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MEASUREMENT OF THE IMPACT ON THE USABILITY OF AN IPAD GAME DEVELOPED WITH A DESIGN GUIDE BUILT BY CHILDREN

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ABSTRACT

Aim/Purpose	This research is a comparative test between two Human Computer Interaction (HCI) design approaches - Apple versus one informed by child users.
Background	There are studies concerning the creation of graphical interfaces for kids, however, they do not involve them in the design process. On the other hand, operating systems such as Apple or Android impose their graphic guidelines designed only for a general outlook.
Methodology	The research has a scope of exploratory nature, with a mixed approach. For the measurement of usability, tests were developed to determine the degree of efficiency, effectiveness, and satisfaction generated in two versions of the same game. Children between six and eight years of age were targeted for this test.
Contribution	This research compares two design guides to determine which one is better to develop games for children.
Findings	This study concluded that the design guide elaborated by children allowed the building a more efficient, effective, and satisfactory game because the total usability percentage was 89.84%. This percentage was much higher than that obtained using the generic Apple guide, where the percentage of total usability obtained was 78.72%.

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Recommendations for Practitioners	Using design guides to develop games for children helps to increase the level of usability for them.
Recommendations for Researchers	These design guides can be used for other devices that have different operating systems as guidelines to develop games for children.
Impact on Society	The future generations of game developers that focus on games for children can take into account the following guidelines to create games that children will enjoy more.
Future Research	Perform usability tests with users of different ages, for example children, adolescents, and adults. It is also suggested to take into account mobile devices with Android operating system.
Keywords	usability, mobile devices, games, children

BACKGROUND AND MOTIVATION

Mobile technology is closely related to the modern way of life. Children who cannot read or write until they are six years old already know how to use a tablet or a smartphone (Kraleva, 2016). In the United States, 97% of kids between six and ten years have a mobile device, tablet, or smartphone (Bate, MacNish, & Males, 2014). On the other hand, in Ecuador, 11 of every 100 children have a mobile device, tablet, or smartphone and 74% of these children use the cellphone to play (Instituto Nacional de Estadística y Censos, 2016). In recent years, many schools have made the implementation of videogames as pedagogical material.

Educational applications such as Scratch, chess, sudoku, puzzles are some of the examples of didactic teaching materials applied in educational institutions. Despite this, teachers do not trust games as enhancers of academic performance. On the other hand, the "fun tools" for pedagogical purposes that are used in schools are generally perceived as boring by students (Gomez Domingo & Badia, 2016). One of the main reasons is that children between five and eight years old easily change their center of attention (González-González, Toledo-Delgado, Collazos-Ordoñez & González-Sánchez, 2014). The way in which the children perceive the games not only varies with respect to the way adults do, but also between boys and girls (Çakir, Gass, Fster, & Lee, 2017; Lucas & Sherry, 2004; Stahl, 2016). There are many studies about creating graphical interfaces for children (Wu, Tang, & Tsai, 2014), however, they are designed by adults and do not involve children in the whole design process. Developers must establish the fundamentals of design focused on the end user and understand the response of users to their products meets the usability objectives (Ames, 2001). This usability has specific sense in Human Computer Interaction (HCI) (Zheng, Zheng, Ma, & Zu, 2018), a system can achieve its specified functions creating a user experience easy to use; games, unlike most other mobile applications, emphasize the user experience more than the functionality (Barnett, Harvey, & Gatzidis, 2018).

Furthermore, another existing problem is due to the fact that operating systems for mobile devices impose their graphic guidelines in a general way. For example: Apple proposes "Human Interface Guidelines" and Android proposes "Material Design for Android". Both design guides are designed in a general user environment and not with a specific audience in mind (Kornilova, 2014). The plan for this research is to develop a game for iPad using two HCI design guidelines a generic suggested by Apple (Cucho Run Apple) and another designed by children (Cucho Run Kids); it will allow measurement of the impact on usability in terms of effectiveness, efficiency, and satisfaction. To achieve this, an experiment will be carried out in order to determine the final usability percentage of this two HCI design study.

THEORY

USABILITY ON MOBILE DEVICES

Nowadays, computers and mobile devices are not only used by programmers and engineers, they are used by everyone, including children who want to expose themselves to technology from an early age (M. Ismail, Diah, Ahmad, Kamal, & Dahari, 2011). The usability according to ISO 9241-11 is the degree to which a product can be used by a user to perform specific tasks with effectiveness, efficiency, and satisfaction, in a specific scenario (ISO, 1998).

With usability, User Experience (UX) develops, which is a field of research that generally evaluates the user's experience in web pages and mobile applications. Donald Norman (2016) defines UX as all the cognitive aspects that a person experiences when interacting with a system. According to Baxter (2005), author of "Understanding your Users", UX is a field of study that focuses its efforts on improving the interaction of people with technology. While others, such as Partala and Saari (2015), believe that the UX involves emotions, psychological needs, values, and manners, other authors indicate that the UX is a response to the perception of usability (Lallemand, Gronier, & Koenig, 2015). A friendly graphical interface on mobile devices allows users to obtain the greatest amount of feedback through the screen and, above all, to understand the available options and the connection between different functions of the application (Tsai et al., 2016). Given the great growth in the deployment and use of mobile devices, a large number of researchers have turned their efforts to maximize the usability of applications in these devices. The efforts of the UX researchers are focused on counteracting the usability problems of mobile devices, for example, graphical user interface, small screen size, information entry methods, connectivity, among others. The implications of each of these sections and how they influence the user's final experience are detailed below (N. Ismail, Ahmad, Kamaruddin, & Ibrahim, 2016):

- User interface on mobile devices has become a challenge for graphic designers and UX architects. The main activities involved in the design of the graphic interface are button design, positioning of graphic elements, text writing, color, and icons (Bardram et al., 2013).
- Also, the size of the screen and organization of graphic pieces are the most important usability challenges, and therefore they are the most attacked point in this investigation. The manufacturers of mobile devices seem to be aware of that limitation; it is evident how many of them have increased the sizes and screen resolution from generation to generation. Such is the case of the Samsung Galaxy, which began with a 4-inch screen in 2010, the fourth generation increased the screen size to 5 inches, while the current generation (Samsung Galaxy S9) has a screen size of 5.8 inches (Al-Ismail and Sajeev, 2014; Xu, Ding, Huang, & Chen, 2014).
- Information entry methods also complement the limitations that mobile devices have. For example, the size of the text buttons on the keyboard is too small to get all the letters of the alphabet to show on the screen of the device, which sometimes means that multiple functions are required in a single key (Bardram et al., 2013). Additionally, using a keyboard on a mobile device is a difficult task since you need to make a keyboard change when you want to type uppercase letters, lowercase letters, numbers and symbols (Xu et al., 2014).
- Finally, present day connectivity needs to be considered. Mobile devices connect to the internet using connection methods such as Wi-Fi and mobile data. However, these types of connections do not yet have the same speed as wired connections (Kumar, Nilsen, Pavel & Srivastava, 2013). A common result of the slowness of using Wi-Fi and mobile data connections is frustration, although there may also be larger consequences such as loss of signal (Yeh & Fontenelle, 2012).

Usability Evaluation

In the assurance of the quality in applications for mobile devices, the measurement of usability is an essential task. Part of the scope in measuring usability is to ensure that the mobile application is usable, fast enough, and safe for users. In its first years, usability was determined subjectively; nowadays multiple tests and methodologies have been developed that evaluate the usability of a mobile application from the objective-quantitative point of view (Harrison, Flood, & Duce, 2013; Hussain, Abdulkadhum, Abdulwaheed, Mohammed, & Abdulhussein, 2015). Nielsen (2001, 2003) considers that the usability of a system has five main components: Learning, which expresses the users' ease doing a task the first time that they interact with a system; Efficiency, once users have learned to use the system, how fast can they perform tasks? Memory, after users have stopped using the system for a long period of time, how easy can they control it again? Errors, how many errors do users make when using a graphical interface, how severe are these errors and how do they recover from them? Finally, Satisfaction, which is a qualitative qualification parameter and defines the pleasant or negative sensation that the user perceives while using the application.

According to M. Ismail et al., (2011) and ISO (1998), the three main components to assess usability in applications for mobile devices are the following: Effectiveness, refers to the accuracy and percentage of compliance that result after users reach certain objectives. Efficiency, refers to the accuracy and percentage of compliance, using the least amount of resources, which results after users reach certain objectives. Satisfaction, subjective-qualitative opinion of users, taking into account their positive or negative emotions, after using a mobile application. The tests performed in this research article are based on the principles mentioned above. Therefore, effectiveness and efficiency can be determined by using the "User's success rate: The simplest usability metric" metric proposed by Nielsen (2001). In this study, the input data for the quantitative tests will be obtained using a list of annotations that the evaluator will have during the usability tests. The input data for the qualitative tests will be obtained through a questionnaire that will be given to the children after the usability tests.

User-Oriented Design

As an alternative to the complexity and errors caused by the technology-oriented design philosophy, the user-oriented design was born, which has as a principle to make the most effective systems. The user-oriented design poses an additional challenge to graphic designers and UX architects, since they must model graphical interfaces according to the capacity and needs of users (Endsley, 2016). Norman (1988) defines user-oriented design as "a philosophy based on the needs and interests of the user, with an emphasis on making products usable and understandable". Norman also considers that the products are usable and understandable when the user can decipher what to do and can say what is happening. Rubin (1994) describes the user-oriented design as techniques and procedures to design user-friendly systems as the center of the whole process. Most authors of publications agree that the principles of user-oriented design emphasize the development of usable and useful products, actively integrating the user throughout the design stage (Dumas & Redish, 1993; Eason, 1988; Gould & Lewis, 1985; Shackel, 1991).

Apple's Regulatory Design Guideline

There are regulatory design guidelines created by Apple that are aimed at graphic designers, graphic artists, UX architects, and software developers with the aim of creating intuitive mobile applications and with a consistent user experience at all levels. The most notable features of this design guide are the following.

- Clarity, throughout the application the text is legible despite the screen size, the icons are accurate and lucid and the decorations are appropriate.
- Spacing, color, typography, graphics and interface elements subtly highlight important content and convey interactivity.

- Content often fills the entire screen, while translucency and blurring often hint more of the content. The minimal use of bevels, gradients, and parallel shadows keeps the interface light and ventilated, while ensuring that content is paramount.
- Depth, different visual layers, and realistic movement transmit hierarchy, impart vitality, and facilitate understanding.
- Transitions provide a sense of depth as content is navigated (Apple, 2018).

On the one hand, the design principles promoted by the "Human Interface Guidelines" of Apple (2018) are Aesthetic Integrity, which represents how well the appearance and behavior of an application are integrated with its function. For example, an application that helps people perform a serious task can keep them focused through the use of subtle and discrete graphics, standard controls, and predictable behavior. On the other hand, an immersive application, like a game, can offer a captivating appearance that promises fun and excitement, while encouraging discovery.

- Consistency - a consistent application implements familiar standards and paradigms through the use of interface elements provided by the system, well-differentiated icons, standard text styles and uniform terminology. The application incorporates characteristics and behaviors in the way that people expect.
- Direct manipulation - direct manipulation of content on the screen involves people and facilitates understanding. Users experience direct manipulation when they rotate the device or use gestures to affect the content on the screen. Through direct manipulation, they can see the immediate and visible results of their actions.
- Feedback recognizes actions and shows results to keep users informed. Integrated iOS apps provide perceptible feedback in response to each user's action. Interactive elements are briefly highlighted when they are clicked, progress indicators communicate the status of long-running operations, and animation and sound help clarify the results of actions.
- Metaphors - people learn faster when the objects and virtual actions of an application are metaphors of family experiences, whether they are rooted in the real world or digital. Metaphors work well in iOS because people interact physically with the screen.
- User control - in all iOS, people, not applications, are in control. An application can suggest a course of action or warn of dangerous consequences, but generally the application shouldn´t be responsible for making decisions. The best applications find the right balance between allowing user actions and avoiding unwanted results, as can be seen in the location of graphic pieces denoted in Figure 1. Users can move the views out of the way to expose the content below; the concept of "drag and slide content" also applies.

Design Guideline Elaborated By Children For Children

This is a design guide proposed by Radoslava Kraleva, a research professor at the Neofit Rilski University in Bulgaria and an author of publications in designing environments for children. In the research, much emphasis was placed on the usability of mobile applications for children; for this reason 65 children between 4 and 13 years old were included as the sample, who elaborated different proposals of graphical interfaces according to their personal preferences. Finally, a quantitative and qualitative evaluation of the common aspects of these graphic proposals was made, and the following conclusions were reached (Kraleva, 2016; Kraleva, Kralev, & Kostadinova, 2016): First, children between 4 and 13 years old prefer games where the characters are humans or animals. Secondly, it was determined that playing games on mobile devices such as smartphones and tablets is more attractive to children than playing games on larger devices such as computers. As a third conclusion, it was established that games with the native language of the country of origin is the favorite of the children. Fourth, children who use games whose controls are by voice commands or tactile gestures are more likely to have a higher level of satisfaction. As a fifth point, in the sample of the tests performed by Kraleva, she thinks that the blue color is the most suitable for a game intended for a mo-

bile device. Sixth, the same children with whom Kraleva developed her tests believe it necessary to obtain a prize after completing a task. Seventh, it was concluded that children prefer that the main character of the game be an animal with which they can identify. In addition, Kraleva and her research team decided to develop a mathematical game, shown in Figure 2, which has a graphical interface based on the graphical guidelines suggested by children. Finally, it is concluded that the design of applications adapted to the individual capacities and needs of each person is an essential activity in Software Engineering (Kraleva, 2016, 2017).

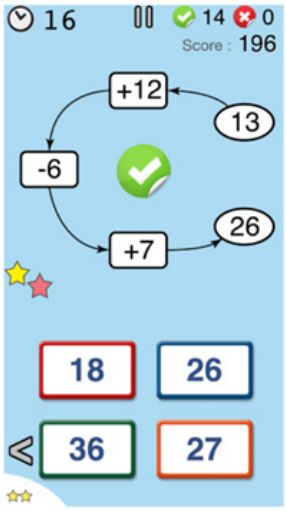

Figure 1. Example of a game developed using the design philosophy suggested by Apple. Adapted from "We design fun educational games for kids and grownups", by AB MATH (2019)

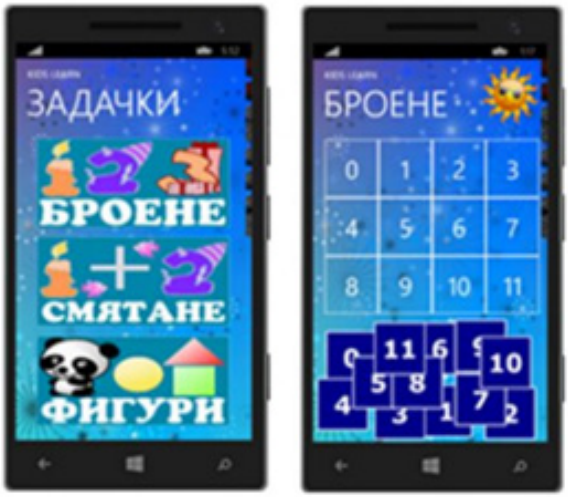

Figure 2. Example of a mathematical game that uses the graphic guideline proposed by Kraleva in her research

Finally, all the actors mentioned in the theoretical framework converge among themselves to form a single cycle of usability and metrics, as can be seen in Figure 3.

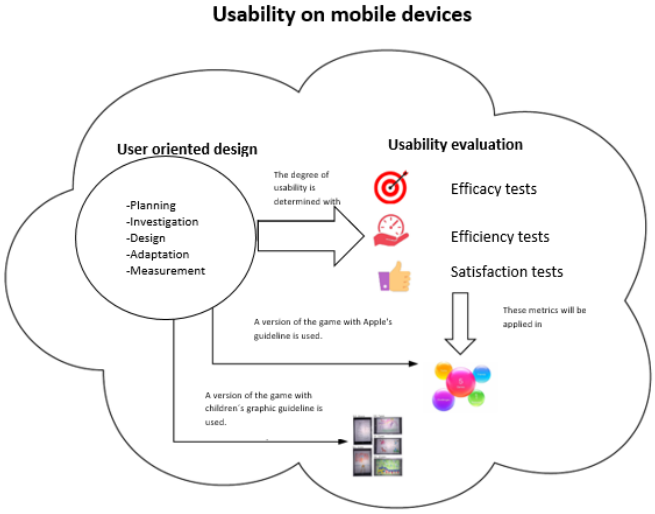

Figure 3. Graphical flow that represents the interaction of all the entities involved in the usability tests developed in this research.

INVESTIGATION METHOD AND IMPLEMENTATION

The research presented in this article has a mixed approach, since parameters of a quantitative (effectiveness and efficiency) and qualitative (satisfaction) nature were evaluated. The scope is of an exploratory nature, because tests were carried out that determined the effectiveness of the use of a specially designed design guide for children. The research design consists of three main stages: selection of the children-oriented design guide, development of a game using the two graphic guidelines previously selected, and the design of usability tests aimed at children and video games. In the first stage, selection of the design guide aimed at children, two different design guides proposed by respected entities and recognized researchers in the UX area were investigated, compared, and selected. The evidence of the tests carried out is found in Appendices A and B (actual model of effectiveness, efficiency and satisfaction tests).

In the second stage, the development of the game Cucho Run was executed using two previously selected design guides, the first version based on the design guide "Human Interface Guidelines" proposed by Apple and aimed at the general public, the second version of the application was inspired by a graphic guideline found in Kraleva's research that uses visual interfaces made by children for children.

Cucho Run is a platform-type game developed exclusively for Apple mobile platforms with iOS 10.1 or higher operating system. The 2D Sprite Kit framework, owner of Apple, was used to calculate movements and physical reactions. The programming language used is Objective-C under the native Apple Model-View-Controller framework. Additionally, the database implemented in the project is SQLite version 3.

Cucho Run is a game whose purpose is to control through screen touches to Cucho, a very adventurous cat, who needs the help of game users to jump obstacles and reach the end of each level. Beyond the functional objective of the game, Cucho Run is not conceived as an educational game but as a game of entertainment and cognitive development. The adventures of Cucho Run are divided into 5 worlds: forest, ice, fire, water, and cemetery; each world has five levels with different degrees of difficulty. At each level, Cucho has three lives available to reach the goal; each life is reduced by contact with an obstacle. The inclusion of special powers such as score multiplier, defender shield, and flying wings allow Cucho to have different behaviors in each level.

The two versions of the game with different graphic guidelines can be seen in Figures 4 and 5, which represent different ways of choosing a world. The game also has additional components such as the integration with Game Center (Apple multiplayer platform) for the counting and viewing and comparison of scores of all game users in real time.

Figure 4. Screen of worlds selection in the version of the game that uses a generic graphical directive suggested by Apple

Figure 5. Screen of worlds selection in the version of the game that uses a graphic directive elaborated by children for children

Finally, in the third stage of the research design, the selection and execution of usability tests aimed at children and video games was carried out. We investigated usability tests previously proposed by respected entities and researchers recognized in the UX area and that were detailed in the theoretical framework.

Calculation of the Sample

The calculation of the sample in this investigation was based on the following statistical formula. The sample formula was used in order to determine the population of children in this experiment. Moreover, the "desired characteristics" refers to the number of children that accepts the experiment hypothesis; on the other hand "unwanted characteristics" are the ones not willing to be in favor of it:

$$(1)\quad n = \frac{z\hat{}2*(p*q)}{e\hat{}2+\frac{(z\hat{}2(p*q))}{N}}$$

n = Sample size
z = Confidence level
p = Proportion of the population with the desired characteristic (success)
q = Proportion of the population with the unwanted characteristic (failure)
e = Level of error willing to commit
N = Size of the population

The population was determined by a total of 75 children between six and eight years old enrolled in an Educational Unit of the Quevedo city - Ecuador, since it was the only one that openly expressed its intention to participate in this investigation. Using the statistical equation for population proportions with a margin of error of 10% and a confidence level of 95%, the necessary sample was composed of 43 children randomly selected from the total population. In addition, mostly male children participated. Due to the lack of schools willing to participate, the children were chosen counting as they were located in the classroom. The choice was quite random; there were no additional criteria of selection.

The experiment was carried out in an open space of the institution using five iPads in total. The 43 children were previously divided into three groups of ten people and a group of thirteen; in addition none of the children had previously played Cucho Run. Before conducting the usability tests for each group, an introductory talk was given where the purpose of the test was explained and basic guidelines were given on how to maintain order during the tests, at no time it was mentioned how to use the game. The total duration of the tests was five hours.

Calculation of Effectiveness and Efficiency

For the calculation of the effectiveness and efficiency, the usability test methodology "User Success Rate" was used, based on the successes and errors of the user when interacting with a graphic interface (Nielsen, 2001). If a task is successfully completed it will automatically be classified as "YES", which means 100% effectiveness / efficiency within the Nielsen scale. The tasks that are not completed will be classified as "NO", which is equivalent to 0%. Within the segment of tasks not completed include cases such as the child giving up before the attempts to perform the task, the child completing the task incorrectly, and the child not able to start the task. Additionally, there will also be a "PARTIAL" classification, which denotes a level of partial effectiveness when performing a task, which means 50% effectiveness / efficiency within the Nielsen scale. For the determination of the effectiveness and efficiency score, the observer will be responsible for keeping track of each of the tests and writing down the score that, according to his expert judgment, he deems appropriate. During the tests, informal conversations will also be allowed between the child who performs the task and the observer, in order to have a more grounded criterion of the child's opinion about the game.

Calculation of Satisfaction

To calculate the satisfaction of the sample when playing the application developed for iPad, a questionnaire will be carried out after the quantitative usability tests. This questionnaire is designed according to the Likert score scale, using questions and answers with possible values ranging from 1 to 5. All the questions are formulated with the objective of knowing how the child feels when playing the two versions of the developed game for iPad, if they like the game, and if the game was easy to play or not. For the determination of the satisfaction score, the observer will be responsible for recording the children's responses to each of the statements exposed in the survey based on the Likert scale. For the structuring of the matrix of tests carried out in this research, a design proposed by the Malaysian Teknologi Mara University was used, which measured the usability of an educational game aimed at children between 5 and 6 years old (M. Ismail et al., 2011). The design of evidence on which this research was based was only available in the American English language. Therefore, the help of a

certified translator was needed to carry out the translation in order to preserve the integrity of the statements.

Resume of the Experiment Phases

During the first phase of the investigation several generic graphic guidelines were analyzed, however the official guide and suggested by the iOS operating system is "Human Interface Guidelines", which was used as a design guide for the version of the game called Cucho Run Apple . On the other hand, the design guide proposed by Kraleva, which specifies, according to seven attributes previously mentioned, how children prefer games to be developed, was the only one that involved children from the design stage of the guideline. This generated a sufficient interest and competitive advantage to be chosen as a base guide for the version of the game called Cucho Run Kids.

The second phase resulted in the creation of the game Cucho Run, in its two versions: Apple and Children. The development time of both versions was two months. This software was made by the developers and members of this project, so they have a direct relationship with the research. The source code and technical manual were delivered to the School of Systems, Telecommunications and Electronics of Universidad de Especialidades Espiritu Santo (UEES).

Finally, in the third phase, the experiment was designed and the usability tests were carried out in the sample. In this phase, the equation was selected to calculate the percentage of effectiveness (2) and efficiency (3), which is based on the methodology "User's success rate: The simplest usability metric" proposed by Nielsen (2001). Here is its composition:

$$(1) \quad Effectiveness = \frac{(YES+(PARTIAL*0.5))}{TOTAL}$$

$$(2) \quad Efficiency = \frac{\left(YES+(PARTIAL*0.5)\right)}{TOTAL}$$

Discussion of Results

In order to provide a context for the discussion of the most suitable guideline to design games for children, the "Cucho Run" app was created and tested to find the effectiveness, efficiency, satisfaction, and general usability, which are the arguments used in this experiment to provide the correct user experience. After a brief analysis the following information was found.

Effectiveness And Efficiency

The first part of the usability tests covers the success / error test when navigating with a graphical interface. These results can be evidenced in Tables 1 and 2, which represent the total number of hits (YES), total errors (NO), and partial errors (PARTIAL) committed by children when playing Cucho Run with two versions that use different graphic lines; for example, the percentage effectiveness of the version of the game that uses Apple's generic graphic guideline is 84.10%. While the percentage effectiveness of the version of the game that uses the graphic guideline proposed by children for children is 91.24%.

Table 1. Results of the tests of effectiveness in the version of the game Cucho Run that uses the generic graphic directive suggested by Apple. The number of responses per statement denoted in this table were grouped according to what is established in Appendix A.

Answer	Starting screen	World selection screen	Level selection screen	Game screen	Subtotal
YES	137	55	69	230	491
PARTIAL	30	30	15	28	103
NO	5	1	2	43	51
				Total percentage of effectiveness:	**84.10%** = (491+ (103*0.5)/645)

Table 2. Results of the effectiveness tests in the Cucho Run version of the game that uses the graphic guideline elaborated by children. The number of responses per statement denoted in this table were grouped according to what is established in Appendix A.

Answer	Starting screen	World selection screen	Level selection screen	Game screen	Subtotal
YES	153	70	73	263	559
PARTIAL	17	13	10	19	59
NO	2	3	0	19	27
				Total percentage of effectiveness:	**91.24%** = (559+ (59*0.5)/645)

Once the effectiveness of both versions of the game is determined, the second part of the test focuses on determining the efficiency that is calculated based on the number of attempts the child needed to execute an action. Tables 3 and 4 show the results of the efficiency tests, which finally determined that the efficiency of the game developed using the generic graphical directive suggested by Apple is 67.14%, on the other hand the percentage efficiency of the game based on the Design guide proposed by children for children is 84.88%.

Table 3. Results of the efficiency tests in the version of the Cucho Run game that uses the generic graphical directive suggested by Apple. The number of responses per statement denoted in this table were grouped according to what is established in Appendix A.

Answer	Starting screen	World selection screen	Level selection screen	Game screen	Subtotal
YES	84	112	122	154	472
PARTIAL	16	29	39	69	153
NO	29	31	11	121	192
				Total percentage of efficiency:	**67.14%** = (472+ (153*0.5)/817)

Table 4. Results of the efficiency tests in the version of the Cucho Run game that uses the graphic guideline elaborated by children. The number of responses per statement denoted in this table were grouped according to what is established in Appendix A.

Answer	Starting screen	World selection screen	Level selection screen	Game screen	Subtotal
YES	112	150	162	240	664
PARTIAL	14	17	6	22	59
NO	3	5	4	82	94
				Total percentage of efficiency:	**84.88%** = (664+ (59*0.5)/817)

SATISFACTION

Satisfaction tests using the Likert scale reflect qualitative results that are subject to the child's perception at the time of the test. In Table 5, high percentages of satisfaction expressed by the child can be evidenced when playing Cucho Run with the Apple version, in each of the five questions based on the experiment of M. Ismail et al., 2011. The overall total percentage of satisfaction is 84.93%, which is equivalent to the average of the individual percentages of satisfaction of each statement. However, the version of the game that uses the graphic version proposed by children has even higher levels of satisfaction, which are reflected in Table 6; the overall total satisfaction percentage is 93.39%, which is equivalent to the average of the individual percentages of satisfaction of each statement. It is important to note that in neither of the two versions are the satisfaction percentages lower than 80%.

Table 5. Satisfaction test results in the version of the Cucho Run game that uses the generic graphical directive suggested by Apple. The number of responses per statement denoted in this table were grouped according to what is established in Appendix B. The subtotal is calculated by adding the multiplication of the number of responses in each statement by its equivalence on the Likert scale.

Statement	Strongly agree (5 points)	Somewhat agree (4 points)	Neither agreement nor disagree (3 points)	Somewhat disagree (2 points)	Strongly disagree (1point)	Subtotal	Total %
The game was fun	35	7	0	0	1	204	94,88%
The game was easy to play	16	17	6	2	2	172	80,00%
I liked the character of the game	22	12	5	3	1	180	83,72%
I can control the movement of the character easily	21	11	5	6		176	81,86%
I would like to play this game again	25	8	6	2	2	181	84,19%
					Total of possible points:	215	Average = 84.93%

Table 6. Results of satisfaction tests in the Cucho Run version of the game that uses the graphic guideline elaborated by children. The number of responses per statement denoted in this table were grouped according to what is established in Appendix B. The subtotal is calculated by adding the multiplication of the number of responses in each statement by its equivalence on the Likert scale.

Statement	Strongly agree (5 points)	Somewhat agree (4 points)	Neither agreement nor disagree (3 points)	Somewhat disagree (2 points)	Strongly disagree (1point)	Subtotal	Total %
The game was fun	40	3	0	0	0	212	98.60%
The game was easy to play	27	13	2	1	0	195	90.70%
I liked the character of the game	30	7	4	2	0	194	90.23%
I can control the movement of the character easily	33	7	1	2	0	200	93.02%
I would like to play this game again	35	5	2	1	0	203	94.42%
					Total of possible points:	215	Average = 93.39%

General Usability

To calculate the general usability of the two versions of the Cucho Run game, the average percentage results of effectiveness, efficiency, and satisfaction were calculated. Figure 6 shows that the version of the game that uses the design guide developed by children for children has a considerable advantage in all the sections that were evaluated in this research.

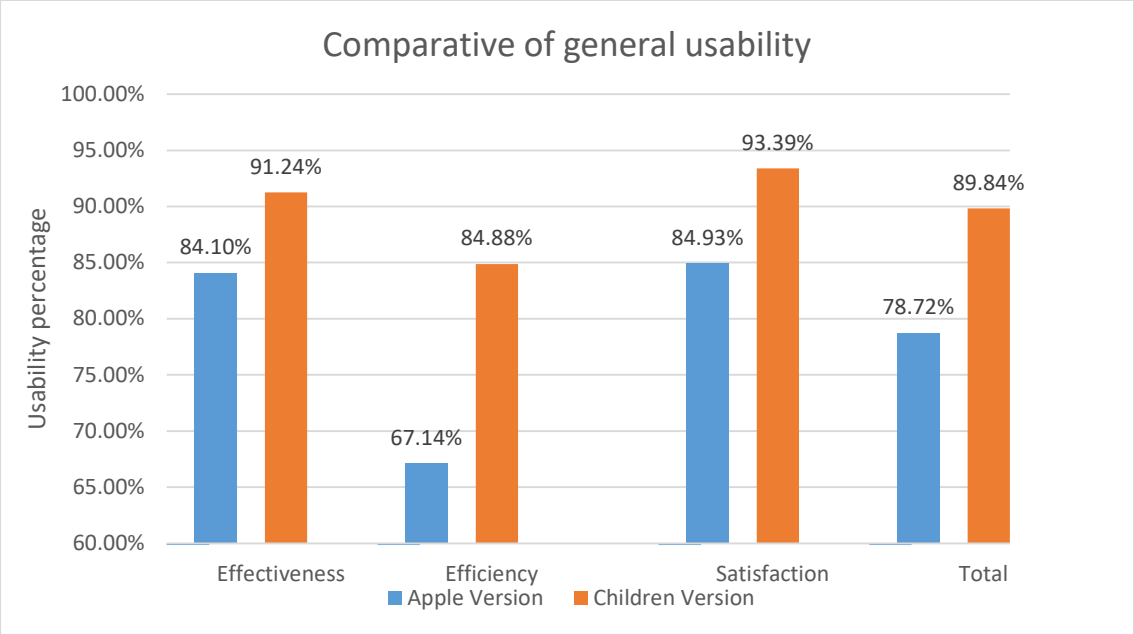

Figure 6. Comparative chart that shows the general percentages of usability divided into: effectiveness, efficiency, satisfaction and total.

CONCLUSION, LIMITATIONS AND FUTURE WORK

The main purpose of a mobile application or game, apart from its central functional objective, is to provide the best possible user experience. There are many variables that need to be taken into account to achieve a positive perception of the application with which the user interacts. It is imperative to involve the end user in the initial design of the product to know in advance the expectations and reactions caused; it is also important to consider the flaws in hardware that by nature occur in a mobile device. Finally, to determine the usefulness of usability generated in the user requires the intervention of quantitative and qualitative components, for example, efficiency, effectiveness, and satisfaction.

Once the research is done, it can be determined that a design guide that involves the user from the conception of its guidelines has a greater degree of usability than a design guide aimed at a general public. The percentages of effectiveness, efficiency, and satisfaction were considerably higher in the version of the game that used a design guide elaborated by children. However, it could be shown that the Apple design guide, although not specifically aimed at children or games, decently meets the expected effectiveness of using the game and browsing on its different screens. In addition, it was found that children prefer symbolic icons instead of texts to denote actions on buttons. The preference of interactions as lateral gestures was also reflected to select options against static vertical lists.

The limitations of the present investigation are related to the number of mobile test devices that were used for the tests, in total five iPads were used, which generated a waste of time. There were also some inconveniences when keeping the users attentive to the initial talk since there were no dedicated teachers to supervise the children. On the other hand, most of the children participating in the tests of this research were male, which can lead to biased conclusions about the preferences of characters and colors.

It is important to point out for future work, that usability tests be performed with users of different ages, for example children, adolescents and adults. It is also suggested to take into account mobile devices with Android operating system, which have a greater degree of presence in the market. Additionally, it is recommended to develop an investigation that denotes the differences of visual preferences among users according to their age range.

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APPENDICES

APPENDIX A: EVIDENCE OF EFFECTIVENESS AND EFFICIENCY

Nombre: Gean S Valle
Edad: 8 años
Prueba de eficacia

Tarea	**Cantidad de "SI"**	**Cantidad de "NO"**	**Cantidad de "PARCIAL"**
Pantalla de inicio			
El niño no tiene problema en encontrar el botón de jugar	X		
El niño no tiene problema en desactivar los sonidos del juego	X		
El niño no tiene problema en desactivar la música del juego			X
El niño no tiene problema en ir a los créditos del juego			X
Pantalla de selección de mundos			
El niño no tiene problema en navegar en el slider de selección de mundos	X		
El niño puede seleccionar con facilidad el mundo deseado	X		
Pantalla de selección de niveles			
El niño no tiene problema en navegar en el grid de selección de niveles	X		
El niño puede seleccionar con facilidad el nivel deseado	X		
Pantalla de juego			
El niño no tiene problema en navegar en el tutorial	X		
El niño no tiene problema en pausar el juego	X		
El niño sabe que hacer para ganar el juego	X		
El niño muestra reacciones positivas durante el juego	X		
El niño hace saltar al personaje solamente cuando debe saltar	X		

El nino reconoce claramente el obstáculo que debe ser evadido	X		
El niño reconoce claramente lo que debe ser recolectado	X		

Prueba de eficiencia

Tarea	**Cantidad de "SI"**	**Cantidad de "NO"**	**Cantidad de "PARCIAL"**
Pantalla de inicio			
El niño seleccionó el botón de jugar en el primer intento	X		
El niño desactivó el sonido del juego en el primer intento	X		
El niño puede recuperarse fácilmente de los errores o equivocaciones que cometió	X		
Pantalla de selección de mundos			
El niño seleccionó el mundo deseado en el primer intento	X		
El niño puede recuperarse fácilmente de los errores o equivocaciones que cometió	X		
El nivel de interacción entre el niño y el observador fue mínima	X		
El nivel de ayuda prestada por el observador fue mínima	X		
Pantalla de selección de niveles			
El niño seleccionó el nivel deseado en el primer intento	X		
El niño puede recuperarse fácilmente de los errores o equivocaciones que cometió	X		
El nivel de interacción entre el niño y el observador fue mínima	X		
El nivel de ayuda prestada por el observador fue mínima	X		
Pantalla de juego			
El niño completó el tutorial sin equivocarse al utilizar lo botones de navegación			X

El niño pudo pausar el juego al primer intento			X
El niño superó el nivel en el primer intento		X	
El niño hizo saltar al personaje en el primer intento	X		
El niño superó el nivel con más de la mitad de vidas		X	
El niño puede recuperarse fácilmente de los errores o equivocaciones que cometió	X		
El nivel de interacción entre el niño y el observador fue mínima	X		
El nivel de ayuda prestada por el observador fue mínima	X		

APPENDIX B: SATISFACTION TEST

Satisfacción

Enunciado de satisfacción	**Muy de acuerdo**	**Algo de acuerdo**	**Ni acuerdo ni en desacuerdo**	**Algo en desacuerdo**	**Muy en desacuerdo**
El juego fue divertido	X				
El juego fue fácil de jugar		X			
Me gustó el personaje del juego			X		
Puedo controlar el movimiento del personaje fácilmente		X			
Me gustaría volver a jugar este juego de nuevo			X		

BIOGRAPHIES

Monica Flores Marin is a research professor at the Espiritu Santo University in Ecuador in the area of Information Technology (IT) applied to Mathematics education. She is currently a Ph.D. candidate in Didactics of Mathematics; she also holds a degree in Electrical Engineering, an MBA and a diploma in finance.

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Victor Pinto Tapia is a systems engineer graduated at the Espiritu Santo University. He has working as a developer since 2015. He is currently a Link Digital's Chief Technology Officer (CTO). He has certifications: Linux System Administrator, Google Analytics Individual Qualification and his skills and domains are: SQL Databases, eCommerce development, mobile applications, video games frameworks.

María Teresa Espinoza Salguero is a systems engineer graduated at the Espiritu Santo University. She has been working as a developer since 2017 at Software Factory, in projects related to the improvement of the university system. This current year, 2019, she entered as a tester engineer in the multinational company Global Hitss, digital solution company, and is currently working in projects related to Claro, telecom group, giving quality assurance in their systems functionalities. Additionally, she is studying her master degree in Management of Information Systems with mention in Business Intelligence.