International Journal of User-System Interaction 12(3) 2019, 133-148

Design assistive technology for handling moldable mass for children with absence of upper limb. (Project “Marte, Imagination is the Limit")

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Abstract. "Marte" is the result of an academic project, undertaken in 2017 at the University El Bosque in Bogotá during the undergraduate degree of Industrial Design, it is a product that facilitates and optimizes therapies for pre-prosthetic and prosthetic rehabilitation by handling molding compositions and molding tools, in order to improve trophism and muscle quality of children with upper limb amputation, transradial congenital malformation type. According to the observations of children with this type of malformation, generally their limited participation is improved in artistic activities which also require coordination and controlled use of both hands. The development of the therapies was performed by a multidisciplinary team at the Laboratory of University Manuela Beltran, with children between 3 to 8 years for 5 months (around 17 hours). The approach to the therapies was to invite playful exploration and creation of clay models using assistive technologies. It was concluded that levels of attention and memory were related to the selection processes for their development models in clay and the freedom that the children had to choose them; it was also concluded that the therapies helped improve their motor, coordination and planning skills thanks to the gradual increase in difficulty of the tasks.

Keywords: Assistive technology, sculpting, muscle training, Phocomelia, 3D printing.

1. Introduction

"Marte" was the name selected for the project, union of the words "mano and arte" (hand and art in Spanish); the project is based on an Orthosis addition type, which allows children with agenesis upper end of transradial type or cross congenital malformation forearm to manipulate deformable mass, based on the exchange of certain molding tools, with the main objective of

optimizing muscle rehabilitation therapies and prevent muscle tropism.

The development of the project consists mainly of three stages; research, in which the topic to be treated was deepened, including the scientific concepts of the area; design, process in which the objective of the research was defined and developed; and finally the verifications with real users.

"In Colombia Almost 20 out of every 10,000 children are born with some type of malformation in one of their extremities, and 14% of the population has some type of physical disability ". So in Colombia there are about 1,400,000 people with physical disabilities" 0 of which 1,245 are children who have congenital malformations partial or total upper limbs (Focomelia), treated as alterations in a limb from birth; approximately 50% use their prosthesis regularly, 25% permanently and the remaining 25% do not use it at all ,causing loss and deterioration of muscle mobility.

When starting the fitting process or after amputation, different stages are determined prior to installation of the final prosthesis, a process that can last between 45 to 60 days, the extensive process tends to provide psychological susceptibility of patients who sometimes prefer to leave the process, causing subsequent orthopedic problems.

2. Background

Modern rehabilitation therapies use some type of mechanical device to help the patient develop basic muscle memory for simple tasks, like grabbing.

These devices tend to be simple prosthetics for general use, and are not specifically design to teach, they are not a tool that can be modified to reinforce a specific activity, like fine motor movement, strength gain, collaboration with other people or self-expression through art and customization.

For the daily life of someone who uses a prosthetics arm, there are a wide range of accessories depending on the function that is required, from grabbing, eating, bathing, etc. These traditional prosthetics help restore part of the function of the extremity, but there is a wide field of exploration for the psychological development and acceptance of the prosthetics by using art and collaboration that can have a significant impact on restoring other aspects of the missing limb, taking into account this, it is observed that at present the need for personalized and based objects according to the dimensions of the person is increasingly common, so the incursion of new technologies such as

3D printing is not only necessary and fundamental, It is also a reality, optimizing the production processes and obtaining results with greater feasibility of success in its use.

According to the articles and abstracted literature, the remarkable potential and future of 3D Printing technology is demonstrated, as it is, it is increasingly used in areas where its need was not believed or visualized, design and construction reports are observed of attachments for feeding processes or as a method of producing replacement parts of organs or body segments such as prostheses or orthopedic elements.

However, currently it has not been explored in the artistic area and that is how the "Marte" Attachment becomes the first 3D printed product, which allows children with agenesis of the upper limb to perform plasticine molding activities.

The objective of the research was set to filling this void using design think and implementing the following fundamental concepts of design:

2.1 Universal Design

Defined as the development of objects and spaces accessible to as many people, including people with disabilities; this applies to functionality, anthropometry, aesthetics and price (National Disability Authority, 2012, P.27). The universal design proposes seven principles:

1. Equitable: provides equitable, identical or equivalent solutions and avoids segregating any user.
2. Flexible use: allows the choice of the method of use and facilitates precision and precision.
3. Intuitive: provides consistent information for a wide range of literacy and language skills.
4. Perceptible information: provides essential information in a readable way by graphic or verbal means.
5. Error tolerant: it provides the elements to minimize errors and possible risks, and also warns about it.
6. Use of minimal effort: it facilitates the user to execute the activity under a neutral body position, minimizing the necessary forces.
7. Size and space: adapts to grip variations, and is comfortable for the user regardless of position changes.

2.2 Minimalism

Artistic trend, based on "less is more" famous phrase of Mies Van der Rohe, one of the most influential designers of all times, this style is known for handling various basic elements such as lines and planes, as well as trying to reduce to essentials, reducing excess elements or accessories
The minimalist design features represented in the project are:

- Simplicity: emphasizes the functionality and experience of the user against unnecessary ornamentation, using fluid forms and neutral colors.
- Balance: through the use of reticles you get a symmetrical and proven aesthetic.
- Accents: shapes and colors are manipulated to highlight some important details in the compositions.

2.3 Human Activity Assistive Technology

Proposed by Susan Hussey and Albert Cook in 1995, this conceptual model provides guidance for the selection and evaluation of assistive technology in intervention processes under this premise, it is taken into account that when the person's abilities are diminished or barriers that limit the function are presented, it is considered that a resource can be the assistive technology, however, the identification of the required skills must also be taken into account for the use of assistive technology, since this technology must be adapted to the needs of the person in order to achieve the objective and development of activities autonomously and independently.

During this process of selection, evaluation, training and use of assistive technology, the person is accompanied by a team of professionals that will allow adaptation to be enjoyable and effective, improving the participation levels of people who use assistive technology to develop some type of activities.

2.4 User Centered Design UCD

The product development is based on this multidisciplinary approach, the quality with the objective and the concern of obtaining products with a thorough investigation and evaluation regarding anthropometry, biomechanics, ergonomics and user usability techniques. Among the main

designers and architects that influence this approach are Norman Bel Geddes, Henry Dreyfuss, George Nelson and Ray Eames, who offered a vision around the needs of people, obtaining products with a high degree of innovation, more useful and usable, In addition to new techniques and working methods.

The UCD rather than a methodology is considered a design philosophy, since users must be located as a center and guide for each of the decisions to be made during the design process, that's why designers not only create objects but also create experiences , where under no circumstances is it possible to decouple the relationship between the use, context, needs and motivations of the consumer; being so that although the usability factor is one of the fundamentals of DCU, it also allows the design of products with a greater visual impact and more desirable around the UX user experience (Galeano, 2008, P. 2).

As of ISO 13407 (currently ISO 9241-210 (International Organization for Standardization, 2010)), there are four phases for product development:

- Context of use: process in which the target user is identified and defined, mode and conditions in which the product will be used.
- Requirements: identify the needs and requirements of the user, as well as the principles for proper and proper use of the product.
- Design solutions: through different methodologies such as brainstorming, possible solutions are conceptualized which are synthesized and developed to obtain the final design solution.
- Evaluation: normally through the verification phase with real users, the proposed solutions are validated, according to the stipulated requirements, or on the contrary usability problems are detected.

A product based on DCU must comply with three fundamental principles; usability, a product that is easier to use, comfortable, understandable and accessible, which facilitates the execution of the workforce or task to be supplied; the utility, conceived as the perception of the person as to the advantages or disadvantages in the performance of the product, system or service when carrying out the activities; and desirability, comprising the three levels of the brain in which the design must act, visceral level, related to the first impression generated by the object; behavioral level, in terms of understanding the use of the object in the interaction experience; and finally reflective level, it allows to create lasting relationships with objects, through the satisfaction of obtaining it, seeing it or using it (Norman, 2004, P.63).

3. Metodology

Type of research: This research is of a qualitative type with a type of descriptive study that aims to identify and relate the interaction of boys and girls with agenesis of upper limbs with assistive technology during the performance of plasticine molding activities.

Population: boys and girls with agenesis of the upper limb with ages between 2 and 12 years, the presence or comorbidity of another disability was considered as exclusion criteria.

Information gathering techniques:

- Direct observation: the observation was carried out through structured activities, which were divided into two phases; To begin as an approximation method, the children had to execute basic geometric figures, giving the possibility of experiencing the different tools and their functions; subsequently, the guide or step-by-step of the compositions graduated by difficulty levels was included, where the babies had to follow the sequence of steps and sequences to reach the chosen character.
- Field diaries: an audiovisual record of each of the sessions was obtained, in order to describe and analyze the behavior of children in the activity, therefore, the attitude and response of the user during the development of To identify how is the relationship between technology and the child was established, these results were recorded in a field diary.

4. Concept development

The training planning process in the use of “Marte” for boys and girls, consists of 30-minute sessions in which the approach and exploration to technology is carried out, as well as activities graduated by levels of complexity that invite boys and girls to make modeling clay models.

The planned activities were incrementally more difficult and were designed to evaluate two things:

- Motor Capabilities: mirrored positions in the frontal and sagittal plane, and both bilateral coordination and contralateral; by fine

motor evidenced in the precision of movement, visual monitoring and appropriate handling.

- Sensory Abilities: as pressure points, discomfort and user tolerance with the attachment

The first stage was done at the Laboratory of the University Manuela Beltran of Bogotá, every Saturday for 13 sessions during the second half of 2018, the test was done in company of occupational therapists, physiotherapists and psychologists.

The test was executed as planned, and even if initially, one of the children did not felt like using the attachment, the activities and collaboration with the other child encouraged him to do so and eventually both completed all of the tasks and were highly involved and excited during the process (Figure 1 and 2).

The results of this initial test gave important information for the direction that the project and prototype should take, from ergonomics to aesthetics.

Figure 1. Artistic Therapy

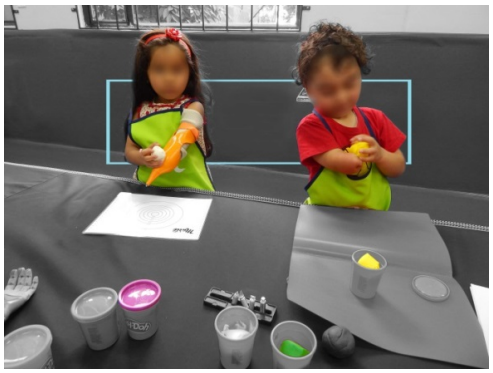

Figure 2. First test phase.

For the second test, participant data was collected through basic exercises and tests, this included motor, sensorial and social skills, this served as a baseline for the second stage, this was important to understand the improvements from the use of the attachment and the therapy, in addition, a 12-year-old infant was included as a case study, with agenesis of the upper limb at the wrist level and with Down syndrome (Figure 3), with whom the assimilation of an external element is sought, in this case “Marte”, in order to later become in candidate for the prosthesis. One of his greatest advances was the assimilation of the texture, color and fragrance of the masses, the increase in the time of acceptance of the delay, by following instructions and relating the consequences by not aplaccepting them; subsequently, the independent use of the orthosis was appreciated, and the independent organization of the complementary elements such as the plasticine in its respective receiver.

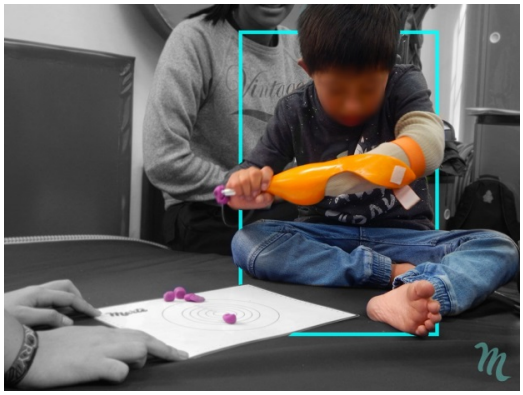

Figure 3. Second checking period.

The results were encouraging, as children saw the therapy as a game and an opportunity, not only to sculpt figures, but as a freeform exploration that helped them relax and avoid frustrations while learning to use a prosthesis.

5. Design and Prototype Development

The prototype was modeled (Figure 4 and 5) in a CAD (Computer Assisted Design) software that allowed easy variations for each child, depending on individual conditions. Once the design for each child was done, it was 3D printed and assembled. Additional components as bolts and padding were standard off the shelf components (Figure 6 and 7).

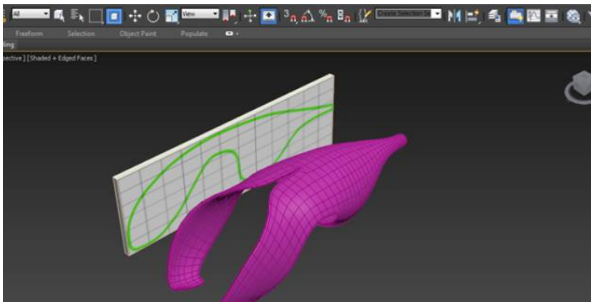

Figure 4. 3D modeling in CAD program.

Figure 5. 3D printed prototype.

The shape of the device was a lightweight shell and only focused on one function, this allowed the prototype to be easily manufactured, easy to use

and economical. Its soft organic curves and the single point for the tool at the end was ergonomic, approachable and of great interest to the children.

The tool allowed easy control and gave the children the ability to make fine details with its tip. The Idea was to develop a complete system that would include everything needed to get started: the attachment, multiple tips, three different colored clays, instructions, apron and activity guides.

Figure 6. kit components.

Figure 7. kit components.

The activity kit has multiple options for each task, this was shown to improve concentration and memory, when the child was given the option to choose what model they wanted to make (Figure 9).

The gradual increase in difficulty for each task was shown to improve motor, perceptual and planning skills, and tasks that promoted collaboration

were shown to improve social skills and self-perception and acceptance.

During the process of development, a website (Figure 8) was created to allow a better communication between the research team and parents, it was also used to share resources and results and although this was initially only planned for the trails, it was later developed further as an additional component of the system, which will also allow access to support network and create a community to improve adoption of the device and therapy and create an environment where barriers to the child's development are reduced.

Figure 8. Online community proposal.

Figure 9. Use of "Marte".

6. Results

The After 17 hours of therapy, a significant improvement in motor, sensorial and social skills were measured in all participants.

The use of a proto-prothesis with recreational tasks with flexible goals and an environment with other children with disabilities improved the child's self-perception and that of the prostheses.

All participants were happier at the end of each therapy session and felt increasingly more comfortable with the use of the device and more capable at manipulating complex objects and reaching a satisfactory result with their projects.

The results were specific according to the following study categories:

6.1 3D technology design for artistic activities:

According to the articles and the summarized literature, the remarkable potential and future of 3D printing technology is demonstrated, since it is increasingly used in movements in which its need is not created or visualized, design and construction reports are observed . accessories for feeding processes or as a method to produce replacement parts of organs or segments of body stories such as prostheses or orthopedic elements.

However, for the moment it has not been explored in the artistic area and this is how the ad "Marte" becomes the first 3D printed product, which allows children with agenesis of the upper limb to perform plasticine molding activities .

6.2 Relationship between activity and attachment:

A pleasant acceptance on the part of the children with the product is visualized, taking into account that the affected activities had a game approach, that had a focus and the possibility of the children's free expression, this happened to them. participation in a stimulating environment that resulted in processes of creation and development of favorite characters with whom they identify.

It was considered that at the beginning, when he had his first approach to attachment, the boys and girls were interested and curious to understand how this design allows them to make clay figures, since some boys and girls initially reported that they were not able to make the model in plasticine, during the sessions feelings of comfort and ease of use were evidenced, as well as happiness and satisfaction to achieve the proposed models.

It was also detected during the execution of activities related to posture, coordination and sensory skills to identify how to influence the use of

attachment on them.

6.3 Posture

According to the tool, the user executed the different movements of biomechanics (flexion, extension, abduction and adduction). The form of use from the beginning was quite intuitive and independent, especially in the installation of the tools, however, to maintain the composition the support person was necessary. At the beginning of the verification phase, the ignorance of the accessory's function was evident, so sometimes we prefer to carry out the molding activity with its stump, although in the process of detailing what the necessary tools are, the need of attachment is understood and how they could replace the different functions of the absent body segment.

It was found that at first the children assumed compensatory and uncomfortable positions that made it difficult for them to perform some steps, such as shoulder difficulties; however, as the activities were carried out, the children assumed a sitting position with flexion angles at the hip, knees and ankle, which facilitated control of the trunk and decreased shoulder tension during the activity.

6.4 Coordination:

It is key to highlight that I expected the boys and girls to prefer the simplest characters or those that are composed only of basic geometric figures, however, the more complex compositions and with more details according to each level of difficulty are eligible, since as well as what he recognized characters. At the beginning, it was evident that the modification of the attached file was more cumbersome and the way of using the tools was more difficult for them, as time passed they obtained greater agility and skill using the tools, thus independently solving the different problems that arose, observing bilateral and contralateral coordination processes with the use of the accessory.

6.5 Sensory

The adaptation process is considered quite short, although at first when more

physical effort is required to perform the functions mainly of cutting figures such as the triangle, there is redness around the stump; later, when obtaining a greater skill in its use, it does not require any participation of the skin.

6.6 Socio-affective skills

The transformation of moldable masses allows children not only to make characters or figures, but does not allow them to autonomously experience a material with infinite possibilities, encourage the solution of small problematic problems that arise and avoid frustration . create short-term achievements or objectives, which makes it a moment of relaxation and concentration, which allows them to interact with both their peers and with the specialists present, to evoke conversations and imagination of stories and games around the compositions.

During the execution of the activities it was observed that the children were more empathic with their peers, expressed feelings of satisfaction and achievement as they built more complex models; likewise, the growing interest in participation in artistic creation activities with easy-to-use attachments was noted (Figure 10).

Figure 10. Resulting Composition.

7. Conclusions

It was observed that there is a good disposition to the material, the activity and the product, observing that from the beginning there was an omission of the arm with agenesis, however, during the participation in the proposed activities, the children began to use it. more frequently, as a tool to mold and detail the constructed figures, how to perform in greater detail the volumes in clay, in addition to specifying some physical qualities, such as the mouth, eyes, ears, among others.

The use of the device "Marte" allowed the potentialization of bilateral coordination skills, precision, regulation of strength and agility of the upper extremities, it was also evident that children improved their concentration, attention and memory levels and started the process of solving small problems, which were presented during the development of the characters.

With the use of artistic activities, the work is encouraged by short-term objectives and goals, which favors that there is no frustration and subsequent decline of the process, plasticine molding activities favor and encourage interpersonal relationships, in addition to evoking conversations , which generates a process of empathy.

Technological projects executed with an interdisciplinary team not only provide a more complete result but also a greater scope and benefit for people.

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