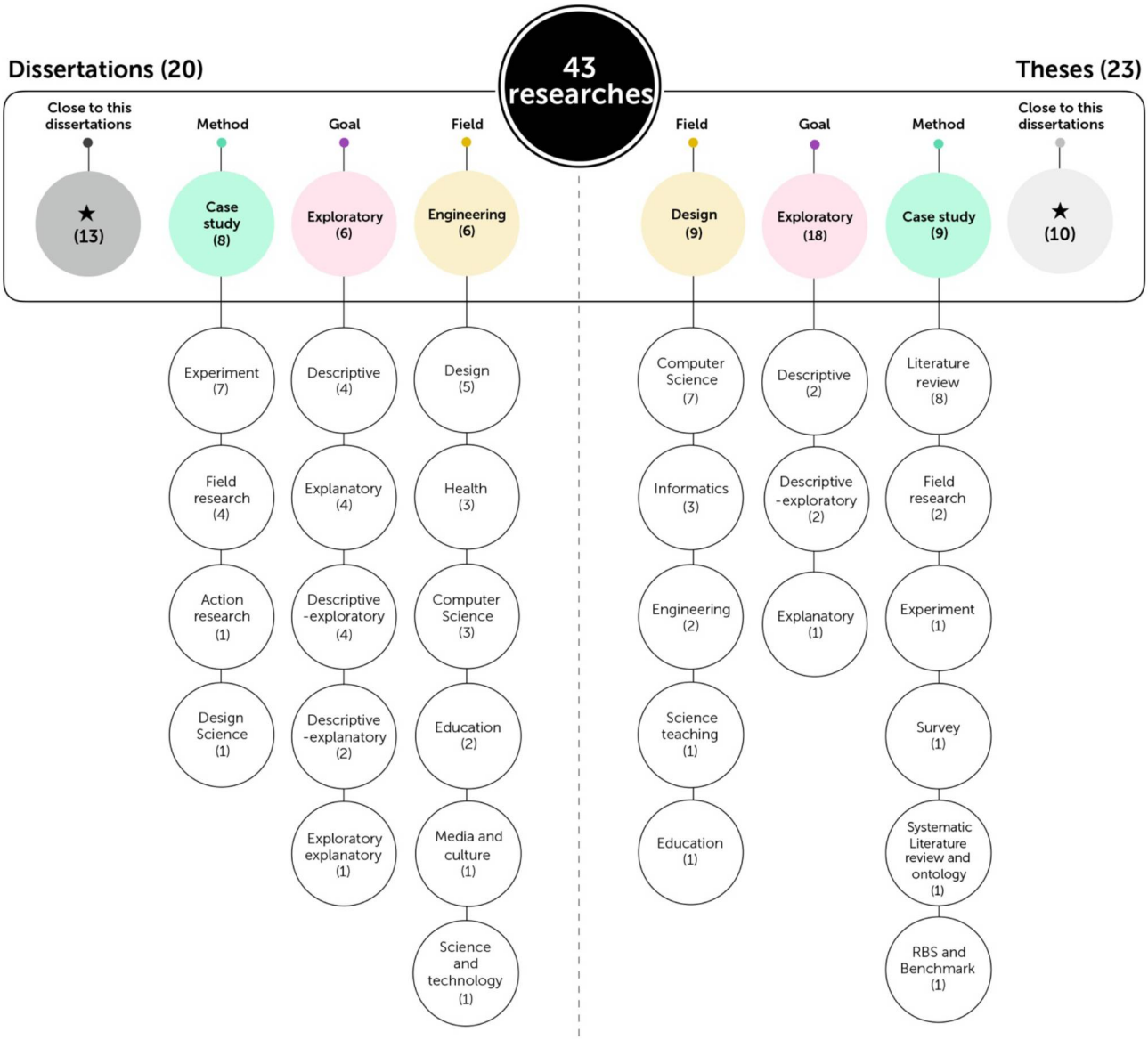

Figure 3: graphic synthesis of the main characteristics of the researches.
Source: the author.

Descriptive analysis of the selected researches

This descriptive analysis covered those selected researches that are close to this dissertation in some way. Only the dissertations were analyzed in depth, due to the relevance of their contributions to this research. Therefore, this descriptive analysis covered 13 doctorate dissertations (table 12).

Table 12: sample of dissertations selected in this review.
Source: the author.

#	Author/Year	Title	
1	Alves, 2017	*Design de animações educacionais: Modelo para a concepção colaborativa de animações educacionais para o Ensino Fundamental*	★
2	Käser, 2014	Modeling and Optimizing Computer-Assisted Mathematics Learning in Children	★
3	Vargas, 2014	*Un Modelo Conceptual Para El Diseño De Videojuegos Educativos*	★
4	Jappur, 2014	*Modelo conceitual para criação, aplicação e avaliação de jogos educativos digitais*	★
5	Savi, 2011	*Avaliação de jogos voltados para a disseminação do conhecimento*	★
6	De Castro, 2011	*Ambiente virtual para auxiliar crianças com dificuldade de aprendizagem em matemática*	★
7	Portugal, 2009	*Design em Situações de Ensino-aprendizagem. Um diálogo interdisciplinar*	★
8	Chagas, 2009	*A Inserção do Designer de Games na Indústria Brasileira de Jogos Eletrônicos*	★
9	Järvinen, 2008	Games without frontiers: Theories and Methods for Game Studies and Design	★
10	Zagal, 2008	Supporting learning about games	★
11	Barendregt, 2006	Evaluating fun and usability in computer games with children	★
12	Chamberlin, 2003	Creating entertaining game with educational content: case studies of user experiences with the children's website, food detectives fight bac!®	★
13	Moser, 2000	A Methodology for the Design of Educational Computer Adventure Games	★

Discussion

Based on the analyses from the selected research, it was possible to make some observations addressing this review research question: "How is the project of educational digital games project accomplished?"

The systematic literature review identified that the design of the educational digital game is a usual topic in the academic fields that foster researches from several areas. These researches have provided different contributions, such as guidelines, recommendations, models, and frameworks.

The review also shows that studies about games and children with dyscalculia, such as the dissertation by Käser (2014) and that of De Castro (2011), focus on the technical aspects of the game, such as game programming, algorithm construction or artificial intelligence. According to the literature review, Chamberlin's (2003) dissertation is the only work whose aim was to investigate the player's preferences in educational digital games. Thus, further research on the experience of children with dyscalculia when interacting with these games is needed. In other words, more needs to be known about qualitative aspects of the use of these games. According to Chamberlin (2003), it is necessary to investigate "how" and "why" the game is fun from the children's perspective, rather than only whether the game is fun or not. Chamberlin (2003) highlights that this lack of qualitative information is recurrent in educational digital games research in general. According to that author further studies on children's preferences about educational games are necessary. According to her, it is this lack of information about the player's preferences in educational digital games that distinguishes these games from those for entertainment. Barendregt's (2006) dissertation also offers some insights into how to evaluate the fun and usability aspects in digital games, although educational games are not the focus of her study.

In addition, some of the sample's, some researches provided recommendations, guidelines, and models to help developers during the design of educational digital games. These researchers discuss the role of the multi and interdisciplinary game design team, motivational and instructional aspects of the educational game, as well as the user-centered design approach in the game project. The user participation in the game design process is highlighted by Chamberlin (2003); Barendregt (2006); Portugal (2009). Moreover, Moser (2000) clarifies that in the user-centered design of educational games there are two mains users: the player (learner) who interacts with the game, and the professional mediator who facilitates the interaction of the player (learner) with the game. These users have different needs and requirements that need to be taken into account in the design process of educational games.

Vargas (2014), whose study focusses on game design models, briefly discusses the importance of finding the balance between entertainment game elements and learning elements. Vargas draws attention to the complex models available in literature which can help in the design of educational digital games. Some of these complex models have been proposed by Jappus (2014), Savi (2011), as well as Vargas (2014) himself.

Additionally, despite the contributions of some researches to the game design field, they still are too theoretical. It means that the connection with the development teams practice is fragile, as occurs in Järvinen's (2008) dissertation for instance. In that perspective Moser (2000) stresses the need of developing games carefully, in other words, based on a multidisciplinary theoretical and practical knowledge. Also Chagas (2009) identified that the game industry is open to receive contributions from the academia.

Finally, Vargas (2014) points out although models and tools may contribute to the game design project, their use does not guarantee the quality of the educational digital game. The efficacy of the educational digital game depends on several factors, which include the ability of the interdisciplinary team (e.g. educators, game designers, content specialists, programmers) to use the model or tool. Thus it can be seen as necessary to develop models or tools of easy use to be used and flexible enough to face the team requirements, from different projects and demands. Also the way that the teacher or mediator uses the game is elementary for the game efficacy. According to Moser (2000) the educational digital game can be valuable educational tool when adequately developed and with a well-planned application with other pedagogical materials, can be a valuable educational tool. However, the educational digital game is not a miraculous tool that will solve all the educational problems only because it is a game.

In summary, this systematic literature review has identified the need for the following further research:

- To study how to insert the user in the game design process of the educational digital games, based on the game industry possibilities;
- How to find the right balance between the entertainment elements and the learning elements of the game;
- To incorporate tools to manage the interdisciplinary game design team;
- To study ways to aligning theory with practice, in a way to elaborate flexible models or framework that can address different team demands.
- Formal orientation for educational digital games, primarily qualitative information regarding the game elements and how these do affect players' preferences;

- In the context of games for children with dyscalculia, qualitative research regarding user motivation and experience when playing the games. This requires interdisciplinary research that will bring together aspects from the game design field and the neuropsychology field;

Finally, through this systematic review of theses and dissertations, a set of observations could be made and gaps in the researches regarding the design of educational digital games could be identified. This information was elementary for the scope delimitation of this dissertation. Nevertheless, as any other literature review, this systematic review has limitations based on the defined scope coverage and the researcher interpretation. Limitations refer, for instance, to the strings, the database sources, and the inclusion and exclusion criteria used for the review. However, during the process an operationalization in the review decisions was used as much as was possible, in order to allow traceability from the data presented in this document.

APPENDIX D – User semi-structured interview.
Script A: before playing (profile).

Script A: before playing
(Child profile and experience with digital games)

Date:

Profile	
Name:	**Name:**
Age:	**Age:**
Gender:	**Gender:**
Grade and school: (What grade will you be in next year?) ☐Private ☐Public	**Grade and school:** (What grade will you be in next year?) ☐Private ☐Public

About Fun	
1. What things do you use for fun at your home? ☐Tablet ☐Computer ☐ Video games (consoles) ☐Board games ☐Cellphone ☐Toys ☐Books ☐Other: What?	**1. What things do you use for fun at your home?** ☐Tablet ☐Computer ☐ Video games (consoles) ☐Board games ☐Cellphone ☐ Toys ☐Books ☐Other: What?
2. Which one do you use the most? Why?	**2. Which one do you use the most? Why?**

Use of digital artifacts	
3. Do you use the computer or a tablet in some school activity? ☐Yes ☐No	☐Yes ☐No
4. In the school, what activity do you do in the computer or table?	

About digital games	
5. What do you like about playing computer OR video games?	
5. Which games do you like to play most? ☐ Video games (on a game console) ☐ Computer Games on a CD ☐ Computer Games on the Internet ☐ No Preference	☐ Video games (on a game console) ☐ Computer Games on a CD ☐ Computer Games on the Internet ☐ No Preference
7. What is the name of your favorite computer or video game? (why) What is the best thing about this game?	

8. How often do you play digital games (on computer OR video games OR Cellphone)? ☐ As often as I can ☐ Every day ☐ Once a week ☐ Sometimes ☐ Never	☐ As often as I can ☐ Every day ☐ Once a week ☐ Sometimes ☐ Never
9. What should not lack in a game to be fun? Why?	
10. What do you think about playing educational digital games? Why?	

About math	
11. How do you feel about math?	
12. What do you think about math games?	

APPENDIX E – User semi-structured interview. Script C1: after playing (character).

Script C1: After playing
(Child experience and preferences with the game)

Participants names:	Date:
Recommendation focus: **Character**	

About the game	
1. During the gameplay did you feel that the time goes slow or fast? WHY?	
2. How do you feel while played the game? WHY?	
3. Do you want to play this game in your home? WHY?	
4. How do you like the game overall? WHY? 	

About the character	
1. What do you think about the game character? Do you like it?	
2. What do you think if we remove the character from the game? Would the game be cool? WHY?	
3. How would you make the Monster school bus character better? What changes would you make? (Jhonny or Jenny)	
4. A game character to be fun and cool need to do what in the game? WHY?	

5. In what moments of the game the character should appear? (e.g., before, after or during the levels) WHY?	

About the character	
6. Can you describe what makes a game character to be cool? WHY? (Do you have a favorite game character: WHY he/she is your favorite?)	
7. The game is more fun if you can control some character during the game? WHY?	
8. What do you think of the character giving you tips about the game challenges? WHY?	
9. What do you think when you can choose your character or customized it? WHY?	
10. What do you think if the character talk (audio) or text to you? (teaches you about the game, before the game started)	
11. What do you think if the character tells you when you do the right thing and when you make a mistake in the game?	

APPENDIX F – User semi-structured interview. Script C2: after playing (world building).

Script C2: After playing
(Child experience and preferences with the game)

Participant name:	Date:
Recommendation focus: **World Building**	

About the World Building (narrative)	
1. What do you think about the game narrative (story)? Do you like it?	
2. What do you think if we remove the narrative (game story) from the game? WHY?	
3. In your opinion a game should or not have a story? WHY?	
4. How would you make the Monster school bus narrative (story) better? What changes would you make?	
5. A game narrative to be fun and cool need to teach about the game challenges? WHY?	
6. In what moments of the game the narrative should happens? WHY? (e.g. before starting the game or during the levels)	

About the World Building (narrative)	
7. What is more fun a narrative with static images (like a comic) or short animations? WHY?	
8. What is more fun a narrative with text of screen or a narration? (DO you like to hear a story by someone telling the story during the game or do you prefer to read it? WHY?	
9. What do you think if you can choose and change the game story? (e.g. Decide what will happen with the character) WHY?	
10. What do you think if to play the game you need to understand the story? WHY?	
11. Do you like funny moments in the game story?	

APPENDIX G – User semi-structured interview.
Script C3: after playing (rewards).

Script C3: After playing
(Child experience and preferences with the game)

Participant name:	Date:
Recommendation focus: **Rewards**	

About math and games	
1. How do you feel about math, after playing Monster School bus?	
2. If you need to tell a friend how do you like a math game, what would you say?	
4. If you are asked to advice a game developer for the next game to be developed, what the future designs should be?	
5. What else would you like in a game?	

About the game	
1. Do you like playing the Monster School bus at home? WHY?(Do you play again)	
2. How do you feel while played the game? WHY?	
3. During the gameplay did you feel that the time goes slow or fast? WHY?	
4. How do you like the game overall? WHY?	

About the Rewards	
1. What do you think about the game rewards? Do you like it?	
2. What do you think if we remove the rewards from the game? (stars)	
3. How would you make the Monster school bus rewards better? What changes would you make?	
4. A game reward to be fun and cool need to be like what?	

About the Rewards	
5. What is more fun a physical reward (e.g., receive a certificate in the real world) or virtual rewards (e.g., stars in the game)? WHY?	
6. Do you like more to receive a reward that you can use in the game (resources) or rewards just for collection? WHY?	
7. When do you think is the best moment in the game to receive a reward? WHY?	
8. Can you tell me one type of game reward that you do not like at all? WHY? (e.g. price)	
9. What is more fun as rewards, number scores or items? WHY?	
10. How do you describe for a friend what/how is a cool game reward?	

APPENDIX H - Game developers' questionnaire

Consent form

This questionnaire is part of the doctorate research titled: "Detailed game design recommendations to provide and sustain the motivation of children with dyscalculia in educational digital games". This dissertation purpose is to detail game design recommendations to foster and sustain the motivation of children with dyscalculia in educational digital games. This research stands as part of the research line Design of Information Systems at the Design Postgraduate Program of the Federal University of Paraná (Brazil).

Taking part in this research is entirely voluntary. If you decide to take part, you are free to withdraw at any time. You are not responsible for any of the expenses necessary to carry out this research. If you decide to take part, you will not receive any monetary value.

The questionnaire takes approximately fifteen minutes to be filled in. The risk occurs that you experiment some of the questions as too sensitive. You may skip any question that you do not wish to answer. You are also free to withdraw from the research at any time.

Principal investigator: Matheus Cezarotto

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Research supervised by prof. Dr. André L. Battaiola

(Professor at the Design Postgraduate program of Federal University of Paraná)

ufpr.design.profe.ppg@gmail.com

[ ] I consent to voluntary take part in the study. I also agree that the data collected can be used in scientific publications, preserving my identity.

Game developer's questionnaire

1. In your opinion, is it difficult to develop an educational game that promotes and sustains the player's motivation?
   a) Yes
   b) No

2. What is your opinion about the level of difficulty for the following game development challenges? (1) Minimal; (2) Low; (3) Medium; (4) High; (5) Extreme.
   a) To find a balance between fun and learning.
   b) To compete with the entertainment market.
   c) To sustain the player-learner's motivation and interest in the educational game.
   d) The high cost of educational game development.
   e) The communication between developers, content specialists, players, and clients.
   f) The lack of practical tools for educational game development.
   g) The preconceptions regarding the use of educational games in schools and universities.

3. What is your opinion about the importance of the following game elements for the player motivation? (1) Very low; (2) Low; (3) Moderate; (4) High; (5) Very high.
   a) Remarkable characters.
   b) Well-developed narrative (e.g. setting, story).
   c) Rules set.
   d) Feedback (e.g. visual, sound).
   e) Rewards.
   f) Intuitive interface.
   g) Challenging goals.
   h) To offer information about how to play.
   i) To offer help when the player is making mistakes.
   j) Visual and sound effects.
   k) How the game is used by the teacher.

4. In your opinion, can the player help to set up the elements of the educational game to promote motivation? (e.g. characters, theme, narrative, interface)
   a) Yes
   b) No

5. How do you/your team set up the game elements to promote the player´s motivation? (e.g. characters, theme, narrative, interface)
   a) The development team using a creative process (e.g. artists, programmers, managers).

b) The development team with a teachers or content specialists.

c) The development team with the client of the project.

d) The development team and theoretical guidelines by well-known developers (e.g. books, papers).

e) The development team and successful entertainment games.

f) The development team and information gathered with users (during the development process).

6. In which moment the player usually participates in the development process of an educational game?

a) The user participates in the preproduction phase (conceptual definitions).

b) The user participates in playtests with initial game prototypes (during the game development).

c) The user participates in playtests with an almost finished version of the game (at the end of the development process).

d) The user does not participate in the process.

7. In a playtest, what usually is evaluated in the educational game?

a) The evaluation of fun, motivation, the learning experience, and possible malfunctions in the system.

b) The evaluation of the learning content.

c) The evaluation of motivation and fun.

d) The evaluation of the system for possible malfunctions.

e) Others:

8. Usually, how the playtest with the player-learner is done by your development team?

a) Observation of the player while playing (e.g. video recording).

b) A specific test to measure learning outcomes (e.g. pre & post testing).

c) Using interview or questionnaires (more than 10 players).

d) Using interview or questionnaires (maximum 10 players).

e) The game is tested with the project client or the teacher instead of the player.

f) Others:

ABOUT YOU

9. How much time of experience do you have with the development of educational digital games?
    a) Less than 1 year.
    b) Between 1 and 2 years.
    c) Between 2 and 3 years.
    d) Between 4 and 5 years.
    e) More than 5 years.
    f) More than 10 years.
    g) Others:

10. In what city do you work?
    a) Open response:

11. What is the field from the educational digital game that you work?
    a) Art and design.
    b) Programming.
    c) Education.
    d) Management.
    e) Other:

12. Where do you work for?
    a) University laboratory or a research center.
    b) Company.
    c) Independent developer.
    d) Others:

APPENDIX I – Specialists in rehabilitation (Questionnaire)

Consent form

This questionnaire is part of the doctorate research titled: "Detailed game design recommendations to provide and sustain the motivation of children with dyscalculia in educational digital games". This dissertation's purpose is to detail game design recommendations to foster and sustain the motivation of children with dyscalculia in educational digital games. This research stands as part of the research line Design of Information Systems at the Design Postgraduate Program of the Federal University of Paraná (Brazil). The questionnaire goal is to identify requirements for the development of an educational digital game to be used with children with dyscalculia in neuropsychological rehabilitation.

Taking part in this research is entirely voluntary. If you decide to take part, you are free to withdraw at any time. You are not responsible for any of the expenses necessary to carry out this research. If you decide to take part, you will not receive any monetary value.

The questionnaire takes approximately fifteen minutes to be filled in. The risk occurs that you experiment some of the questions as too sensitive. You may skip any question that you do not wish to answer. You are also free to withdraw from the research at any time.

RELEVANT INFORMATION

- In any sort of report that we make public we will not include any information that makes possible your identification. The participants' identity will be kept confidentially.
- In the questionnaire there is no wrong or right answer, only your opinion.

Principal investigator: Matheus Cezarotto

(Doctorate student at the Design Postgraduate program of Federal University of Paraná) matheus.cezarotto@gmail.com

Research supervised by prof. Dr. André L. Battaiola

(Professor at the Design Postgraduate program of Federal University of Paraná)

ufpr.design.profe.ppg@gmail.com

[ ] I consent to voluntary take part in the study. I also agree that the data collected can be used in scientific publications, preserving my identity.

Specialists in rehabilitation (questionnaire)

1. Have you ever used an educational digital game during a neuropsychological rehabilitation?
2. If you said yes to the previous question, which game have you used and how was this experience?
3. What do you think about using educational digital games as an activity in a neuropsychological rehabilitation? Justify your answer.
4. Based on your experience with rehabilitation of children (9 to 13 years old), what must be included in an educational digital game? (e.g. what children like, what children expect from the activities).
5. Based on your experience with the rehabilitation of children (9 to 13 years old), what should be avoided in an educational digital game? (e.g. limitations that you have found in games, problems you had when using a game during a rehabilitation session).
6. What do games used in neuropsychological rehabilitation need to offer you? (e.g. progress evaluation, time per activity, number of mistakes).
7. Have you ever worked as a mediator in neuropsychological rehabilitation of children with dyscalculia or a mathematical learning disability?
8. What should educational digital games stimulate during the neuropsychological rehabilitation of a child with dyscalculia or with a mathematical learning disability? (e.g. specific content, conceptual knowledge from mathematics, progressive activities, repetition).
9. In your opinion what do educational digital games need to be like or need to have, in order to work as an intervention for children with dyscalculia or a mathematical learning disability?
10. What is your level of experience with the neuropsychological rehabilitation of children with learning disabilities?
    a) I am an expert (EL.3)
    b) I know well the topic. However, I am not an expert. (EL.2) (Good knowledge)
    c) I am familiar only with some aspects of the topic (EL.1) (moderately familiar)
11. Where are you from?
12. What is your educational background?
13. Name:
14. E-mail:
15. Please feel free to relay your comments or suggestions for this research:

APPENDIX J – Final User verification (Parental consent form)

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO
Dirigido aos pais das crianças

Nós, Prof. Dr. André Luiz Battaiola e o aluno de doutorado Matheus Araujo Cezarotto – da Universidade Federal do Paraná, estamos convidando você, pai ou responsável legal para autorizar a participação do(a) seu/sua filho(a) paciente do Laboratório de Neuropsicologia do Desenvolvimento (LND-UFMG), a participar do estudo intitulado "Detalhamento de recomendações de game design para promover e manter a motivação de crianças com discalculia em jogos digitais educacionais".

a) O objetivo desta pesquisa é detalhar como o jogo digital educacional precisa ser configurado para promover e manter a motivação da criança com dificuldade de aprendizagem da matemática em atividades de ensino sobre matemática.

b) Caso você autorize a participação da criança nesta pesquisa, será necessário que ela jogue um jogo digital educacional sobre o ensino de matemática na companhia de um pesquisador. Ao final do jogo, a criança será entrevistada sobre suas preferências e o que achou do jogo utilizado. Por exemplo, se ela gostou do personagem, da história do jogo, etc.

c) Para tanto, é necessário comparecer no Laboratório de Neuropsicologia do Desenvolvimento (LND-UFMG) para a interação com o jogo, o que levará aproximadamente 30 minutos e fará parte do seu tratamento no laboratório.

d) É possível que a criança experimente algum desconforto, apenas ao teor das perguntas. Caso, isso aconteça o(a) seu/sua filho(a) poderá desistir da participação ou omitir a resposta. Não serão tratados assuntos confidenciais.

e) O estudo envolve riscos relacionados apenas ao teor das perguntas – caso alguma cause desconforto ou constrangimento, o(a) seu/sua filho(a) poderá desistir da participação ou omitir a resposta.

f) Os benefícios esperados com essa pesquisa são o desenvolvimento de jogos educacionais mais próximos das necessidades motivacionais das crianças, ou seja, os jogos serão mais divertidos e consequentemente serão mais eficazes, enquanto uma ferramenta para o ensino da matemática. As crianças conhecerão o universo lúdico da criação de jogos e poderão participar com suas ideias no projeto, as quais ajudarão não somente a elas, mas também a outras crianças.

g) Os pesquisadores responsáveis por este estudo poderão ser contatados para esclarecer eventuais dúvidas que você possa ter e fornecer-lhes as informações que queira, antes, durante e depois de encerrado o estudo no endereço abaixo:

André Luiz Battaiola
Pesquisador responsável | PhD, Prof. Departamento de Design – UFPR
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Rubricas:
Responsável legal (da criança participante) _____
Pesquisador Aplicador do TCLE _____
Orientador _____

Matheus Araujo Cezarotto
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h) A participação da criança neste estudo é voluntária, portanto, é possível recusar participar desta pesquisa ou ainda desistir a qualquer momento e solicitar que lhe devolvam este Termo de Consentimento Livre e Esclarecido assinado. Mesmo que você escolha não participar desta pesquisa, o atendimento da criança no laboratório está garantido e não será interrompido.

i) As informações relacionadas ao estudo poderão ser conhecidas por pessoas autorizadas (Prof. Dr. André Luiz Battaiola, prof. Dr. Vitor Haase e o aluno de doutorado Matheus Araujo Cezarotto). No entanto, se qualquer informação for divulgada em relatório ou publicação, isto será feito sob forma codificada, para que a identidade da criança seja preservada e mantida sua confidencialidade.

j) O material obtido nas entrevistas e relatórios de observação será utilizado unicamente para essa pesquisa.

k) As despesas necessárias para a realização da pesquisa não são de sua responsabilidade e você não receberá qualquer valor em dinheiro pela participação da criança.

l) Quando os resultados forem publicados, não aparecerá o nome da criança, e sim um código.

m) Se você tiver dúvidas sobre os direitos da criança como participante de pesquisa, você pode contatar também o Comitê de Ética em Pesquisa em Seres Humanos (CEP/SD) do Setor de Ciências da Saúde da Universidade Federal do Paraná, pelo telefone (41) 3360-7259. O Comitê de Ética em Pesquisa é um órgão colegiado multi e transdisciplinar, independente, que existe nas instituições que realizam pesquisa envolvendo seres humanos no Brasil e foi criado com o objetivo de proteger os participantes de pesquisa, em sua integridade e dignidade, e assegurar que as pesquisas sejam desenvolvidas dentro de padrões éticos (Resolução nº 466/12 Conselho Nacional de Saúde).

n) **Autorizo ( ), não autorizo ( )**, o uso da gravação do áudio durante a interação da criança com o jogo para fins da pesquisa, sendo o seu uso restrito para a interpretação e transcrição dos dados pelo pesquisador, tão logo a pesquisa termine, os arquivos de gravação serão apagados.

Eu,_____ li esse Termo de Consentimento e compreendi a natureza e objetivo do estudo para o qual autorizo a participação da criança. A explicação que recebi menciona os riscos e benefícios. Eu entendi que somos livres para interromper a participação a qualquer momento sem justificar nossa decisão e sem qualquer prejuízo para mim e para a criança e sem que esta decisão afete tratamento.

Por concordar com os textos acima, eu autorizo a participação do(a) meu/minha filho(a) de modo voluntário neste estudo.

Belo Horizonte, ___ de _____ de _____

Aprovado pelo Comitê de Ética em Pesquisa em Seres Humanos do Setor de Ciências da Saúde/UFPR.
Parecer CEP/SD-PB.nº 2705139
na data de 11/06/2013

_____
(Assinatura do Pai ou Responsável Legal)

_____
(Assinatura do Pesquisador Responsável ou quem aplicou o TCLE)

APPENDIX K - User verification (Children/participant assent form)

TERMO DE ASSENTIMENTO LIVRE E ESCLARECIDO
Dirigido as crianças

Título do Projeto: Detalhamento de recomendações de game design para promover e manter a motivação de crianças com discalculia em jogos digitais educacionais

Aprovado pelo Comitê de Ética em Pesquisa em Seres Humanos do Setor de Ciências da Saúde/UFPR.
Parecer CEP/SD-PB.nº 2705139
na data de 11/06/2018

Pesquisador Responsável: Prof. Dr. André Luiz Battaiola

Pesquisador Colaborador: Prof. Dr. Vitor Geraldi Haase

Pesquisador (doutorando): Matheus Araujo Cezarotto

Local da Pesquisa: LND-UFMG

Endereço: *Av. Antônio Carlos, 6627 (sala 2016) – Pampulha. Belo Horizonte, MG – Brasil*

Telefone: (31) 3409-6295 ou (41) 3360-5238

O que significa assentimento?

Assentimento significa que você, menor de idade, concorda em fazer parte de uma pesquisa. Você terá seus direitos respeitados e receberá todas as informações sobre o estudo, por mais simples que possam parecer.

Pode ser que este documento denominado TERMO DE ASSENTIMENTO LIVRE E ESCLARECIDO contenha palavras que você não entenda. Por favor, peça ao responsável pela pesquisa ou à equipe do estudo para explicar qualquer palavra ou informação que você não entenda claramente.

Informação ao participante

Você está sendo convidado(a) a participar de uma pesquisa, com o objetivo de descobrir o que faz um jogo digital educacional ser legal e divertido. Esta pesquisa é importante porque o jogo educacional pode ensinar várias coisas, mas para isto ele precisa ser legal

Como benefícios da pesquisa, você ajudará a desenvolver um jogo digital educacional legal, que ajudará principalmente a você, e outras crianças, a aprenderem matemática de uma forma divertida. Você verá que é possível aprender matemática brincando com o jogo.

A pesquisa será desenvolvida no ambulatório número laboratório (LND-UFMG). Na pesquisa você jogará um jogo digital educacional que ensina matemática. Antes, durante e depois de jogar você será entrevistado sobre o que gostou e o que não gostou no jogo. Por exemplo, vamos querer saber se você gostou do personagem ou não.

Para não perdermos as suas respostas, vamos gravar o áudio das nossas conversas. Mas não se preocupe sua identidade será mantida em segredo e quando a pesquisa acabar o áudio será deletado. As suas respostas nos ajudarão a criar um jogo bem legal.

O que devo fazer se eu concordar voluntariamente em participar da pesquisa?

Caso você aceite participar, será necessário vir no ambulatório e jogar um jogo digital educacional em um computador, por aproximadamente 20 minutos. Depois de jogar, você responderá algumas perguntas sobre o jogo. Será divertido.

A sua participação nesta pesquisa é voluntária.
Caso você escolha não participar ou queira desistir da pesquisa a qualquer momento, isso não prejudicará o seu atendimento aqui no laboratório, pois ele está garantido.

Rubricas:
Participante da Pesquisa _____
Pesquisador Aplicador do TALE _____
Orientador _____

Contato para dúvidas

Se você ou os responsáveis por você tiverem dúvidas com relação ao estudo ou aos riscos relacionados a ele, você deve contatar os pesquisadores responsáveis por este estudo

André Luiz Battaiola
Orientador da Pesquisa (pesquisador responsável - Prof. Departamento de Design/UFPR)
Universidade Federal do Paraná, Setor de Artes, Comunicação e Design.
Rua General Carneiro 460 – Ed. D. Pedro I, 8º andar
Centro – Curitiba, PR – Brasil – CEP 80060-140
E-mail: ufpr.design.profe.albattaiola@gmail.com | Telefone: (41) 9 9199 9332 ou (41) 3360-5238

Vitor Geraldi Haase
Pesquisador colaborar (Coordenador do Laboratório de Neuropsicologia do desenvolvimento UFMG)
Universidade Federal de Minas Gerais
Departamento de Psicologia - FAFICH - UFMG
Av. Antonio Carlos 6627, CEP: 31270-901 Belo Horizonte, Brasil – sala 2016.
E-mail: vghaase@gmail.com | Telefone: (31) 3409-6295

Aprovado pelo Comitê de Ética em Pesquisa em Seres Humanos do Setor de Ciências da Saúde/UFPR.
Parecer CEP/SD-PB.nº 2705139
na data de 11/06/2018

Matheus Araujo Cezarotto
Pesquisador (Doutorando em Design – PPGDesign-UFPR)
Universidade Federal do Paraná, Setor de Artes, Comunicação e Design.
Rua General Carneiro 460 – Ed. D. Pedro I, 8º andar
Centro – Curitiba, PR – Brasil – CEP 80060-140
E-mail: matheus.cezarotto@gmail.com | Telefone: (41) 9 9199 9332 ou (41) 3360-5238

Se você tiver dúvidas sobre seus direitos como participante de pesquisa, você pode contatar também o Comitê de Ética em Pesquisa em Seres Humanos (CEP/SD) do Setor de Ciências da Saúde da Universidade Federal do Paraná, pelo telefone 3360-7259.

DECLARAÇÃO DE ASSENTIMENTO DO PARTICIPANTE

Eu li e discuti com o pesquisador responsável pelo presente estudo os detalhes descritos neste documento. Entendo que eu sou livre para aceitar ou recusar e que posso interromper a minha participação a qualquer momento sem dar uma razão. Eu concordo que os dados coletados para o estudo sejam usados para o propósito acima descrito.

Eu entendi a informação apresentada neste TERMO DE ASSENTIMENTO. Eu tive a oportunidade para fazer perguntas e todas as minhas perguntas foram respondidas.

Eu receberei uma cópia assinada e datada deste documento.

Belo Horizonte, ___ de _____ de _____

_____

(Assinatura da criança)

_____

(Assinatura do pesquisador que aplicou o TALE)