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Prototype of an Augmented Reality Application for Cognitive Improvement in Children with Autism Using the DesingScrum Methodology

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ABSTRACT

In this COVID-19 pandemic, it has been registered that children with autism are not learning properly with this virtual modality in Peruvian education. The main objective of this research work is to design a mobile application with augmented reality so that autistic children can improve their cognitive development in their virtual and face-to-face classes, the chosen methodology is DesingScrum which is a hybrid of the union of Design Thiking and Scrum, which will have 10 phases (empathise, define, devise, planning meeting, sprint backlog, daily meeting, sprint review, retrospective sprint, prototype, testing), in the case study the Balsamiq tool was used for the design of the mobile application. The results are the responses from the public in Lima - North of the survey carried out on the prototype for its improvement and also the result of the design of the games with augmented reality that was applied with the tools (Tinkercad and App Augmented class). The conclusion drawn from the research work is to be able to help autistic children to improve their cognitive development with the mobile application developed through augmented reality.

1 Introduction

Autism Spectrum Disorder (ASD) is a life-long disorder with several characteristics that can affect how you relate to different people in what you choose to distance yourself from and mostly tend to have trouble learning, in school or in other activities you do [1], almost 70% of autistic people do not have an intellectual disability [2], 1 in 160 children worldwide is diagnosed with ASD [3]. As there is no quick diagnosis to know this disorder, it takes time since it will be analyzed by specialized doctors who observe the child's behavior, these are identified from 18 to 30 months. In Europe and North America they are diagnosed at school, this is identified by problems such as anxiety, hyperactivity or other mood disorders, however when they become adults 10 and 33% have a verbal and non-verbal character, they are able to work but need support, in the USA only about 25% live in their own homes and the rest live with their families [4]. The Covid-19 became a pandemic and many governments have declared their social distancing, due to this the children of ASD are distanced from their therapists and different problems arise in the homes as the children are not adapted to stay at home and are not controlled by the parents [5]. The impact that covid-19 is having on the parents of children with Autism Spectrum Disorder (ASD), is the stress that the parent develops by giving their child peace of mind, that they do not need a nanny, teachers and therapists, it becomes a real challenge for their control [6].

In the city of Quito in 2017 an evaluation was carried out to find signs of autism in which 51,463 students were evaluated, where 0.11% of children were diagnosed with autism and 0.21% with suspected ASD [7]. Due to ASD this diagnosis is made during the first three years of birth and more cases are found in men than in women.

This data from the Institute of National Statistics and Information Technology in Peru recorded 5.2% of the population of Peru with this disability, in which 10,223 people have autism spectrum disorders [8]. Considering that we found four factors that are related to socioeconomic status (SES), level of maternal education or having public health insurance, low income measure in the census or having a diagnosis of ASD in the records, because of these factors we cannot make a correct balance in Peru on how many exact people suffer from ASD or the autism spectrum [9]. The importance of our project will help the ASD child to develop cognitively, emotionally and socially, as this augmented reality system consists of fun activities and games for their development.

The objective is to make a prototype of a mobile application for the cognitive development of ASD children using augmented reality so that parents can use this application for therapies or learning of children with autism, taking into account that in the Covid-19

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pandemic, children do not have physical contact with their therapists or educators.

This work will be structured in the following way, in section 2 the methodology to be used will be explained, in section 3 the case study of the research work will be developed, in section 4 it will be explained in detail what were the results and discussions during the tests carried out, in section 5 will be the conclusions obtained through the evidence made of the results.

2 Methodology

To begin with, we will show how you will start our methodology in which we will use 2 methods, Design Thinking and Scrum. These two methodologies will form a hybrid, which will have 10 phases (Empathise, Define, Ideate, Planning Meeting, Sprint Backlog, Daily Meeting, Sprint Review, Sprint Retrospective and Test) and to finish we will talk about the tools that will be used for the design of the prototype.

2.1 Design Thinking

This methodology has brought a lot of interest to the Professionals as it is new in the field of Innovation and Problem Solving [10]. Design Thinking has 5 phases (empathise, define, devise, prototype and test), it is mostly used to realise products, processes and business environments that require the help of users to identify strategies and future solutions, [11] as shown in Figure 1.

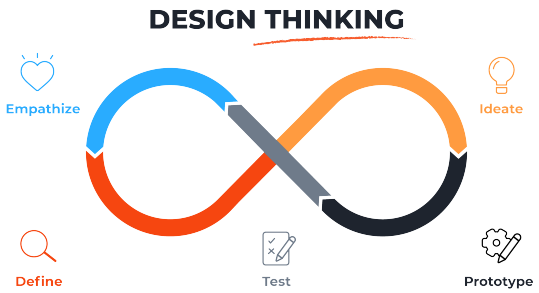

Figure 1: Design Thinking

2.2 Scrum

Scrum allows us to have a better iterative and incremental approach that prioritizes flexibility and adaptability to changes and in a complex environment, scrum is not a standardized process as it involves several steps to ensure a quality product. Scrum starts from the initial meeting to having the user capture, these are collected characteristics that are prioritized through the product list, through the planning sprint, followed by the execution sprint and ending with the review and the retrospective [12], as shown in Figure 2.

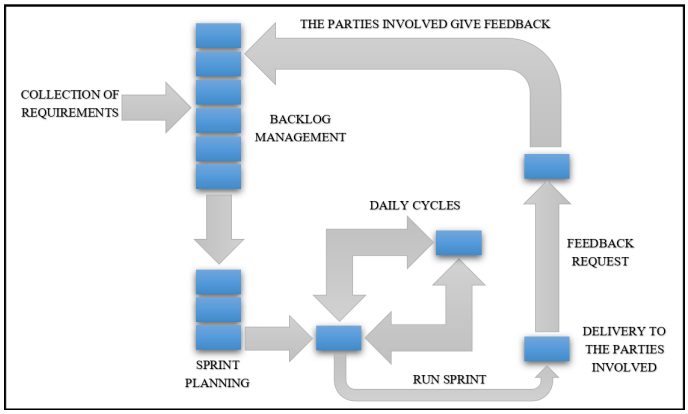

Figure 2: Methodology Scrum

2.3 Phases of the Hybrid Methodology

This part will explain a little of the hybrid methodology between Design Thinking and SCRUM that is being carried out, which will have 10 phases as shown in Figure 3.

2.3.1 Empathize

Empathy is centred on the users, it is dedicated to the observation of their behaviour, iteration and personal interviews which allows the designer to have a greater understanding of the needs of those involved [13].

2.3.2 Define

The team will use the first phase to define the problems and complexities of the User [13].

2.3.3 Ideate

This stage is connected with the second phase, its objective is to brainstorm, to generate solutions, this allows the team to choose the ideal solution [14].

2.3.4 Planning Meeting

The user stories that will go into the backlog will be defined. The user stories are a set of simplified stories or requirements that identify a user, who and why they want this system functionality and the backlog is a list of user stories [15].

2.3.5 Sprint Backlog

The sprint backlog contains a set of tasks for each team member this will allow you to have a better implementation in the system, this are divided into sprint that would be like the deliverables that would have as a date for each deliverable to be made with the ability that you can work in a more orderly manner, taking into account this is done through the user stories.

2.3.6 *Daily Meeting*

The daily scrum meeting is the main way to review the adaptation processes in the scrum practice, the ideal is to meet for 15 minutes at the beginning, each team member declares his or her work to be done, taking into account that the meetings will discuss: What have I done since the last meeting, what am I going to do from now on, and what impediments do I have or will I have?

2.3.7 *Sprint Review*

At this stage the sprint will be checked, the check takes approximately four hours per month for each deliverable. In the sprint check an evaluation is made which is achieved during the sprint, the scrum team which inspects the increase and adapts to the delayed product if necessary checks the product and is responsible for defining the product and then moves on to the next sprint [13].

2.3.8 *Sprint Retrospective*

In this sprint we will identify which improvements can be implemented in the next sprint or in the current one to solve any issue or problem we find in the device [16].

2.3.9 *Prototype*

Finished with Phase VIII , this phase allows us to show the final prototype of our research.

2.3.10 *Testing*

In this final phase, feedback is requested from the user, with the aim of improving the Prototype.

METHODOLOGY.png

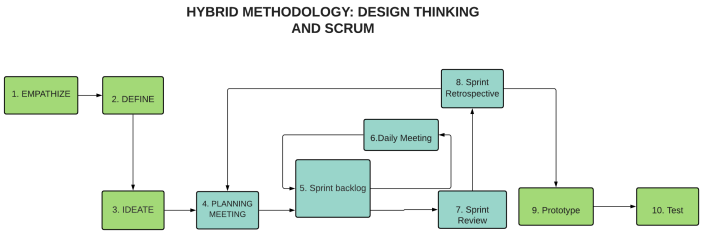

Figure 3: Hybrid methodology: Design thinking and scrum

2.4 *Tools for Designing our Prototype*

The tools for The tools for the design of the prototype with Balsamiq Mockups 3, Tinkercad and Augmented Class App will be defined, and finally the technical innovation explaining the technical development of augmented reality will be shown.

2.4.1 *Balsamiq Mockups 3*

Balsamiq Mockups is a tool to design mobile and web prototypes [17], with the components of the tool this will serve us to design our mobile application.

2.4.2 *Tinkercad*

Tinkercad is a tool that provides the creation of 3D models. It is currently free and runs from the browser [18], allowing the creation of simple or complex objects [19]. This tool will be used to perform in the design for the games and the 3D image will be exported so that it can then be imported into the Augmented class application.

2.4.3 *App Augmented Class*

It is an application to create augmented reality projects, this app is in Play Store which is currently in free mode, we use it to import the images that were designed in Tinkercad and we show it our prototype of the cognitive games.

2.4.4 *Technical innovation*

There are several ways to develop augmented reality, but in this article, the development of augmented reality with Unity 3D and Vuforia SDK will be explained.

Unity 3D is a 3D game engine in which it allows the design, creation and operation of a video game, integrates a multiplatform developed by Unity Technologies Co.Ltd. Unity 3D can add several virtual scenes sunlight, fog, water, fire, among other animated scenes. With the support of an extension called Vuforia SDK they can make several applications and games with Augmented Reality [20].

Vuforia SDK is an augmented reality software development kit used to capture flat images or 3D objects in real time which developers use to place virtual objects through a camera [20].

In this Figure 4 it can be seen that the mobile phone camera captures the real scene and Tracker is in charge of processing the image or rather tracking or analysing an image since together with the Targets they can recognise the 3D object, after matching the identification of the 3D object through the Frames of the camera (its function of the Frame is to capture image and convert it to a different resolution) The aim is to find matches in the database and thus create an augmented reality.

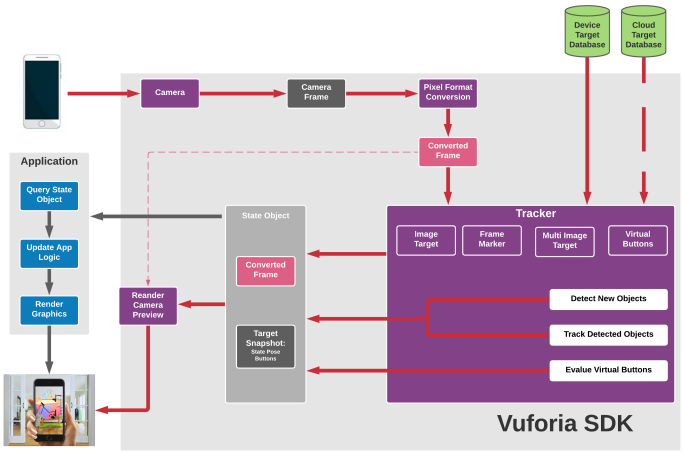

Figure 4: Vuforia SDK Architecture

3 Case Study

3.1 Empathize

We started with the first phase that was commissioned by applying surveys to parents about their children's education or how they feel in this new virtual mode so we used the Google Forms tool to formulate the questions.

Table 1 shows the questions (Q1 to Q10) that are formulated for the parents, which will have to complete the data of the children, age, gender, district, if the child learns correctly at home, if the child has stress at the time of his virtual classes, what type of autism the child has, it also shows at what level of autism the child is, the activity he likes, the family situation and if he currently has therapeutic treatment.

Table 1: Survey on the problems of autistic children in Lima-North

Questions	
ID	Questions
1- Q1	Child's age
2- Q2	Gender of the Child
3- Q3	District
4- Q4	Do you feel that your child is not learning properly at home?
5- Q5	Does your child get stressed out by virtual classes?
6- Q6	What type of autistic child does your child have?
7- Q7	What level of autism is your child at?
8- Q8	What activity does the child like?
9- Q9	What is the family situation in the child's home?
10- Q10	Does the child currently have therapeutic treatments?

3.2 Define

In this phase we will define the problems that are found according to the survey answered by the public.

In this Table 2, the problems presented by the survey will be indicated. Q1 through Q10, means the questions shown in Table 1 and their most relevant responses from the survey.

1. Q1 : It is understood that 7 to 9 years old are the most likely to have responded to the survey and have ASD.
2. Q2 : It shows that more male cases were found in children with ASD.
3. Q3 : It indicates that in Lima - North, in the district of Los Olivos it has a greater number of children with autism.
4. Q4 : It indicates that 51% of children are not learning properly in their educational training.
5. Q5 : This survey indicates that children are stressed out by the new virtual platform provided by the State of Education.
6. Q6 : This survey has identified that there are more children with Austistic Disorders and is followed by Asperger's Syndrome in Lima-North.
7. Q7 : A balance has been made that 47.1% suffer from a slight level of autism in the area of Lima-North.
8. Q8 : The survey shows that games are the activity most chosen by children.
9. Q9 : The survey shows that 54% of children with a disability are cared for by their parents.
10. Q10 : The survey indicates that 54.9% have therapeutic treatment, while 45.1% have no therapeutic treatment.

Table 2: Relevant answers according to the problems of the Public.

Answers	
ID	Answers
1- Q1	8 Years 31.4% , 9 Years 19,6% , 7 Years 11,8% .
2- Q2	Male 68,9 % , Female 31,4%
3- Q3	Los Olivos 25,5% , Comas 19,6% , Carabayllo 19,6%.
4- Q4	Yes 49% , No 51%.
5- Q5	Yes 62,7% , No 37,3%.
6- Q6	Autistic Disorder 52,9% , Asperger's syndrome 19,6%
7- Q7	43,1% Level 1(Light) , 47,1% Level 2(Medium) ,9,8% Level 3(Heavy)
8- Q8	Playing 39.2% , Dancing 25.5% , Drawing 19.6%
9- Q9	The father and mother live together, both raise the child 54%.
10- Q10	Yes 54,9% , No 45,1%

These statistics were taken from the survey that was conducted in September and October 2020 to parents who have children suffering from this disease, it was found that there was an increase of autistic disorder with level 1, level 2 and level 3 in northern Lima, taking into account that the district with more cases was the olive trees.

3.3 Ideate

According to the Problems identified in Phase 2, these solutions have been successfully devised to improve the cognitive development of ASD children. The team has then implemented a score from 1 to 20 and the best solution will be selected to develop it as shown in Table 3.

1. S1 : In this first solution it was identified that a mobile application for the cognitive development of autistic children can be elaborated using augmented reality in which their score is estimated by each working member (M1, M2 and M3), the M1 estimates 19 points, the M2 estimates 19 points and the M3 estimates 17 points and adds up to a total of 53 points.

2. S2 : In this second solution it was identified that it is possible to elaborate a Web Application for the child with autism to improve with cognitive activities in which his score is estimated by each work member (M1, M2 and M3), the M1 estimates 14 points, the M2 estimates 14 points and the M3 estimates 13 points and adds up to a total of 41 points.

3. S3 : In this third solution it was identified that it is possible to elaborate a Mobile Application for therapies and orientations for ASD children in which their score is estimated by each working member (M1, M2 and M3), the M1 estimates 14 points, the M2 estimates 12 points and the M3 estimates 11 points and adds up to a total of 53 points.

Table 3: Punctuation of the Ideas

Punctuation of the Ideas				
Solutions	M1	M2	M3	Total
S1- To make a Mobile Application with games for the cognitive development of autistic children using Augmented Reality	17	19	17	53
S2- Developing a Web Application for the child with autism to be trained with cognitive activities	14	14	13	41
S3- Developing an application for therapy and guidance for children with ASD	14	12	11	37

At the end of this phase, the solution with the highest score (S1) was identified by the members of the work team, which they used to carry out the project.

3.4 Planning Meeting

In the following table 4, the user story was important for the creation of the prototype design, which required an in-depth analysis of table 1. Table 2. Table 3. Which allows us to have the following 7 user stories.

1. H1 : The first user story will create an interface where any user will be able to create a new account to be registered in the system.

2. H2 : In the following user history 2, it will be possible to enter the system using the user and password that were created in the H1.

3. H3 : In the third user history, an option will be implemented so that the user can recover his or her password if for any reason it has been forgotten or lost.

4. H4 : In the user history 4 there will be an option where you can select your corresponding age, depending on your age that the user has you will be shown a list of available games.

5. H5 : In the user history 5 you can choose the game mode where you will get the games with their respective categories, this will depend on which option you have chosen in the H4.

6. H6 : In the following user story 6, the client will be able to rate the game, where he can leave his comment if he liked the game or what things we should change to make it more interactive and fun.

7. H7 : In the user history 7 you can check your history, where an interface will appear showing you how many hours you have played, your username and the date.

Table 4: User Stories.

User Stories	
1- H1	The user needs to register a new account (user, age, email and password) to enter the application.
2- H2	The user needs to log in by entering their registered username and password to access the application.
3- H3	The user needs to recover his password every time he forgets it.
4- H4	The user needs to select his/her age to enter the list of games.
5- H5	The user can select the game mode to get a list of the chosen mode.
6- H6	The user can indicate the rating of the game.
7- H7	The user will have a history of the games used.

3.5 Sprint Backlog

In this phase the four sprints will be carried out, according to the user stories that have been defined in the previous phase as shown in Table 5.

Table 5: Sprint Backlog.

Sprint Backlog		
ID	DESCRIPTION	SPRINT
1- H1	- The user needs to register a new account (user, age, email and password) to enter the application.	Sprint 1
2- H2	- The user needs to log in by entering their registered username and password to access the application.	
3- H3	-The user needs to recover his password every time he forgets it.	
4- H4	- The user needs to select his/her age to enter the list of games.	Sprint 2
5- H5	- The user can select the game mode to get a list of the chosen mode.	
6- H6	- The user can indicate the rating of the game.	Sprint 3
7- H7	- The user will have a history of the games used.	Sprint 4

As shown in Figure 5 the first deliverable that would come to make the sprint 1, would be made up of the first interface that would come to make the home page that has 2 options to register and log

in, then the next would be to register if a new user, log in if you already have a registered account and finally recover password if the user forgot the password of the login.

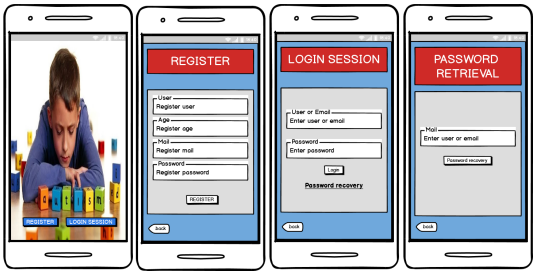

Figure 5: Sprint 1

Sprint 2 in Figure 6 shows h4 and h5, which would make the selection of the game mode by age and the selection of the game mode chosen by the user.

Figure 6: Sprint 2

In this Figure 7 will go the h6, this will include the sprint 3 that dealt with the qualification of the game and comment this would serve to ask the user what he thought about the experience of the game and what improvements he would recommend.

Figure 7: Sprint 3

As shown in sprint 4 of Fig 8 of h7, you can see the user's history by date, the name of the game, start time, end time and how many hours they have played, this will serve to see how much time they spend on the game.

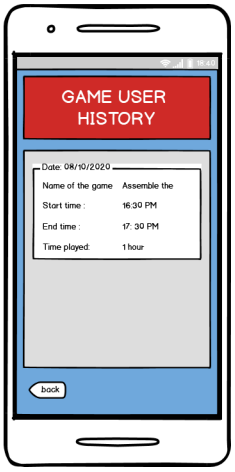

Figure 8: Sprint 4

3.6 *Daily Meeting*

When each Sprint is carried out, it is essential to hold these meetings for 15 people in order to better position ourselves in the collective work. The Scrum Master is in charge of generating the meeting and asking these questions: What did you do yesterday? What are you going to do today?

3.7 *Sprint Review*

After finishing each Sprint, it is necessary to carry out this review by the team, you will have a maximum of 3 to 4 hours for evaluation, and they must be explained to the Product Owner for him to accept, then be shown to the users or assistants to obtain some comment or an improvement of the product. After the assessment is completed, the next Sprint is issued and if all Sprints are completed, the next phase is performed.

3.8 *Sprint Retrospective*

In this case the process will be evaluated and the Scrum Master generates a meeting with the Product Owner and the Work Team, to improve the next process, then it asks itself: What did we do well, what can we improve and what should we stop doing?

3.9 *Prototype*

In this phase, the Final Prototype will be shown as it can be seen in Figure 9 that will be made with Balsamiq Mockups 3, this will be the final sample of the Application that will be used by means of the Augmented Reality where 4 games were made.

3.10 *Testing*

In this final stage a survey will be carried out on Google Forms where 5 questions of the prototype will be asked (QP1 to QP5),

the public will give their point of view about the prototype or what improvements would be applied as shown in Table 6.

Figure 9: All Games

Table 6: Survey about the Prototype for the Cognitive Development of ASD children applying Augmented Reality

Questions	
ID	Questions
QP1	Tell us what you thought of the Prototype.
QP2	Tell us how you found the Cognitive Games for your child.
QP3	I would recommend this application for TEA children.
QP4	You think your child will learn using this application.
QP5	Write your opinion on how we can improve the application.

3.11 Mobile Application Algorithm

The design algorithm of the mobile application is shown in Figure 10 and will be explained in detail in the following description.

1. Identification of cognitive problems for autistic children: The research work started on how we could identify cognitive problems in autistic children.

2. Are there any cognitive problems? : The first conditional was made if a problem was found, the cognitive problems in the autistic children had to be identified again, but if no problem was found in the identification, the next process was made.

3. Analysis of the problems identified: In the 2 process an analysis of all the problems was made on all the processes that have been accepted from point 1.

4. Feedback: In the 3 process we made a feedback where we are going to analyze all the requirements we need together with the new ideas of the work team.

5. Do you meet the requirements? : We carry out the 2 conditional where we ask ourselves the question of point 4 if it fulfils all the requirements to go on to the next process. If it does not, new requirements will be reconsidered in order to be accepted.

6. DesignScrum Methodology: Then in the 4 process we apply the DesignScrum methodology which will carry out the research work

7. Mobile Prototype: In process 5 we started to create the prototype of the mobile application after having identified all the problems and created the necessary requirements.

8. Do parents agree with the prototype? : On the 3rd conditional a survey was sent to all parents who are using the prototype to find out their opinion and what new ideas we should add. If the parents did not agree, we would have to go back to the previous point to restructure the prototype of the mobile application. If they accepted, we would go on to the next process.

9. Augmented Reality Prototype with Tinkercad and App Augmented Class: In the sixth process, the application was begun with Tinkercad and the Augmented Class App. This will serve to add the design of the prototype and add the Augmented reality to the project in which the project will be completed.

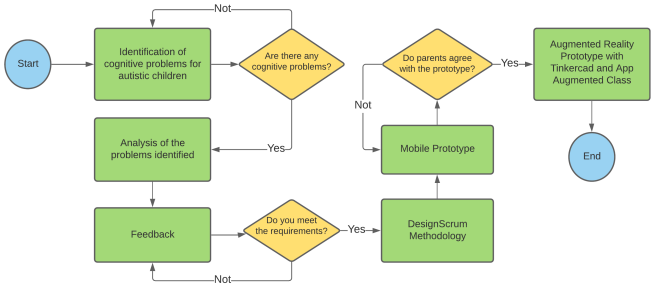

Figure 10: Mobile Application Algorithm

4 Results and Discussions

In this chapter we show our results according to the analysis of the survey of the last phase of the survey carried out, The Application of the Prototype and the methodology.

4.1 About the Survey

In the last part of the case study, a survey was carried out with 5 questions on the final prototype (QP1 to QP5). In this result from Table 7, we show the relevant responses indicated by the public about our prototype.

1. QP1: In this result he indicates which prototype the parents think is good.

2. QP2 : Parents indicate that they find games very good for the cognitive development of autistic children.

3. QP3 : It indicates that in Lima - North, in the district of Los Olivos it has a greater number of children with autism.

4. QP4 : Parents feel confident that their children will learn using the application.

5. QP5 : Good feedback was obtained on the improvement of the Prototype of the mobile application.

Table 7: Relevant answers according to the prototype shown to the public.

Answers	
ID	Answers
1- QP1	Good 46,2% , Very Good 23,1% .
2- QP2	Very Good 38,5% , Good 23,1%
3- QP3	Yes 84,6% , No 15,4%.
4- QP4	Yes 84,6% , No 15,4%.
5- QP5	The public indicate that they must do better in developing more games for their children.

According to the responses from the public, it can be seen that the vast majority of the respondents are satisfied with the prototype, which was our expectation when the work started. In the survey, 46.2 % of the respondents were satisfied with the prototype and 23.1 % were very satisfied, which shows that they found the prototype very interesting. It is also noted that cognitive games have 38.5 % very good and 23.1 % very good, which impresses us that the public is comfortable with the games, taking into account that 84.6 % of respondents say that the mobile application will be recommended and that their children with autism strengthen or improve their cognitive development. Finally we obtained positive recommendations from the public as it encourages us to improve the prototype, fulfilling the objective of the methodology.

4.2 Prototype Application

According to the design of the prototype of the game, it was possible to design the games with Augmented Reality using the Tinkercad tool and Augmented class.

In Figure 11 you can see the prototype is working correctly in the mobile phone by means of augmented reality, the game being presented the child will have to guess the correct word as shown on the screen of the mobile phone.

As shown in Figure 12 the prototype works correctly, the game will be a maze where the child will have to identify the correct path so that he can reach the end of the maze and move on to the next level.

Figure 11: Game 1

Figure 12: Game 2

Figure 13: Game 3

As shown in Figure 13, the child will try to assemble the human body where he will have several opportunities to finish the first level of the game.

Figure 14 shows the last set made of the prototype working correctly on the mobile phone. It tries to allow the child to build his house with the objects shown on the mobile phone.

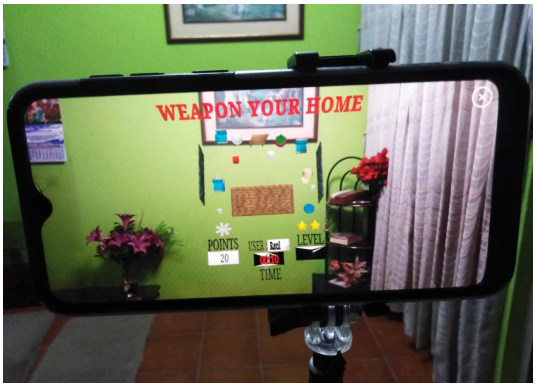

Figure 14: Game 4

4.3 About the methodology

4.3.1 Advantages

The union of two methodologies was made to carry out the hybrid methodology. This gave us a usefulness since it allowed us to better structure the phases of the research work. Scrum allows us to work on different projects with different requirements. With a compromise, this offers to guarantee a model that benefits all the needs of the project having the facility to put together other methodologies and tools [21]. Design Thinking will include these benefits as transformation, innovation to improve decision making as well as results [22], allowing the combination of empathy, creativity, coherent analysis of information and adjustment to the environment according to the solutions [23].

4.3.2 Disadvantages

The disadvantage of the hybrid methodology that is being applied is a little complex as it has 10 phases. Therefore, what is disadvantageous is that some fundamental steps cannot be eluded, taking into account these phases require a longer time of analysis to develop the processes.

4.3.3 Comparison

According to what was evaluated, from the scrum methodology and Design Thinking it was decided to carry out a hybrid methodology where it would contain 10 phases so that it would have a better structure when developing the research work. On the other hand, the difference of these two methodologies with the hybrid methodology is that scrum is structured more to the software part and Design thinking is structured to the analysis part, taking into account the hybrid methodology focuses on the software and analysis part allowing a better understanding when deploying the project.

5 Conclusions

The application was developed to work with augmented reality allowing to improve the cognitive development of all the autistic children. For the mobile application different games were added, where each category will have its corresponding game so that the user can choose the game the option he wants. Allowing us to implement the hybrid methodology where the application was developed, helping us to innovate and manage the development of the mobile application. In the case study, we defined how the application was structured so that the child could learn with the use of technology. It would be of great help to use the mobile application for cognitive development for the treatment of all children suffering from different cases of autistic disorder, so that children can have a better experience, allowing to generate a great impact of learning in education in Peru. For future research work it is recommended to use Tinkercad's tools with Arduino, this will allow for a better optimization when developing the application. It is also possible to use unity3D for the operation of the application while vuforia SDK would serve to apply augmented reality to any system, be it web or mobile application.

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