“MEMORYSTROOP: A Mobile Game for Children with Attention-Deficit and Hyperactivity Disorder”

By

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Undergraduate thesis

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A Undergraduate Thesis presented to Sistemas de Informação of Departamento de Ciência da Computação of Universidade Federal da Bahia in partial fulfillment of the requirements for the degree of Bsc. in Sistemas de Informação.

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Abstract

This undergraduate thesis approaches the construction of a diagnostic and therapeutic game for Attention Deficit Hyperactivity Disorder (ADHD) for young patients. ADHD presents a series of challenges, including many related problems for example dysfunctions on working memory due the correlations between attention problems and neural functions of memory. The psychological phenomenon of Stroop Effect exploits the attention faults when people are submitted to conflicting stimuli tasks and is employed in the proposed application because Stroop Effect is a common mean to diagnose those patients. Combining a memory game for exercising working memory health with Stroop Effect tests for exercising attention tasks, the proposed application in this undergraduate thesis, called *Memory Stroop*, presents itself as a project of gamification. A gamified system is a application that implements a serious process of human daily life in a pleasant game-like way. This gamified alternative has been used in many fields of knowledge, market and health services in order to turn fairer very rigorous tasks. The theoretical basis and principles needed to implement that application is found mainly in psychology and computer sciences Literature. In such interdisciplinary analysis, knowledges of Computer Sciences and Psycho-pedagogy are combined to perform the main objective, which is to show correlation evidences of the use of that gamification software and possible improvements in attentions level measures of the disease, following Stroop Effect paradigms. At the end of the research, an experimental case study has been conducted to verify the viability of *Memory Stroop* among computer scientists.

Keywords: Gamification, Mobile Application, Educative and Therapeutic Software

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List of Acronyms

ABDA	Associação Brasileira de Déficit de Atenção - (Brazilian Association of Attention Deficit)
ADHD	Attention-Deficit/Hyperactivity Disorder
APA	American Psychiatric Association
DSM-5	Fifth edition of Diagnostic and Statistic Manual of American Psychiatric Association's
IDC	International Data Corporation

1 Introduction

Attention-Deficit/Hyperactivity Disorder (ADHD) is a neurodevelopmental disturbance, including genetic and social factors, among others. According to Russell A. Barkley (Barkley, 2012), Clinical Professor of Psychiatry and Pediatrics, it was first described in 1797, and manifests itself with agitation, impassiveness, impulsive bodily control and concentration faults. There are even many others psychological problems main symptoms. That health disorder affects children and adults, but in different ways. Younger patients, generally, challenge difficulties in education and initial socialization process more than adult ones, besides these may suffer with serious relationship problems in work and family management. It afflicts between 5 and 7% of world children, and 4 to 5% adults (Barkley, 2012).

Some affected children may grow and preserve the same behaviour, cognitive and emotional complications all over their life. In this graduate thesis, the analysis will be focused only on young patients, particularly, before 12 years. Although many life scenarios may ridden by this mental ailment, effects of it may be detected mainly towards education, not only in academic grades, but also in everyday school life, including comportment in class and interpersonal relations with other classmates. Today ADHD children become a serious problem for educational systems, because their number have increased rapidly to higher figures. Their academic grades and interpersonal relationships are extensively affected by its symptoms, namely, focus difficult. In present informational society, in which flux of fast information turns life by itself agitated, that disorder may aggravate ADHD young patients' problems.

Parents, teachers and pedagogues have a huge challenge to promote health conditions for the students in that situation. Common treatment of this disturbance involves strong controlled remedies. However, there are many controversies in using this medicaments. Like all medicaments, they have side effects. In order to seek alternatives, researchers

must use creativity. One of these non-drug treatments is the use of brain games sessions. But, before discussing that, it necessary to approach the use of games in ADHD diagnosis. According to Center of Disease Control and Prevention (CDC, 2014), there are some health signals and symptoms, grouped in DSM-5 check-list, that identifies presence of disturb among patients.

1.1 Motivation

Alternatives to strict medicament therapy includes gamification for health proposes. The word "gamification" means funny activities prototyped in video games' interface to serious aims, for example, for a human resources' sector of an enterprise. Here, it will be presented an incremented fork of a gamified application designed in this work to improve ADHD health conditions for children and teenagers. Many gamified applications could be suggested in this sense. For instance, memory, which is associated with various ADHD malfunctions impacts on afflicted young people, may be trained. Then, the gamification proposed in this present undergraduate thesis is directed to train memory activities by simple tasks, presents itself as promising initiative because popular app records such as Google Play Store does not offer many solutions like to the proposed here.

Many gamification softwares are projected to personal computers, but nowadays most used computational devices are mobile ones - namely smartphones and tablets. Developing mobile applications for hyperactive young students may collaborate in their academic performance, among others benefits. In Brazil, for example, from 2012 to 2013, the number of mobile devices sold have increase 157%, and they have been more sold than personal computers and conventional notebooks (Villa, 2014). Costumers' preferences for "smaller computers" could be inferred taking on account that they are, usually, cheaper and easier to carry and to use.

Most of them are based in Android operating systems. Programmers involved in health informatics should be aware to produce more solutions for that platform. They, working conjunctively with psycho-pedagogues, may access easier young students, and offer them healthier life. On the other hand, near 1.9 million of children afflicted by ADHD in this country are waiting to use funny methods of treatment. As the ABDA have stressed, it is commonest psychological illness among this strait of age (Villa, 2014). Its necessary to address new computational efforts so that these millions of children around the world could play for benefit to their own health.

1.2 Problem Statement

Many psychologists are searching others ways than remedies for controlling problems related to hyperactivity. This does not mean that they are totally disagree with prescription. The point lies in the almost virtual exclusivity of drug resources used among various techniques against the problem. There are considerable number of studies approaching such question.

1.3 Objectives

The objective of this work is to improve, with new software functionalities and search quantitative evidences a gamified application in diagnosis and treatment towards ADHD children, of efficiency.

Secondary objectives are: discuss the place of proposed application in context of gamified health alternatives to drug treatment; develop a gamification project targeting memory impacts of ADHD with Stroop Effect paradigm; and present reflections of possibilities of this application to ADHD diagnosis and treatment.

1.4 Out of Scope

This research, having so scarce resources beyond author's personal budget and initiative, could not map cerebral activity during experiments, neither follow up participants some moths after core sessions using medical application. Other experiments could involve parents and other agents in its tabulation. However, here it is foccused only in children that afflicted by the said disturbance.

1.5 Statement of the Contributions

This work contributes to Psychological/Psychiatric diagnosis and therapy, Social Computer Science and Pedagogics in the measures in which it offers them a gamified solution to identify and treatment. The gamification proposed involves a application that trains memory in a conflicting-stimuli condition (classical Stroop Effect): the health game Memory Stroop. Besides, theoretical contribution of this undergraduate thesis lies in offering computational and academic tools for new researches in non-drug approaches to ADHD-driven problems. Finally, minor contributions are set along this text, namely

towards educational game modeling, gamification in health projects and interdisciplinary approaches in Information Systems projects.

1.6 Graduate Thesis Structure

In the Chapter 2, “ADHD”, treats psycho-pedagogical features of this mental condition. The Chapter 3 discuss gamification, medical video games and related questions. After that, in Chapter 4 it will be presented the application and methodological principles adopted in codification. Finally Chapter **??** is the practical experiment of software validation.

2

ADHD

ADHD is one of the most serious mental dysfunctions afflicting children and teenagers (there are also subtypes of ADHD but all forms of ADHD are here considered in its general form). It includes a set of patterns associated with inattention, impulsivity and hyperactivity, as the APA defines: “The essential feature of attention-deficit/hyperactivity disorder (ADHD) is a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development. Inattention manifests behaviorally in ADHD as wandering off task, lacking persistence, having difficulty sustaining focus, and being disorganized and is not due to defiance or lack of comprehension. Hyperactivity refers to excessive motor activity (such as a child running about) when it is not appropriate, or excessive fidgeting, tapping, or talkativeness. In adults, hyperactivity may manifest as extreme restlessness or wearing others out with their activity. Impulsivity refers to hasty actions that occur in the moment without forethought and that have high potential for harm to the individual (e.g., darting into the street without looking).” (Association, 2013a).

Today there exist many types of treatment, although the main efforts of medicine and psychology are directed to the strict drug-based therapy. In this chapter, will be discussed some general features of children and teenagers afflicted by this disorder, like symptoms, common problems and diagnosis. After that, it will be presented the fundamentals of Stroop Effect, a psychological mechanism related to ADHD, that is used by us to structure the proposed application. The Stroop Effect is correlated to the Stroop Test an psychological procedure used to identify ADHD. In the end, we assemble articles of ADHD children-directed projects of gamification, which contribute to the purpose of this work.

2.1 ADHD Features in Childhood and in Teenage

Science yet ignores the existence of physiological characteristics and symptoms that are associated with strong disturbances in frontal segment of the brain, a region that is responsible for many neural activities linked to attention and coordination movements. Its symptoms may vary a little. However, the American Psychiatric Association defines the DSM-5 the most usual like frequent failing to focus to details or excessive talking (Association, 2013b; Ghanizadeh, 2013). Some scholars believe its causes are genetic only, but others disagree in this point suggesting there are also influence of environmental reasons (Barkley, 2012). There is no consensus toward this issue. As causality of ADHD is not the subject of present graduate thesis, it is necessary to let this aside by now. In order to define more precisely, what the main features of ADHD are, one needs to recognize some aspects:

"The disorder is also reflected in impairment in will or the capacity to control the child's own behavior relative to the passage of time, that is, to keep future goals and consequences in mind. It is not, as other books will tell you, just a matter of being inattentive and overactive. It is not just a temporary state that will be outgrown in most cases, a trying but normal phase of childhood. It is not caused by parental failure to properly discipline or raise the child, and it is not a sign of some sort of inherent "badness" or moral failing of the child. ADHD is real: a real disorder, a real problem, and often a real obstacle. It can be heartbreaking and nerve- wracking when not treated properly" (Barkley, 2013).

In 2010, 10 million individuals with maximum age of 18 years old have been suffering with ADHD around the world (Leuzinger-Bohleber, 2010). At the same time, the consumption of psychiatric medicines to treat this disease has also grew intensively (Leuzinger-Bohleber, 2010). Although this psychological disturbance was first described by a German doctor early in 1790´s there is no permanent and 100% -efficient mean of treatment. In most of cases it is limited to exclusive use of amphetamines which are associated to severe side effects or may show itself inefficient at long run (Leuzinger-Bohleber, 2010). But its real extension could be even larger, because people usually do not understand ADHD main characteristics:

"ADHD is underdiagnosed in most populations, with 40–60% of such children in any given community in the United States not being diagnosed or treated. But most children do show occasional signs of inattention, over activity, or impulsiveness. What distinguishes children with ADHD from other children is the far greater frequency and

severity with which these behaviors are demonstrated and the far greater impairment children with ADHD are likely to experience in many domains of life" (Barkley, 2013).

In order to reduce the present way of treatment based almost only in drugs, some physicians and psychologists are suggesting alternatives, including ludic or playing treatments (Leuzinger-Bohleber, 2010; Randolph, 2012). But, how can one offer this by granting the quality and, at the time, targeting most of affected people at low costs? An reasonable answer lies in mobile computing. Nowadays, speaking only about Brazilian market (Brasil, 2014), smartphones and tablets are the majority of computing machines, about 150 hundred million, 90% of them running with android operating system, to a population of 200 hundred million people(Brasil, 2014)), and this may be the mean to achieve ADHD children with the lowest costs.

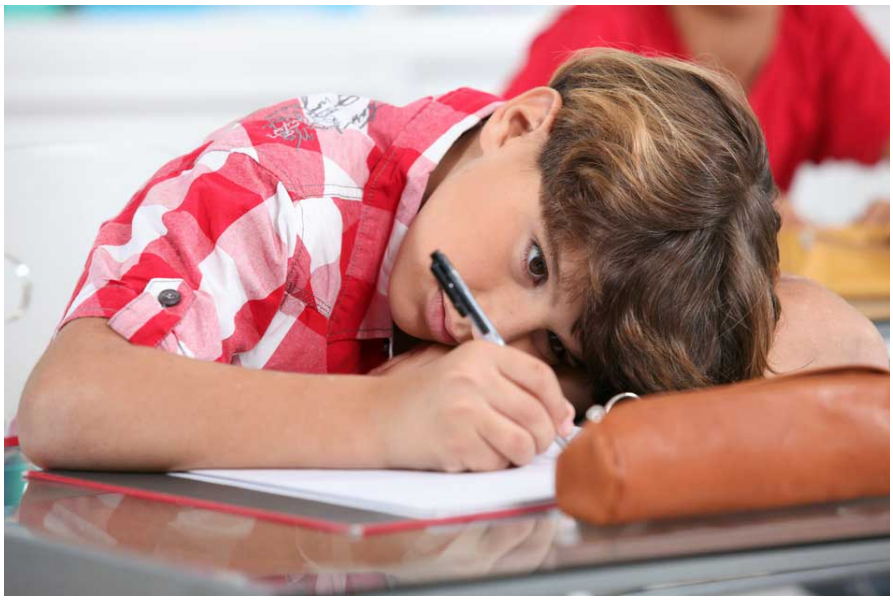

Figure 2.1 Situation common for ADHD children: their behavioral specificities generally affects negatively its academic capacities. They generally lose their concentration and use to sit without the regular posture to do their homework (Works, 2016).

These are the reasons to develop the proposed gamified application, Memory Stroop, which is designed for android mobile devices in order to offer auxiliary conditions to ADHD children. However in order to understand how the game really ought to aid ADHD children it is necessary understanding, firstly, the psychological paradigm in that the game was based, the previous games used on the same purpose that have been presented in literature and, finally, what is the paradigm of gamification used to sustain the game, the Stroop Test, subject of the next chapter.

2.2 Stroop Effect

The Stroop effect is a psychological phenomenon which happens when human mind and coordination enters in a state of delay in reaction time to perform some task upon conflicting stimuli condition, for example, reading aloud the name of colors written in different inks from the word representing color. Its name derives from John Ridley Stroop, the first psychologist to develop a solid theory about this phenomenon and to design tests for it, both presented in a scientific article in 1930's (Stroop, 1935). This test is still employed in many areas of psychology, sometimes with modifications like its Stroop-Gonden modality (to be explained more in the next section), particularly interesting for the present research. It is one of powerful tools to ADHD diagnosis and because of that the base of our gamified implementation.

Before John Ridley Stroop, many researches have tried to explain why the same person tends to perform similar intellectual actions (but with different inputs) in average times so distant. For example, in 1886 James McKeen Cattell published an academic study to show that someone lasts more seconds to say that an object was red than to read aloud the word 'red' on a card. But Stroop is appointed as the first to purpose an experiment mixing ink color identification stimulus with reading aloud a different name (MacLeod, 1991).

In fact his experiment has three stages well defined: neutral combination between ink colors and color names, congruent combination and incongruent (in figure 2.2 we see the last of three moments of Stroop original experiment). Each moment has its own characteristics and results as it follows. It is important to examine each one, for after, present general conclusions of stroop.

1. step: Neutral mixing. In this part, there is only a list of colors printed all in black ink, a neutral color. The intention is to store data performing time to read aloud all words for comparing with two other stages.

2. step: Congruent combination between ink and word. Neutral cards are substituted by cards with words printed with the same color. The average time to read aloud all words is shorter than in the first step. John R. Stroop explains this by the existence of semantic congruence between pure visual stimulus (color ink) and which facilitates mental activities. Years after, other psychologists substituted color names by sequences of colored 'X' characters in this stage. In this modified stage the test taker must say the name of color ink of sequence of 'X' characters. The congruent effect was, in the latter case, put aside.

3. step: Incongruent combination. This is the main stage. Now cards containing color word are printed in contrasting ink colors Semantic like the word ‘red’ printed in yellow color ink (any person should say only ‘yellow’ instead the written name ‘red’). The test taker must say only ink color names. Comparing with the average time in first step, the time in this step was drastic lower. This is attributed to an mental context of semantic interference between symbols and concepts by the author.

The general conclusions of three parts of Stroop’s experiment may be summarized in follow manner: congruent stimuli (ink name) could facilitate mental activities as conflicting ought to difficult their functioning. After Stroop analysis, a lot of authors have proved that people having attention disturbs and hyperactivity like ADHD children has a particular lower performance.

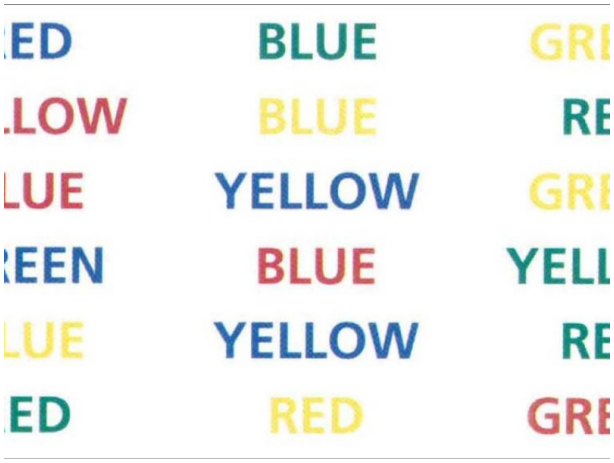

Figure 2.2 Example of the third stage of test of Stroop in its original form (Brabant-Dagblad, 2015).

Although there are many other applications in psychology, with this test, a psychologist or psychiatric can identify problems in attention, coordination, concentration and inhibitory control – typical problems of ADHD patients, who massively fail particularly in the third phase of Stroop experiment (Lansbergen and J. Leon Kenemans, 2007). Although Colors has some specific implementations, which are presented in next chapter, the game was inspired by the Stroop-Golden modality in order to identify and improve ADHD patients’ health.

We understands it is possible to use Stroop experiments not only to detect ADHD but also to treat that mental disorder. As MacLeod et al underscore, John R. Stroop was

aware of it: ‘Experiment 3 also explored the impact of practicing color naming on the development of interference in word reading. Comparison of a pretest and a post-test where subjects read words in incongruent colors showed that the intervening 8 days of practice introduced interference into word reading (from 19.4 s before to 34.8 s after), but that this newly developed interference quickly disappeared in a second post-test (22.0 s).’ (MacLeod, 1991). In this way continuous practice could benefit capabilities of test takers.

To achieve this end we have chose the Golden-Stroop modality of this psychological test. In this modality the test taker does not use reading name of colors aloud (a controversial feature for some authors (MacLeod, 1991)) and the tests are made in different approach of conflicting stimuli because there is a limited time of 45 seconds to perform tasks counting quantity of mistakes and successes (instead of mean time to perform the test, as it was purposed originally by John Stroop in his own version of test) (Golden, 1976). This approach is the basis of our application or, at least, of initial game levels of it.

2.3 Use of Computing for Play Therapy involving ADHD Children

There is a relatively considerable number of scientific works about play therapy directed ADHD patients, in particular, children. Some of them emphasize the importance of computing in diagnosis and therapy by coordinating computing and psychology. This graduate thesis follows these articles, besides none of the selected articles presents an application based extensively on the Stroop Effect paradigm discussed in previous section.

The relevance and role of games (not specifically electronic games, but in a larger sense) for treating ADHD in earliest ages (Leuzinger-Bohleber, 2010). In this article, it is discussed about the role of playful therapy methods, which are presented as effective alternative to strict medicine-based one. Although no mention to gamified application is detected in that article, we found useful theoretical foundations to play therapy in it. These foundations allow anyone to make some mechanisms to treat the ADHD-afflicted children.

In Brazil, computer scientists of Federal University of the State of Rio de Janeiro (UNIRIO - Universidade Federal do Estado do Rio de Janeiro) implemented gamified applications for the ADHD and subtypes diagnosis. The study involved a practical experiment with patients. Time and number of right acts were tabulated and submitted to machine learning algorithms of fuzzy logics, whose output classifications may identify ADHD behavior and type (Santos, 2011). However, there are no mention to the therapeutic

potential of its application as we are trying to do here. That work offer some basis to our application in the use of game features to extract diagnostics of ADHD children.

Other article uses a normal game, Pokémon, in pratical experiment with ADHD-diagnosed children and a control group of non-ADHD-dignosed (Shaw, 2005). Along several weeks, the playing yield was quantified and produced two interesting conclusion. First, all the time there is a distance in the quantity of every movement and right movements from two distinct groups is quite perceptible. This evidences a simple game may be used in diagnosis of the intellectual disorder, distance of scores is characterized among two categories. Second, ADHD children's scores are largely improved at the end of the experiment, assuring potentialities of play therapy (Shaw, 2005).

There are academic articles produced by psychiatric and psychological staffs, who emphases less in the algorithmic features of application and explore the neurological beneficial effects of using serious games, called also 'brain games', by children (Randolph, 2012). This study monitored the cerebral activity ADHD children and teenagers, of various ethnicities, during their playing of a brain game made of a famous enterprise. Its methodology was quantitative and its results show notorious improvements in frontal lobe of brain activity, associated with symptoms attention and hyperactivity disorder. We do not seek to employ any physiological monitoring during our experiments but it is important to keep in mind that eventual quantitative improvement in ADHD children scores in our game are related with this major neural context.

Lastly, there is another article (Olga Pykhtina, 2012) that uses the qualitative methodology employed by observing reactions of a fully gamified application, without levels or final aims. The child plays exploring a magic world – with many 3D landscapes and mechanisms – and can choose which way to follow and which activities, among many possibilities. Authors' intentions lies in the emphasis in developing creativity and coordination without frustration of too strict rules of playing. This application has some similarities with ours namely in their emphasis in design stimuli of interface, that in both cases was planned to let usability the most fanciful as possible (Olga Pykhtina, 2012). That work had influenced the present research in order to put more attention in graphic interface features.

2.4 Memory Stroop: Implementing a System to Explore the Correlation between Memory and ADHD

The proposed application is designed to treat memory complications of the studied disturb. In many ways, attention and memory complements each other, because mental concentration requires all mental functions working well, so far so good, two of main symptoms of inattention component presented by DSM-V, symptoms g. and i., talks about it: “g. Often loses things necessary for tasks or activities (e.g., school materials, pencils, books, tools, wallets, keys, paperwork, eyeglasses, mobile telephones). [...] i. Is often forgetful in daily activities (e.g., doing chores, running errands; for older adolescents and adults, returning calls, paying bills, keeping appointments).” Association (2013a).

Memory faults are common in patients’ daily life, mainly the working memory, which is defined as memory of related of coordination and execution of immediate tasks, but not only of short-term duration as prior studies emphasized, according to relatively recent approaches (Baddeley, 2000). There is evidence that training mental skills could improve working memory of ADHD children (Hilton, 2009). In this way, the proposal of gamification in this graduate thesis combine a common memory game engine with the Stroop Effect colors scheme. The psychological literature has indicated the application of Stroop Effect to working memory, but without an approach of gamification (Prat, 2002). By combining them, it is possible to train working memory. More details about the proposed gamification lie in chapter 4.

2.5 Summary

As a serious psychological disturb which afflicts millions of children, teenagers and even adults around the World, ADHD requires more and more resources to combat its symptoms and improve damaged skills and life conditions of its patients. The Stroop Effect and correlated Stroop Test are relevant measures of identification for attention and hyperactivity problems. As the working memory is a core mental skill affected by ADHD, the coordination with memory and attention must to be trained.

3

Commercial Games, Serious Game and Gamification

In this chapter it will be discussed the theoretical basis of gamification concept. First of all it is necessary to answer some short, but also difficult, questions: what is a game? Every high-interactive and imaginative application is a game? Which are the main applications, features and types of gamification? Authors of many knowledge areas have tried to find a good response in this way, from history to economics, through the game theory and other interdisciplinary fields. None answer among them is consensual. Here, it will be drawn a conceptual sketch of game mixing many points of view from related areas, including psychological treatment of ADHD children.

3.1 Concept

There is also other important question: what is 'gamification' and which are its implication upon heath computing? Kate Kelland defines: 'Gamification [is] turning boring, unpleasant but necessary tasks into an online game - is a new way of thinking that is gaining momentum among drugmakers and health campaigners' (Kelland, 2012). Although not necessarily such a gamified application must to be 'online' in sense of an web application, Kellandb's definition offer a good comprehension of what is gamification and which are its benefits. In this section it will be discussed not only the concept but also types, features and applications. In short, Gamification is the application of game elements, like interactive electronic mechanisms, for the non-gaming purposes in order to conduct users to make certain activity or set of activities more pleasant and funner (Deterding, 2012; Huotari and Hamari, 2012; Zichermann and Cunningham, 2011). Repetitive and boring actions or set of actions are the main targets of this process. By creating gameful

scenarios, is possible to turn them more entertaining and permits that users to perform these actions for more time and with better performance (Deterding, 2012; Huotari and Hamari, 2012).

Relatively recent academic works like (Burke, 2012) show gamified applications as a powerful tool used by larger companies' business strategy today, targeting, mainly but not only, consumers and employees. For example, gamification is used to attribute a fun to traditional management systems, offering pleasant tasks for workers in gamified applications and showing scores of gamers/workers in funniest way (symbolized by bright stars, medals and trophies in a raking). The results are astonishing. Gaming atmosphere promotes more acceptation to usually described unpleasant tasks. When a corporation collaborator becomes a 'gamified' player, he may encounter various stimuli for developing his own pro leadership capabilities, creativity, protectiveness, cooperation and work together (Zichermann and Cunningham, 2011). It occurs because individuals tend to be more engaged in a context of active participation (proper of gamified systems) than in a passive and boring environment (MEDINA, 2013).

3.2 Place in Gaming Taxonomy, Subtypes and Variations

Some authors (Deterding *et al.*, 2011) have also characterized the said concept as the use of game design and resources in non-game contexts. It's part of a larger process of ludification of culture, not only by 'digital' means, but also by 'analogical' ones, as presented in Figure 3.1.

Kelland's definition contributes largely to aims of this research, but, before developing more consistent argues to associate 'gamification' and health services, its necessary to explain differences among normal games (toys), serious games, playful design and 'gamified' applications. Considering division only of the vertical axis of the figure 3.1, serious games and toys have both a entire narrative or trajectory of playing acts, compounding a whole. On the other hand, a gamified application and an application with playful design are both planed to perform short tasks, in a particular approach. And then considering horizontal axis, on the plan of gaming, gamified application are close to serious games because both are focused on developing intellectual capabilities more the simple joy, as games and toys are. Colors is an authentic gamified application, but, to simply communication, it is often referred to that as a 'game'. The class of gamified applications includes some subtypes. Some authors suggest it can be divided into three subcategories:

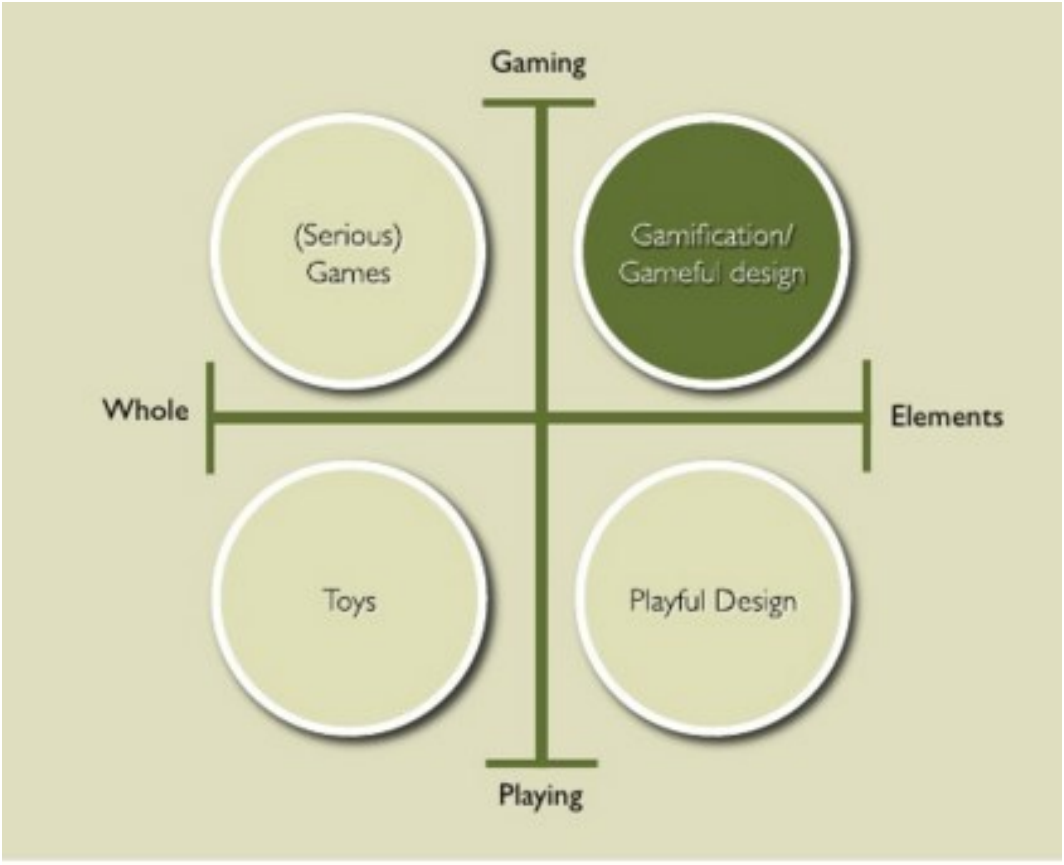

Figure 3.1 A topology of interaction of game-like applications according to its proposes. From (Deterding *et al.*, 2011) and slightly modified by Ordas (2016).

1. **Product gamification**: this subtype groups any game-like software designed for attracting the final user in his personal life without a collective or a corporative dimension. That's why it is called **product** gamification, because it is designed to be used by a single person. Colors' gamification may considered as one of this subcategory.

2. **Marketing gamification**: then, when a gamified application targets a entire public of customers, it should be called a process of marketing gamification. The application end is to provide information, brand promotion and satisfaction for potential or usual customers of some enterprise. Today more and more organizations employ this subtype of gamification.

3. **Workplace gamification**: finally, some game like-systems are designed to ameliorate working relationships at office. Bonuses, fun challenges and cooperation are

general aspects of it. As it will be shown, civil engineering is one of sectors that seems to increase productivity by using of this type of gamification.

3.3 Elements of Gamification

This process becomes an overused term in computing but sometimes it is applied without the needed scientific rigor. So that it is important to underscore which are the aspect necessary to apply the term to a information system or computational solution. Some of them may be seen as accessory, however, it could sketched a abstract model of gamification essential components. There is also elements that differs the so-called 'bad gamification' of simple gaming from the effective gamification, that could be summarized in the following main features (Yamakami, 2013):

1. **Goals**: the player must to have clear objectives to be achieved. On the contrary, the gaming tends to be not useful for constructive purposes and the player's performance never could be measured by a single principle. A gamified application ought to have one general aim in order to be acceptable in such category.

2. **Rules**: besides the aforementioned requirement of having at least a single aim, a gamified application requires some valid ways to achieve the goals in opposition to prohibited means. This is possible by a defined set of rules. Generally, gamified applications use to present and teach each one of their rules basing on tutorials, tips and helps. Common games not always follow that point, because sometimes it is interesting for players the process of discovering the rules.

3. **Feedback system**: this feature is required only by gamified application and by serious games in comparing with common or commercial games. The application must check if it has effectiveness targeting its with the public, because it could not be used only by pleasure and be deviated from its original purpose. The feedback process happens both automatically and by human-made intervention.

4. **Voluntary participation**: if a gamified program has obligatory and imposed an aspect by authorities, the player will not show any compromise with it. Furthermore, the gamification is chosen, as it was said before, to turn boring tasks more pleasant. So, it will a contradiction to impose something designed to transform negative stimuli in positive reception. People could simply prefer return to their functions as they have been designed before the introduction of the pretended gamified application.

The combination of these four characteristics compounds a gamified software. If one of them misses, the application maybe a serious game, a toy or a commercial game, but it could not be classified as a gamified application. These considerations will appear one more time when it was discussed the design of the proposed implementation in the next chapter. The proposed application, *Memory Stroop*, regarded isolate, is a serious game, but when their results are used to check patients' performance by its statistics (whose content is provided by the application proper), it integrates a gamification process, because the gaming will be employed as a mean, as a part of total therapeutic process. Another way to explore gamification essential features is best to show potentials of gamification, as the following figure 3.2 presents a table with game elements that generally match to human desires (like altruism or reward), suggesting the correlation between gamification demand and its possible uses.

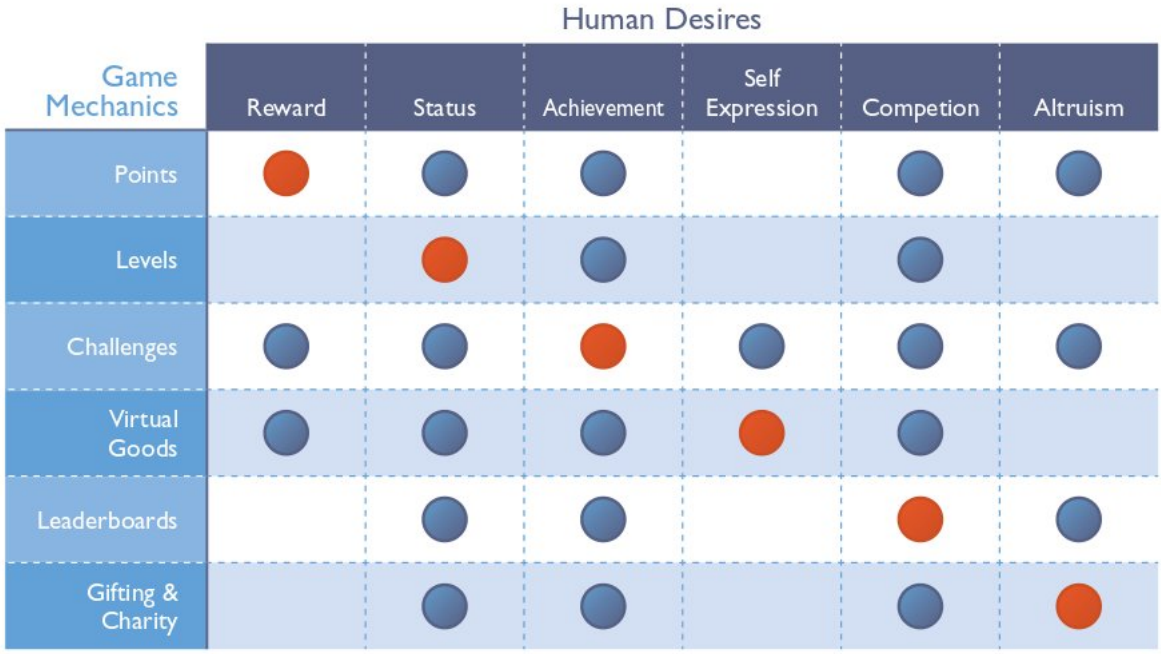

Figure 3.2 Gaming aspects and human desires (Bunchball, 2010).

Both approaches are equally useful for the main purposes of this research. Colors apply all of these features in its gaming structure in order to implement a full gamification process. The combination between human desires and gaming features is the mechanism which allows the main aim to bring ADHD diagnosis and treatment more pleasant.

3.4 Real Life Cases and Related Work

Gamification is employed in numerous fields, from construction to psychological therapy. In the case of civil engineering, gamification is part of a deep schema of innovation and investment in technology. By using 'gamified' features it's possible to manage activities of labor force, raw materials, plants and other variables of construction, workers can fun themselves with the job without being aside of it. Productivity and satisfaction could be measured from workers' performance in 'gamified' ranks (Formoso *et al.*, 2012). In 2012 the government of Texas, United States, adopted the a gamified system for security monitoring. Before that the Texan public security only monitored the streets by conventional cameras recording activities in streets and by police surveillance, as it is usually performed in all places around the world (Aud, 2013).

However, after that year introduced a system of security gamification with rewards, rankings and fun-like challenges to reinforce participation of the policemen and of population on monitoring tasks. It was conceived as event-trigger system, by which some criminal occurrence or suspecting acts are regard as a game. Some reduction in violence taxes are registered after that and, according some evidences, this reduction is related with the gamified system (Aud, 2013). This is a very uncommon use of gamification, that shows the potential offered by that technique. With these basic concepts and instances, can understand how Gamification systems, independent of its application area, could benefits humans in doing unpleasant or iterative tasks, offering them the possibility of perform these tasks as if they were not 'performing' them directly, instead they act as if they are playing a game with real consequences, for example, for its health care.

There is a significant set of scientific works discussing gamification solutions applied to ADHD children. To starts, an article written by Johnstone et al. (Johnstone, 2013) evaluates ADHD children neuoral activities along some monitored video gaming sessions and presents evidences that monitored playing. The gamification employed by those articles is based on a specific playing software that implements the notion of cognitive training, by which cerebral tasks are stimulated continuously and progressively (like the logic of "levels" of commercial games) in order to improve child's attention or other mental skills in a almost non-invasive or minimally-invasive way. Using electrodes in a classical Electro-Cardiogram evaluation in each session, the reduction of concentration deficit's symptoms are statistical significant in their study, what reveals the potential of gamification treatment for ADHD young patients.

Similar method and results are found in another interesting paper (Nemeth, 1997).

In fact, that paper is earlier and pioneers some aspects to medical gamification. That work presents how a therapy by gamification for ADHD children and teenagers may have advantages comparing to drug-centered treatment. They argue that effects of their gaming intervention group has more effective impact and are more permanent than the exclusively psychoactive substances treatment of their control group. So, authors conclude that gaming therapy must gain space in academic studies and, consequently, in clinical psychology. Another space of gamified ADHD child treatment is the school. In this way the work of Izaltino Oliveira (Oliveira, 2014), Brazilian psycho-pedagogue and research, that designed a conceptual model centered in ADHD educational intervention based on gamification. Author says that gamification is one of most powerful tools for younger students in order to develop concentration, mobility and other skills damaged by attention disorder or hyperactivity.

Some authors have stressed relationship of the use of gamified software both for diagnosis and for treatment. It is a total non-invasive method to identifies, and sometime, to treat symptoms related to psychological disorders. There are games of famous corporation like Nintendo, with its NDSBA (Nintendo DS game Brain Age) game among institutions developing brain games directed to hyperactive young people. Unfortunately, so little number of programmers are engaged in this type of medical computing initiative. For that reason, all initiative in this way must be seek anterior work which build new implementations.

> However, based on the literature, it seemed feasible that playing brain games such as NDSBA could stimulate the prefrontal cortex of students with ADHD, simulating the effects of stimulant medication, thus helping these students improve their ability to engage in classroom activities and perform tasks of executive function (Randolph, 2012).

Letting aside, by now, physiological details, the quotation informs about the importance of gamification in treatment of ADHD. Sérgio Villa (2014), a Brazilian computer scientist, developed an educational game for android devices and presented it in an undergraduate thesis - both game, Villa's remain paradigmatic to present research.

Villa's game is called in Portuguese "Cores Beta´´, *Colors* -, which applies Stroop's test principles in order to exercise mental capacities of ADHD children, like low tolerance to frustration.

As Villa (2014) could not develop statistical research with children using his game by himself due difficulties evolving Ethics Committee of Universidade Federal da Bahia

– likewise it happened to the present research –, its necessary to develop and present the computational facilities involving them to check its validity. Different to ordinary games are not projected to this aspect and majority of them may not offer good results for promoting health to the referred children.

This undergraduate thesis aims to discuss and to present results obtained in practical experiment involving psychologists and computer scientists using principles of "Cores" for evaluate its psychotherapy possibilities. All applications proposed for ADHD children up to now do not exploit enough the potential of working memory training. Generally they emphasize the reflexion tasks by which the player must answer to a game assignment correctly in the shorter time as possible. The present application is directed to train memory, not only to measure reaction time to an assignment.

3.5 Summary

In this chapter it was presented the core features, elementary characteristics, finalities and uses of gamification. Briefly it can be described as follows: video game features such as amusing competition and ranking with prizes, gaming levels, playing design, music and so on are used for it purpose. Gamification combines a serious aim, for example a child psycho-pedagogical treatment, with a playing and entertainment framework, what could present more effective results than conventional ways of the serious aim. Almost all daily activities may be treated as at least potential applicable area to gamification. Although gamified systems represent a very recent approach on Information Systems studies, there is a large space of opportunities by using them.

Generally it is seen as a powerful mean to turn heavy tasks into a pleasant design for its agents, this process has a large set of application, from management and finances to health. Then, it becomes more and more studied and practiced around the world. In the specific case of young patients that suffers with attention and concentration problems gamification may offer a confident and safer alternative to exclusive drug-based treatment (Nemeth, 1997).

4

MemoryStroop: Concept, Design and Implementation

In this chapter, it is presented the guidelines of the implementation with the requirements' analysis, the technical aspects of its development, and the general work (this research is only presented in the next chapter, 'Experiment'). After presenting requirements' basis as it was indicated in previous chapter, it is time to consolidate for validating it with its targeted final users, in this case, ADHD children. As underlined before, a gamified application has to deal, to balance funny features with serious aims in order to turn practical but awful tasks more pleasant. This is the main principle of this thesis, that can be shown in every section of the present chapter, where it could finally evaluate the core features.

4.1 Introduction and Requirements

The requirements are based in the psychologists' perceptions about a another gamified application for ADHD children and in an idea collected from a scientific article of Psychology. First of all, it is necessary explain the fundamental contribution for the present work.

4.1.1 Requirement Prospection

It was pointed out, mainly by psychologists' opinions, some necessities have to be achieved. In general they approved it and they had critical look on the working of the described software as meaningful treatment. In general they approved and viewed with good eyes the use of the said software as mean of the treatment. But some of

them manifested the following points for improving in newer version of software: first, the gaming has too much conflicting stimuli in some of its levels, secondly general performance report is needed and thirdly moving targets the player. Understanding the former application, it is possible to draw similarities and contrasts with the present application. In summary, most of ADHD games implement gaming centered in matching (like the third step of test of John Ridley Stroop (shown in Chapter 2), but more influenced by Golden Stroop modality) of a color's name to an ink but most of times in a situation of conflicting stimuli, mainly a conflict between the color name and its background ink. Along eight levels the player/patient executes progressively-difficult tasks, from the simplest matching of a color name and its ink to a difficult scenario with a series of adverse stimuli in the last level.

4.1.2 Defining Requirements

A general score with the responding time and hit rates was implemented to the satisfaction of the requirement expressed by the some psychologists that evaluated another application (Villa, 2014). Then the following requirements systematize and consolidate their impressions, according to some strict software engineering paradigms, including the functional and non-functional ones. The latter was disposed according to the patterns of ISO9126's norms (ISO 9126, 2003).

Number	As a <role>	As a <goal>	As a <result>
1	Player	access game	select new game
1.1	Player	give the name	write his/her name
1.2	System	generate board	dispose 'Stroop' memory cards
2	Player	seek color name combination	pass levels
2.1	System	manage hits and mistakes	improve difficulty slightly
2.2	Player	advance levels until the end	conclude gaming
3	Psychologist	see statistics	must store and see player's name and numbers

Table 4.1 Table for the all functional requirements

The functional requirements comprises each of game events and human interaction with the system. The are presented as user story-like requirements formatting as way to be more readable by some of the practical 'stakeholders' – the psychologists. The first require They will be verified on Chapter 5 alongside the presentation of the practical research with computer science specialists.

4.1.3 Technologies Applied to Software Development

The working technologies are only the basic infrastructure for software development. The codification of this mobile software was made in Java programming language driven by an Android mobile operating system. It was used the Android Studio framework in version 1.5.1 for the development. Implementing gradle, the package manager for android projects, and some other frameworks too, the lint prototypes checker and OpenJDK 7 (Java Developer Kit) for Java programming language infrastructure on a Debian 8 (Jessie) operating system desktop for development. [1]

What differs from traditional Java for desktops or other mobile platfoms is that Android has some specific functions, like: Calling device resources or sensors. And it runs in another virtual machine than common Java called: the Dalvik Virtual Machine. Android has a stack of operating system levels, beginning from Linux kernel, passing to a device-components layer and other levels until the graphic user interface domain. Which you can see in the Figure 4.1.

The Android environment was chosen especially, because it is currently the most used platform around the world. Particularly in Brazil, where this study was designed, and most of 80% of mobile devices are based on Android, which I mentioned earlier in the introduction. The native application approach, compared to other types of hybrid approaches. Like cross-compile one, was here used to explore all of its possibilities from native devices standard computational resources. In this way, it will be so difficult to develop many native applications driven for each mean mobile device's operating system, like IOs or Windows Phone, because it's demanding more time and resources than a single coursework subject could afford.

The present application was designed for Android, to achieve a greater number of potential users. But the experiment, which was designed for this research. It only comprise a controlled, reduced group of people, because the software is an experimental application. Although there are other versions offered for free in the App store from Google, none of them seems to train working memory skills, which containing dozens of millions of mobile applications with the most different finalities, but the platform from Android is more accessible for developing, compared to platforms like IOs or Blackberry. Because these systems need a considerable number of environmental requirements, which is an exigence of a Mac computer to program in Objective-C or Swift (programing languages for applications in IOs). This turns programming more difficult to be achieved

[1] Although Google warns that using Open JDK instead the Oracle proprietary JDK may let problems to application, but there are no problems related to this in the application.

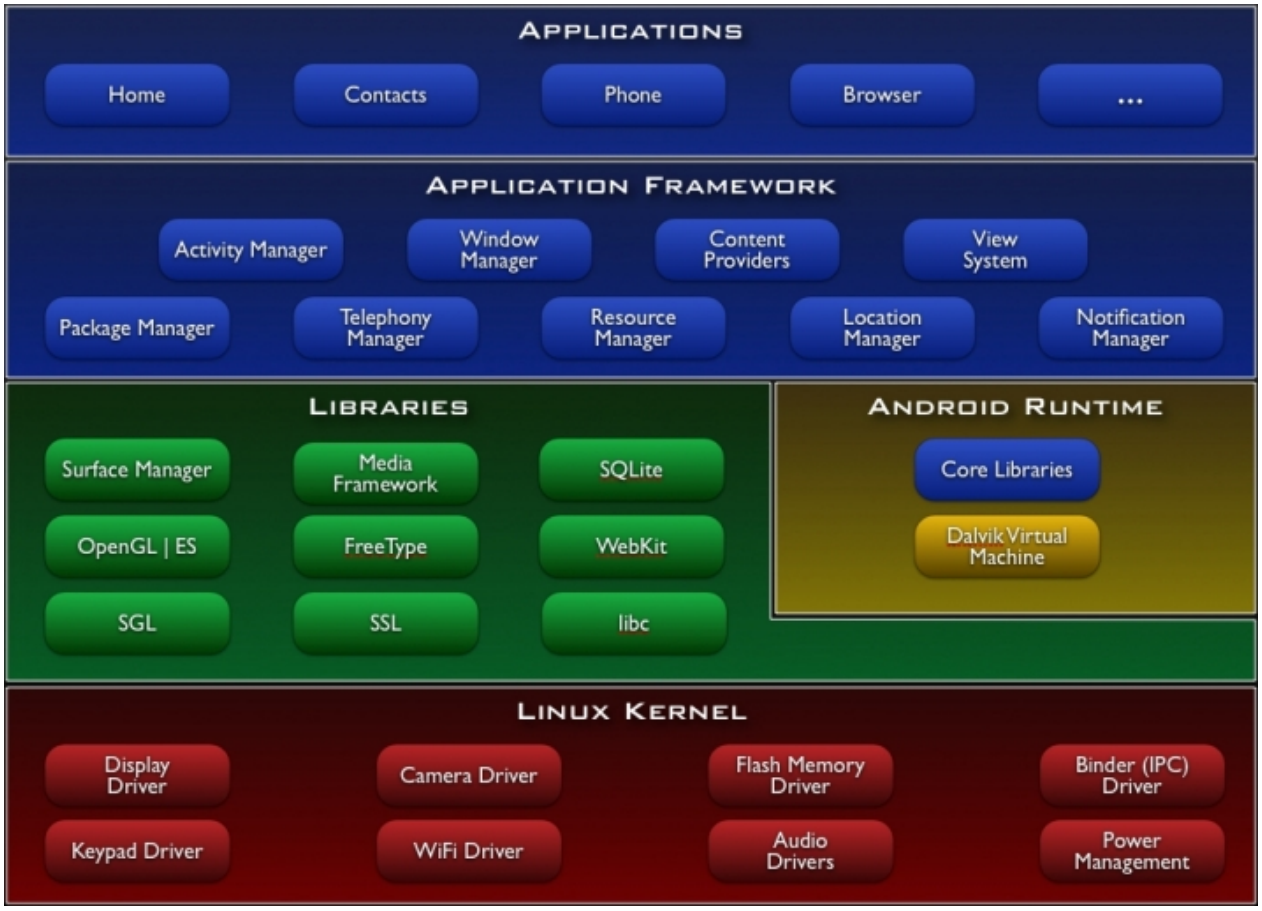

Figure 4.1 Android Operating System basic layer structure (Fundamentals, 2015).

during the time needed for concluding a undergraduate thesis.

There are a couple of reasons to adopt the Android environment for developing the application of this research. Mainly because of its popularity in Brazil and the relative practicality for development. The application is compatible from Android called 'KitKat'(version 4.4) to the most recent versions (the most stable recent version in this moment is version 6 called "Marshmallow"). Which yields a compatibility ratio of 74% of Android devices on a word-wide perspective, according to recent data (Android, ????).The implementation also is driven to treat different resolutions of devices, using scalable images and other strategies, as it will be discussed soon. In this case, tablets and smart-phones with different dimensions like Galaxy Nexus or Moto G and son could run as well the application presented here.

To develop the game core features, the Libgdx Java library engine was used. This is a free software engine that allows anyone to program simple games in 2D or 3D for various platforms, including Android. The proposed application 'Mememory Stroop' is combining Libgdx to android native code and has proper guidelines for this system. Libdgx offers a large set of facilities to develop games better for Android. Maybe the most important thing is: Its simplicity of operations, their basic project's architecture and the by both shared high integration Java programming language: Syntax and so on.

Additionally, Android Studio IDE could easily manage Libgdx projects with gradle and implement extra native code as well. Furthermore, this Java game engine has powerful resources to implement: Game textures, sprites, events, loops, input-getting, abstract and non-abstract screens, and other features that let game development and gamification more accessible to non-specialists in that area.

4.2 Application Architecture

As mentioned before, other ADHD gamification apps comprise multiple conflict situations in a game that appeared undesirable to some psychologists. So these extensions sets of conflicting mechanisms was replaced by only two conflicting stimuli: The classical Stroop Test, and a fixed memory game board, in order to promote a more focused set of stimuli. It was added in the present application. That is why the application is called: MemoryStroop. [2]. All negative stimuli that remained on previous version, like "game over" event, are put aside: only positive stimuli such as commemorative music effects

[2]From many memory game approaches, the present application follows as a improved fork of Mathias Lux proposal avalaible in https://github.com/dermotte/memory-game-android and licensed by Apache 2.0 license.

are implemented, no negative stimuli at all. The application class model is shown in the figure 4.2. and explained next.

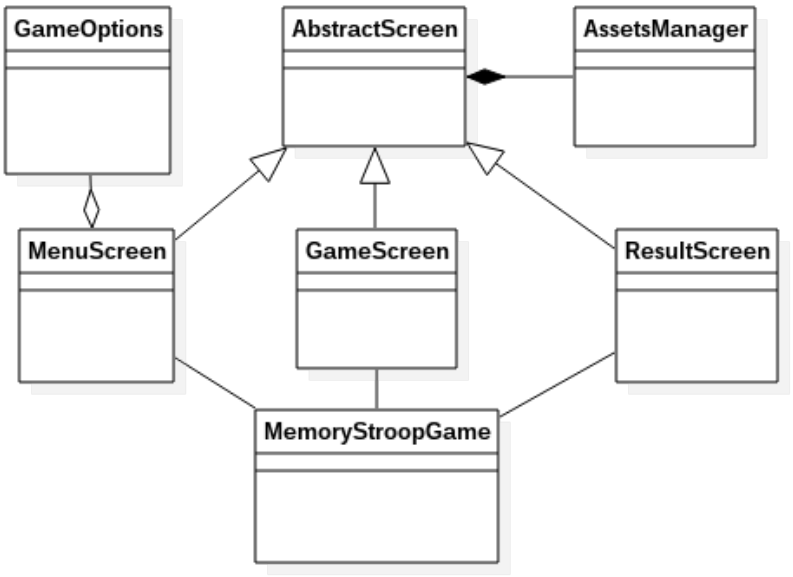

Figure 4.2 Elementary exhibition of class diagram using StarUML tool.

The main class is the MemoryStroopGame, in which the engine is put in a loop to provide touch inputs and manage each reaction of game features like right or wrong card combination, level changing and so on. The screen classes are extended by a abstract class that defines is their common attributes and methods. The class GameScreen receives touches from tablet or smart screen and sends them to the MemoryStroopGame class. Besides it is possible see the game implementation's architecture of Libgdx Java classes and extra native android class, that implements TXT exportation of game statistical data. This functionality is called by a separate android java class that is not shown on main diagram. *Memory Stroop* game is not designed to be played lonely by the young patients but instead this it is designed to be played in monitored way, in which the psychologist may observe actions and after child playing see the statistic results. This process is drawn in the following figure as sequence diagram 4.3.

4.2.1 Game Workflow

The first screen of the game is the main menu, after that is the main menu, in which the player could switch off sound effects or consult the credits.

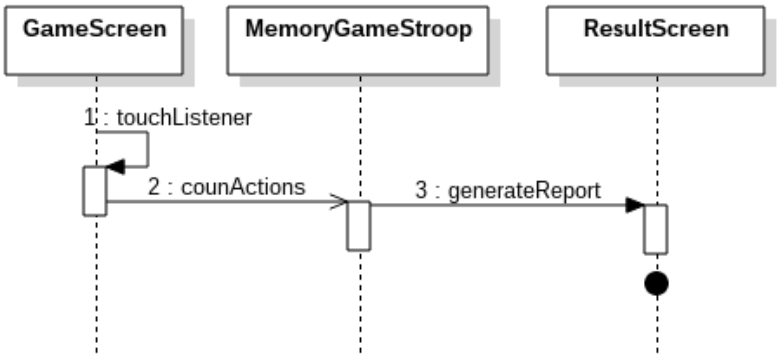

Figure 4.3 Main flux of game loop in a sequence diagram using StarUML tool.

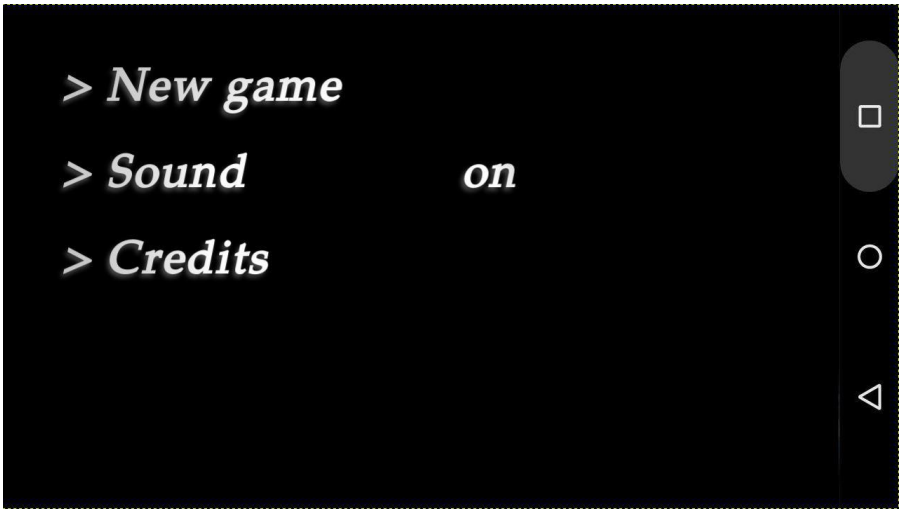

Figure 4.4 Main menu.

After selecting new game option the player is asked to fill its name and the first level begins. In the first level some cards has some figures of fruits or cars to facilitate to children the understanding about how to match 'Stroop Effect' Cards in this and in the next levels. In this level the Stroop cards has only a white background to facilitate even more. Figure 4.5 shows the image of the level 1 with the commemoration message that appears when players win.

Figure 4.5 Level 1.

The second level increments the difficult by removing images. The number of cards is maintained. Figure 4.6 exposes this second level.

The third level become more difficult by the increase of card quantity, and, sometimes, the background color of cards became different among them randomly, but after matching they return to the normal white background. Figure 4.7 exposes this third level with 18 cards.

The fourth and last level only increment the quantity of cards. Figure 4.8 exposes this third level's cards on the moment of beginning of cards distribution, 32 at total.

4.3 Summary

The point was to explain the following aspects: The computational settings and the implementation of MemoryStroop. The first necessity referred to the definition of requirements (this came from a previous application and research) evolved improving some of the main features of other application presented to the psychologists for this

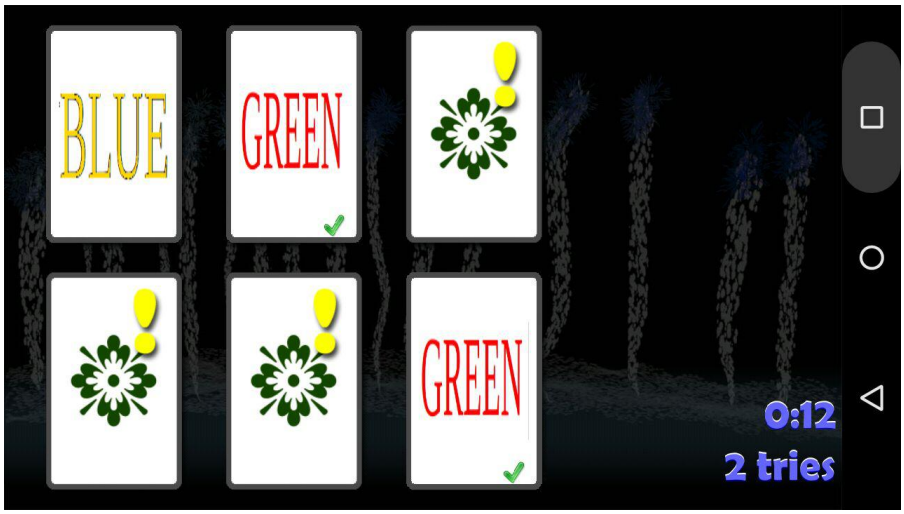

Figure 4.6 Level 2.

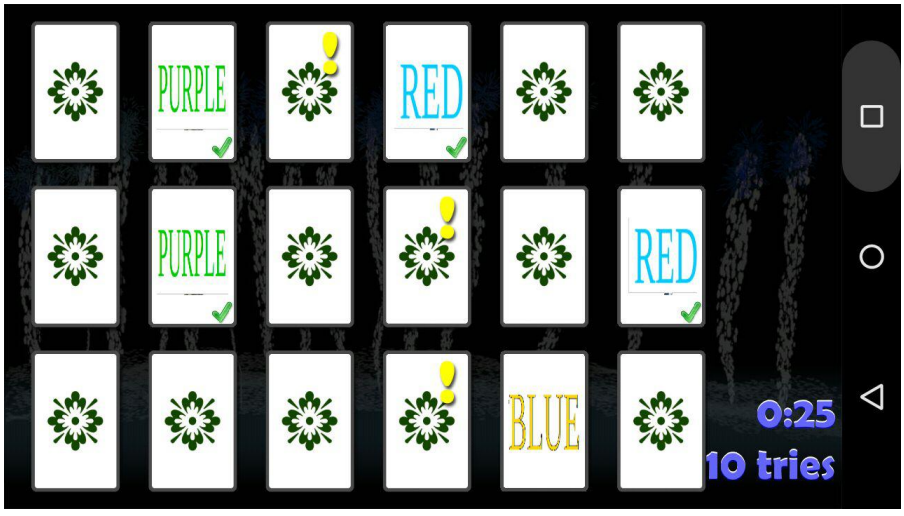

Figure 4.7 Level 3.

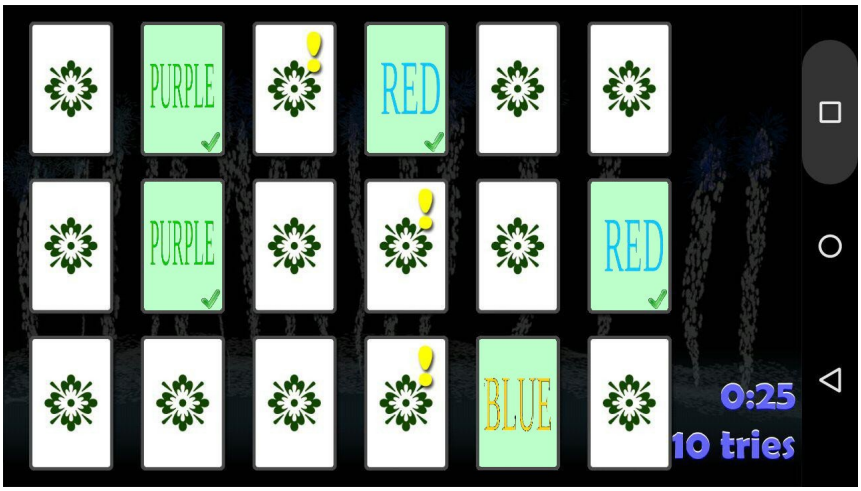

Figure 4.8 Level 4.

application and research. The main requirement of those psychologists was the necessity to offer a limited set of conflicting stimuli in the Stroop Effect during the game. In short, the functional and non-functional requirements that includes all implementations. At the last point, the architectural and practical engine of the gamification was presented to the reader.

Number	Requirements	Quality in use
Functionality		
F1	The player should have a single flow to interact with game screens	Consistency of Interface
F2	The system should furnish statistics of each level separately at the end of game	Consistency of Interface
Usability		
U1	A new player should be able to use the system after less than 5 minutes training	Learnability
U2	The system should be perceived as easy to use by the majority of its users	Understandability
Maintainability		
M1	The system should be easy to extend and modify	Changeability
Portability		
P1	The system should run on the majority of used Android devices without additional resources	Installability

Table 4.2 Table for all non-functional requirements

In following subsections, it is presented each one of the non-functional requirements. They will be checked in a practical experiment involving computer scientist in the chapter 5.

Non-Functional requirement F1

The first of all non-factional requirements F1, as well the second one, implements the norm of Consistency of Interface, that is a measure of quality of the good fitting of elements in interface according to principles of ISO/ISEC 9126 norm and some of Nielsen's heruristics ISO 9126 (2003). To be consistent implies that some design should produce ideas or prospect of actions which are coherent with the expected actions to be done in it.
Because of that, it is desirable that the game's interface does not confuse players with other activities than the correct card matching. By analogy to defines metrics of ISO 9126 (2003), this requirement achievement could be expressed by a high score of positive responses in the survey question (1 and 2) of the practical experiment in 5.

Non-Functional requirement F2

To satisfy the well data visualization for the secondary actor of system (the psychologist), it is necessary furnish him/her a consistent layout of statistics of each level separately. As the previous requirement, there are questions (3 and 4) in the practical survey to evaluate that feature.

Non-Functional requirement U1

This requirement is about the easiness of learning the game. The player must fast get know about how the game proper engine works in the shortest as possible time interval, in this case, five minutes. To check this requirement, two questions in the experiment (5 and 6) were directed.

Non-Functional requirement U2

After the problem of time of learning, the current flux of gaming should be easy to understand every time, i. e., the player should feel easy to understand the new challenges of other levels. This requirement

Non-Functional requirement M1

The code should be evaluated and incremented by the community of programmers. Because of that, all software artifacts need to be accessible in all ways for the community. This requirement could not be tested in an usability survey.

5 Experiment

After presenting theoretical basis and the application's development in previous chapters, it is time to evaluate *Memory Stroop* with specialists. A gamified application have to combine pleasant tasks and serious aims in order to turn practical but awful tasks more pleasant. This is the main topic of the experiment, that can be shown in every section of the present chapter. First it is presented the applied format of case study, after that the questionnaire, following it the results and finally discussion.

5.1 The conduction of the experiment

The quantitative and qualitative research does not involves data of children, only survey data about usability analysis measures. No personal information was collected and, because of this reason, there is no necessity of submission to University's Ethics Council. The questionnaire contains items about viability of gamification, simplicity/complexity of tasks and so on.

It has been performed with five computer science specialists, in May 2016. The general profile of the answerers involves people of both sex, at age of 25 to 32 years-old and with a professional background on mobile programming. There is no randomization or other advanced techniques in composing the sample: it is a common convenience sample. Data collection is made by a written survey shown above. All sessions last 20 minutes, are monitored physically by the author, happens on the students' computer sciences laboratory and consist in three activities as it follows: the author's briefly explanation, the answerer's playing and finally the answerer's respond to the questionnaire.

The identities (names and other personal information) of specialists are protected by identification numbers (IDs) on questionnaires in order to avoid over-exposition. For each automated monitored playing, the respective ID of the user is stored in the header of

common data. In this way, it is possible to track each monitored playing outcomes with the child without employing its name or other specific data. The collected data offer three utilities:

1. Validate the implementation with experiment evaluators;
2. Verify the gamification effectiveness;
3. Collect information for improve the application in newer versions.

5.2 Heuristics and usability evaluation

This questionnaire is derived from some questions proposed by Song and Lee (2007) in its game-playing heuristics.

1. Is the visual feedback, such as their status/score, and visual cue clearly presented?
2. Is the audio feedback, such as the audio cue adequately provided?
3. Does it help that interactions with other characters or targets are analogous or similar to real-world situations?
4. Do you feel in control of the actions occurring on the screen?
5. Are consistent Names/Information/Structure/ Representation being provided?
6. Are instructions for the system retrievable within the game?
7. Is help needed to engage in game play displayed through a tutorial?
8. Is it easy to learn at the beginning of the game?
9. Is it hard to master the game?
10. Is the play between gamers fair?
11. Are the outcomes of the game not predictable?
12. Does it provide variable difficulty levels that are suited to all levels of gamers?

Song and Lee (2007)

5.3 Summary

In order to verify the proposed application's viability and core usability facets, it was performed a case study survey with computer science specialists that work on mobile programming. Only functional aspects were evaluated by a survey involving these specialists. That shows an evolution on gamification and other functional and non-functional in the current version of the project.

6

Conclusion

ADHD challenges in contemporary society beyond common diagnosis and treatments include a fertile soil for gamification like *Memory Stroop*. It is designed as an Android mobile game for diagnostic and therapeutic processes that combines tasks for detection and correction of working memory defaults common for ADHD children. It was possible see has its functional and non-functional requirements comes from the evaluation of a previous ADHD application and validated by psychologists, who let important considerations for the present project. A practical evaluation was performed with computer scientists, and show the positive aspects and negative aspects of implementation.

Thus, the present gamification project has laid foundations for other studies that want to combine gaming and serious purposes. As other fields, for example, civil engineering business and human resources division of certain company, gamification in ADHD diagnosis and treatment of memory ADHD malfunctions is a good issue for Psychology/Psychiatric, Computer Sciences and Pedagogics. Gamification is a promising field of Information Technology & Systems, converting so-called unpleasant tasks into more agreeable activities presented in fashion of video game characteristics.

The Stroop Effect consists in a concentration fault to target correct objective such as saying a color written name instead to saying another different color name ink that lies on background. This conflicting stimuli is precisely feel for ADHD patients, because they present a relative lack in their memory functions.

After basing the theoretical fundamentals on correlate works, that stressed the importance to offer alternatives less invasive to the common ways of treatment, this graduate thesis has presented how gamification can help ADHD children and teenagers with simple but considerable initiatives.

6.1 Future works

In order to increment the potential of the gamification proposed on Memory Stroop and offer it as a future mean of diagnosis and therapy for attention related it is necessary to sum up some core aspects that turns the application usable and medically effective. The following list include newer features, research aspects and implementation resources to be achieved:

- Monitor cerebral activities during game sections in further studies using *Memory Stroop*, by which it will be possible to trace neurological evidences that could corroborate the gaming therapy proposed here;
- Develop the practical research as a really quantitative research with human beings, having 50 or 100 young people by double-blind randomized sampling and examine a high quantity of variables with machine learning algorithms in a Knowledge Discover in Database approach;
- Perform a improvement in the game graphs, sound effects, engine and other usability features;
- Improve application portability to other mobile operating systems than android or desktop platforms;
- Contribute to the formation of a group of study on ADHD gamification treatment including researchers and professionals of many areas, namely, Computer Sciences, Psychology, Medicine and Pedagogy.

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