“MEMORYSTROOP: A Mobile Game Designed for ADHD Children”

By

Vinicius Lins Gesteira

Coursework

Federal University of Bahia
ceapgmat@ufba.br
wiki.dcc.ufba.br/DCC/

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Federal University of Bahia
Computer Sciences House
Information Systems Collegiate

Vinicius Lins Gesteira

"MEMORYSTROOP: A Mobile Game Designed for ADHD Children"

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Adviser: *Phd. Frederico Durão*

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Acknowledgments

Abstract

This paper approaches the use of a diagnosis and therapeutic game for Attention Deficit Hyperactivity Disorder (ADHD) young patients in Salvador, state of Bahia, Brazil. 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 the proposed game and improvements in attentions level measures of the disease, following Stroop test paradigms. The methods employed consist in statistical techniques in order to inquiry validation to the aimed hypothesis.

Keywords: Gamification, Mobile Application, Hypothesis Test, 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
DSM-5	Fifth edition of Diagnostic and Statistic Manual of American Psychiatric Association's
IDC	International Data Corporation
SVG	Scalable Vector Graphics
W3C	World Wide Web Consortium

1 Introduction

The 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 Coursework, 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.

These solutions includes gamification for health proposes. The word "gamification" means funny activities prototyped in video games' interface to serious proposes, for example, for an human resources sector of an enterprise. Here, it will be presented a incremented fork of a gamified application proposed to improve ADHD children's health conditions.

1.1 Motivation

Many gamification softwares are projected to personal computers, but nowadays most used computational devicesare mobile - namely smartphones and tablets. Developing mobile applications for hyperactive young students may collaborate in them academic performance, among others benefits. In Brazil, for example, from 2012 to 2013, 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. In doing so, 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 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.

One of useful alternatives is applying computerized games for ill children. Some authors have stressed relationship of the use of gamified software for diagnosis and 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 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 may 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 above is useful to show 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 coursework - both remain paradigmatic to present research.

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

As he could not develop statistical research with children using his game by himself, its necessary to make an experiment 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.

With open source licence conditions, his application, is expanded here in his application and related research in order to investigate validity of this type of treatment. This coursework aims to discuss and to present results obtained in quantitative research involving children using a fork of "Cores" for evaluate its psychotherapy possibilities.

1.3 Objectives

General

- Improving, with new software functionalities and search quantitative evidences, of efficiency, a gamified application in diagnosis and treatment towards ADHD children.

Specifics

- Inserting new levels and interface incremental modifications in Colors Beta software;
- Discussing the place of proposed application in context of gamified health alternatives to drug treatment;
- Tabulate human experiment of it, based in psycho-pedagogic fundamentals and metrics, involving ADHD children;
- Presenting 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 Coursework Structure

In the chapter 2, "ADHD", talks about psycho-pedagogical features of this mental condition. Afterwards, gamification, medical video games and related questions. Lately, in chapter named "Discussion", it will presented the application and methodological principles adopted in experiment. Finally, chapter "Experiment" is addressed to draw inferences upon primary collected data.

2
ADHD

ADHD is one of the most serious of mental disturbs afflicting children and teenagers. There are also subtypes of ADHD but all forms of ADHD are here considered in its general form. Today there exist many types of treatment, though the main efforts of medicine and psychology are directed to drug-based therapy. In this chapter, it will be discussed some general features of children afflicted by this disorder, like symptoms and diagnosis. After that, we will present fundamentals of Stroop Effect, a psychological mechanism related to ADAH, that is used by this coursework's author to structure our application. In the end, we assemble articles of ADHD children-directed 'games' which contribute to our purpose.

2.1 ADHD features in childhood and in teenage

The characteristics are associated with strong disturbances in frontal segment of brain, 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 main focus to details or excessive talking (Association, 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 coursework it's necessary to let this subject aside by now. In order to define more precisely what are the main features of ADHD, 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 in 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, overactivity, 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.

These are the reasons to develop our gamified application, proposed in this work, which is designed for android mobile devices in order to offer to ADHD children. However in order to understand how the game really ought aid ADHD children it is necessary understand, 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

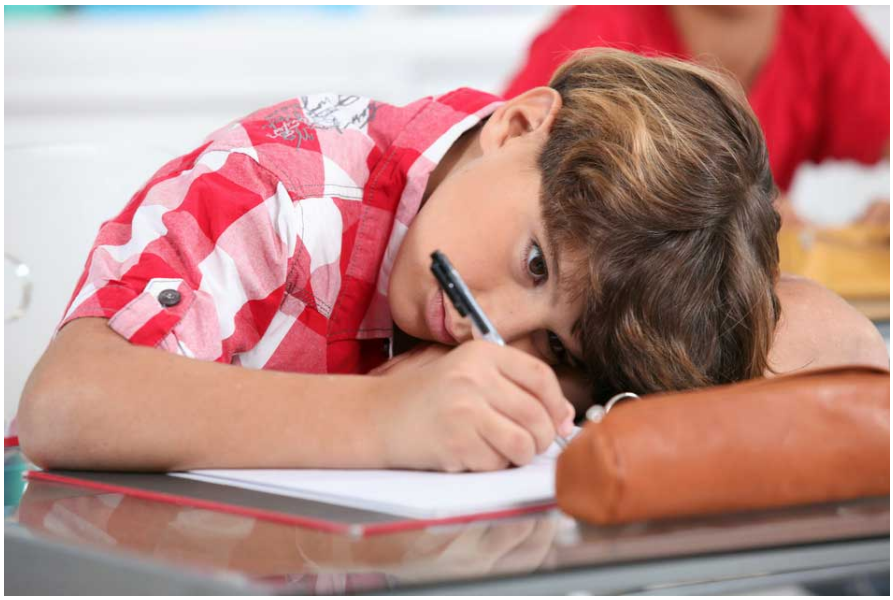

Figure 2.1 Situation common for ADHD children: their behavioral specificities generally affects negatively its academic capacities. They generally lose their concentration and use to sit without the regular posture to do their homework (Works, 2016).

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, particularly interesting for us. 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 publish 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 import 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.

Although there are many other applications in psychology, by this test, a psychologist or psychiatric can identify problems in attention, coordination, concentration and inhibitory control – typical problems of ADHD patients, who massively fail in particularly in third phase of Stroop experiment (Lansbergen and J. Leon Kenemans, 2007). Although

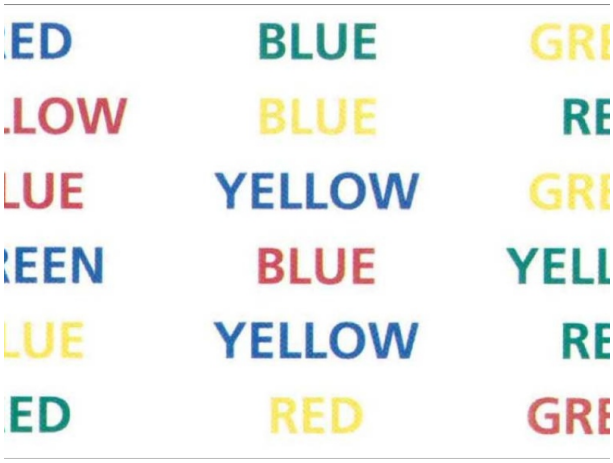

Figure 2.2 Example of the third stage of test of Stroop in its origin form (Brabant-Dagblad, 2015).

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 coursework follows these articles, besides none of the selected articles presents a 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 this coursework's author 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', Federal University of the State of Rio de Janeiro) implemented gamified applications for the ADHD and subtypes diagnosis. The study involved an practical experiment with patients. Time and number of right acts where tabulated and submitted to machine learning algorithms of fuzzy logics, whose output classifications may identify ADHD behavior and type (Santos, 2011). But, there no mention to the therapeutic potential of its application like 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 playings 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 improvements in ADHD children scores in our game are related with this major neural context.

Lastly, there is another article (Olga Pykhtina, 2012) 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 along promenades – and can choice which way follow and which activities, among many possibilities, perform. Authors' intentions lie 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 planed to let usability the most fanciful as possible (Olga Pykhtina, 2012). That work had influenced this coursework 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 (Klingberg *et al.*, 2002)

2.5 Summary

3

Gamification

In this chapter we will discuss 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, Keller's definition offer a good comprehension of what is gamification and which are its benefits. In this section we discuss 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).

New 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 Figuretaxonomy.

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, 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, we often refer to it as a 'game'. The class of gamified applications includes some subtypes. Some authors suggest we can divide them into three subcategories:

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

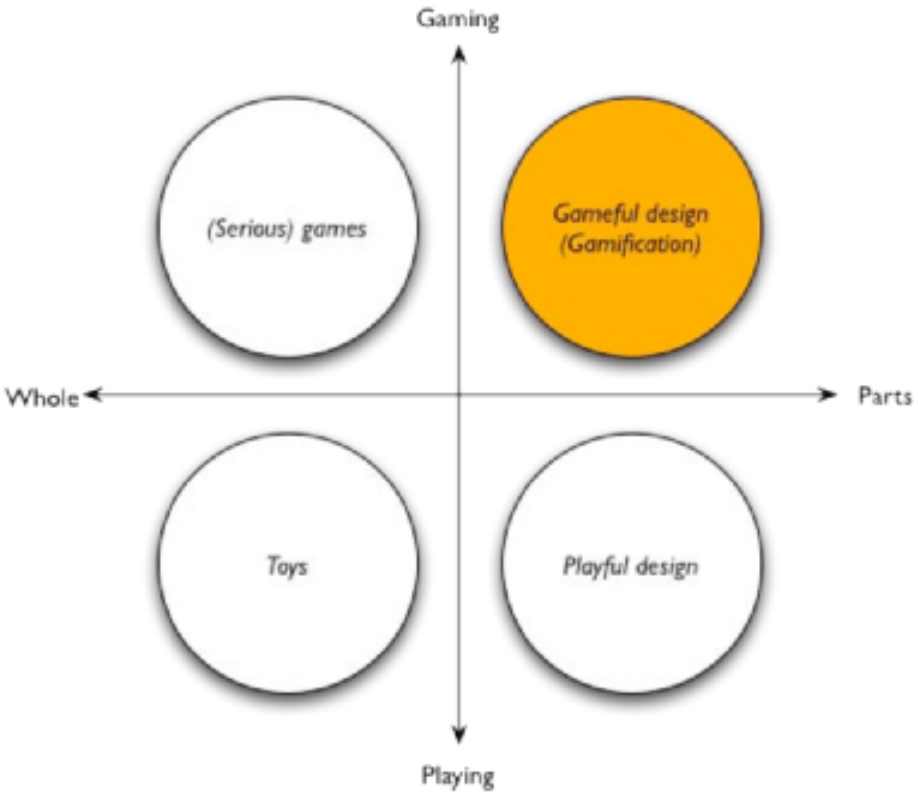

Figure 3.1 A topology of interaction of game-like applications according to its proposes (Deterding *et al.*, 2011).

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 we will show, civil engineering is one of sectores that

seems to increase the use 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, we would sketch a abstract model of gamification essential components. From the work Yamakami13a, how tried to struggle bad what he called 'bad gamification', we summarize 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 we 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

we could not classify it as a gamified application. These considerations will appear one more time when we discuss the design of our application in the next chapter. Another way to explore gamification essential features is best to show potentials of gamification, as the following figure summarize:

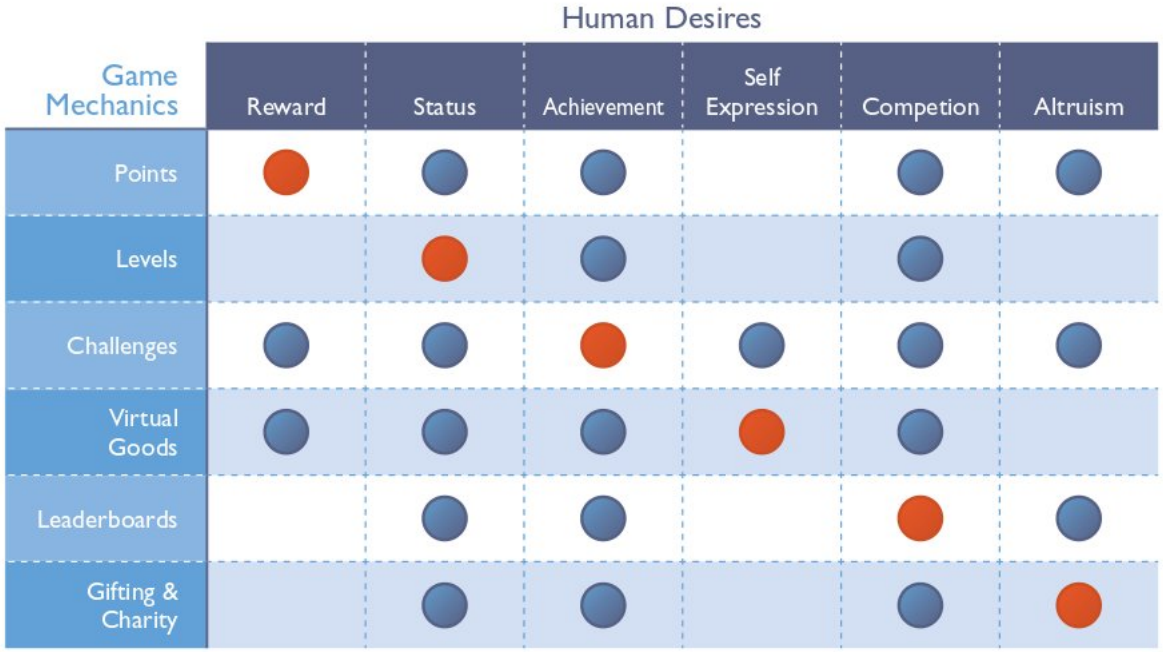

Figure 3.2 Gaming aspects and human desires (Bunchball, 2010).

Both approaches are equally useful for our purposes. 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 our aim to bring ADHD diagnosis and treatment more pleasant.

3.4 Uses and real life cases

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, rakings and fun-like challenges to re-force 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 an very uncommon use of gamification, that shows the potential offered by that technique. With these basic concepts and instances, we 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.

3.5 Related work

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 short 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.

3.6 Summary

In this chapter it was presented the core features, elementary characteristics, finalities and uses of gamification. Briefly it can 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 an confident and safer alternative to exclusive drug-based treatment (Nemeth, 1997).

4

MemoryStroop: Concept, Design and Implementation

In this chapter, we present the guidelines of our implementation with the requirements' analysis, the technical aspects of its development, and the general work (the conduction of this research is only presented in the next chapter, 'Experiment'). After presenting requirements' basis as we indicated in previous chapter, it is time to consolidate for validating it with its targeted final users, in this case, ADHD children. As we underlined before, a gamiefied application have 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 we finally evaluate the core features.

4.1 Requirements

The requirements are based in the release of a previous gamified application for ADHD children and in an idea collected from a scientific article of Psychology. First, it is necessary explain the contribution of the let worth foundations for the present work. As expressed other times before, our application, MemoryStroop is inspired by the research and the application made by Sérgio Villa (Villa, 2014). However, now we have a new and quite different application, although both share some similarities. To starts, the main contribution of Villa's work is its feedback of psychologists, computer science students and non-ADHD children the tested the game, name only "Cores" (Colors, in Portuguese). Villa submitted multiple-answer questionnaires of usability analysis in order to check quality mixed with some open questions in order to present the positive aspects and possible ameliorations to another features.

4.1.1 Requirement prospection

In doing so, it were pointed, mainly in psychologists' opinions, some necessities to be achieved. On general, they approved and viewed with good eyes the use of the said software as mean of treatment, but some of them manifested the following points for improving in a near version of software: first, the gaming has too much conflicting stimuli in some of its levels, secondly a general performance report is needed and thirdly moving targets to player. To discuss and present these improvements, it is necessary before to present briefly the application itself. In summary, Villa's application implements a gaming centered in matching (like the third test of John Ridley Stroop, but more influenced by Golden Stroop modality) of a color 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. So, eight levels lets the player/patient from the simplest matching of a color name and its ink without any conflict in the first level, to a difficult scenario with a series of adverse stimuli in the last one.

4.1.2 Defining requirements

A general score with response time and hit rates is also implemented, satisfying the requirement expressed by the psychologists. Then, these requirements may be grouped and presented as a list of requirements, including the functional and non-functional ones, the latter are disposed according to the patterns of ISO9126's norms.

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

Table 4.1 Table for the all Functional Requirements

4.1.3 Technologies for software Development

The employed technologies are only the basic infrastructure for software development. The codification of the mobile software was made in Java programming language driven for Android mobile operating system. It was used the Android Studio framework in

Table 4.1.2 lists the non-functional requirements to develop the application.

Number	Requirements	Quality in use
Functionality		
F1	The player should have only option to follow the game levels	Consistency
F2	The system should each level's statistics	Consistency
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 at least 85% 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

version 1.5.1 for the development, implementing gradle, the package manager for android projects and some other frameworks too, the lint prototypes validator and OpenJDK 7 (Java Developer Kit) for Java programming language infrastructure on a Debian 8 (Jessie) operating system desktop for development. [1]

As differences of traditional Java for desktops or other mobile platform, Android has some specific functions, as directed to call device resources or sensors, and runs in another virtual machine than common Java, the Dalvik Virtual Machine. Android has a stack of operating system levels, beginning from a linux kernel, passing to a device-components layer and other levels until arriving to a, as we can see in figure exposed below.

The Android environment was chosen, especially, because it is the platform currently most used around the World, particularly in Brazil, where our study was designed and most of 80% of mobile devices are Android-based, as we have been said in our Introduction. The native application approach, against other types of hybrid approaches like cross-compile one, is adopted here as way for exploring all potentialities of the native devices standard computational resources. In this way, it will so difficult to develop many native applications driven for each mean mobile device's operating system, like IOs or Windows Phone, because it will demand more time and resources that a single coursework subject could afford.

So, our application is designed for Android environments to achieve a grater number of potential users. Besides, the experiment designed for this research comprises only a controlled and reduced group of people, since the software is an experimental application, although an older version is offered, for free, on Google Play App store or others, which contains dozens of millions of mobile applications of the most different finalities. Android platform are also more accessible to develop than other platform like IOs or Blackberry,

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

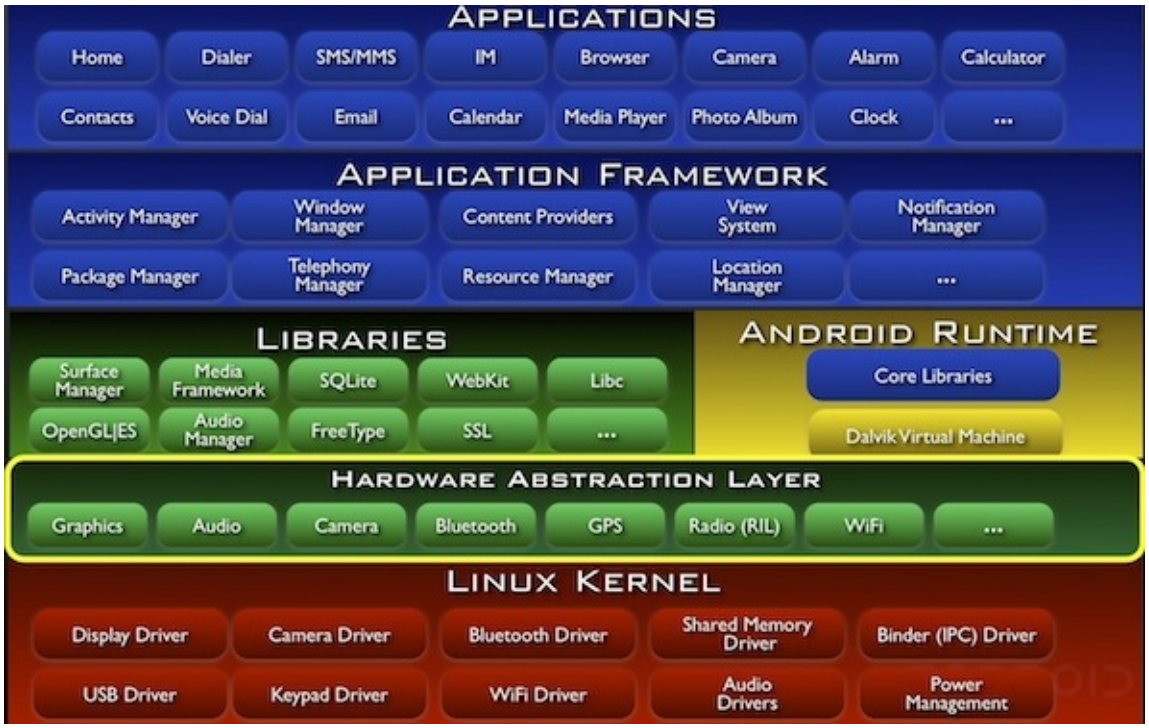

Figure 4.1 Android operating system layers.

for whom it is necessary a considerable number of environment requirements, like the exigence of a computer Mac for programming in Objective-C or Swift (languages that implements applications to IOs), that difficult the programming process. So that, there is a couple of reasons to adopt the Android environment to develop the application of this research, mainly, its popularity in Brazil and its relative practicality for development.

The application is compatible from Android "Kitkat" (version 4.4) to the most recent versions (the most stable recent version in moment which is version 6 called "Marshmallow"), that yields a compatibility ration in order of about 74% of Android devices on a word-wide perspective, according to recent data (Android, 2014). Our implementation also is driven to treat different resolutions of devices, using scalable images and other strategies, as we will discuss 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 it is used the Libgdx Java library and engine. It is as free software engine that allows anyone program simple 2D or 3D games for various platforms, including Android. So, the proposed application, Mememory Stroop, combine libgdx to some native android native code and directives that are proper of this system. Libdgx offers a large set of facilities to better develop games for Android.

One of the, maybe the most important, is its simplicity of operations and basic project's architecture and high integration by Java programming language syntax shared by both. 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 of that area.

4.2 General features and application architecture

As mentioned before, Villa's ADHD gamification comprise multiple conflict situation in game that appeared undesirable to some of the psychologists. So these extent set of conflict mechanisms that is replaced by only two conflicting stimuli of classical stroop test a fixed memory game board, in order to promote a more focused set of stimuli. It was implemented in the present application. So, that's why our application is called MemoryStroop. The number of levels were reduced to four, beginning to the 2x2 board with card without conflicting stimuli in the first level to a Stroop conflict in the next level, that increases board to 4x4, 8x8 and 16x16 boards in each level. All negative stimuti that remained on old version, like "game over" event, were removed too: only positive stimuli such as commemorative music effects are implemented.

Below it is possible see the game implementation's architecture of Libgdx Java classes and extra native android class, that implements PDF exportation of game statistical data.

4.3 Summary

At this moment of the coursework, the point was to present to reader how it were set the computational and technical aspects of MemoryStroop. Thus the first necessity referred to the definition of requirements, which came from a previous application and research (Villa, 2014), improving some of main features presented by the psychologists about that application and research. The main requirement of those psychologists is the necessity to offer a limited set of conflicting stimuli during the Stroop Effect during the game. So far so good the functional and non-functional requirements that

5 Experiment

In this chapter, it will presented the practical approach object of study. In the first section, the subject is the methodology, explaining about the main aspects of our fieldwork and the nature of the practical research to be applied with children. The conduction of this research is only presented in the next chapter followed some institutional constraints that are also presented in it. After presenting theoretical basis as we did in previous chapter, it is time to consolidate for validating it with its targeted final users, in this case, ADHD children. As we underlined before, a gamiefied application have 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.

5.1 Methodology

In this section we presents the methodological definitions and theirs justifications for this research. The object of the present study comprises the development of a tool for detecting and treating the ADHD. This tool follows the notion of gamification, as discussed in previous chapter. Therefore, the main outcome of the research is to offer a game-like mobile implementation thats contributes to children's mental health. In a way of explain its methodological features, the first subsection treats upon the employed means and materials for developing the game-like application and the second one discuss how the precise method of case study is applied along this research.

5.1.1 A case study approach and its implications

Following a cyclical view of process as stated by software Engineering (Pressman and Pressman, 2004), our application all over the implementation sprints has been frequently

submitted to its potential user as way to improve the gamified applications. So that, the method choose to that development is the case study.

As some authors stated (Doolin, 2011), the case study is a powerful tool of analysis of software production. It could, but the same authors employ the qualitative approach, because it promotes fast answers without the necessity of tabulation or other statistical that may cost high computational processing, monetary investment and time.

In this particular aspect of the methodological choice for a qualitative case study approach we follow them, for the reduced resources and the lack of extensive institutional infrastructure of our University Psychological services' for ADHD children, desired in a extensive quantitative analysis.

Since a case study requires the net definition of its tasks (Doolin, 2011), we present them in sequence. To starts, we perform the research with four children diagnosed with ADHD and another four not-diagnosed at the Psychological Clinics of Federal University of Bahia. This research is applied in April 2016.

There is no randomization or other advanced techniques in composing the sample: it is a common convenience sample. Collected data were made by observation and by automated data monitors inserted in application. These are generated as a report legible both by Psychologists and System Analysts.

Moreover, as the research involves human beings, particularly, children, first of all it has been necessary to ask permission of their parents, of the Institution (by a predefined form) and work together with psychological personnel of the Clinics. All documentation and report models may be seen on the Appendix of this work.

The identities (names and other personal information) of children were protected by pseudonyms and identification numbers (IDs) 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 data collected from children are both qualitative (their behavior during playings, reactions, doubts, suggests and general impressions about the gaming application after that) and technical (time of playing, level achieved etc). These massive information is analyzed and general considerations made upon them.

The collected data offer three utilities:

1. Validates the implementation with target-users;

2. Verifying differences in use of ADHD and non-ADHD children;

3. Collect information for improve the application in newer versions.

The results of each one of these aimed features are presented in the next chapter. Evidences should support consistent validations or readjustments in our application, that is another feature for the next chapter. By now, it is necessary to understand the organization of software features.

5.2 Results

5.3 Discussion

5.4 Summary

6
Conclusion

A partir dos resultados levantados com os questionários aplicados, conclui-se que o jogo Cores Beta alcançou o seu objetivo de ser um jogo, para tablets e smartphones Android, que possa ser usado no tratamento de crianças com TDAH, pois os especialistas de psicologia foram unanimes em indicar que acreditam nesse potencial do Cores Beta. Também pode-se identificar que o jogo apresenta uma boa interação com o seu jogador, tomando-se como base as respostas obtidas pelos especialistas em Computação.

Por fim, pode-se identificar que o jogo é divertido para crianças, caracteristica muito importante, já que pretende-se melhorar as capacidades cognitivas de crianças com TDAH. Também, que as regras do jogo podem ser entendidas pelas crianças e que sua dificuldade parece ser adequada. Contudo, muitas são as possíveis mudanças que o jogo pode sofrer para ser mais adequado ao seu objetivo, existindo uma grande área de atuação à ser explorada.

6.0.1 Coming studies

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;
- Extend the practical research to 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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Appendix