Design Practice for Sustainability: development of a low-cost orthosis

Caelen Teger
LABERG (Ergonomy and Usability Lab), UFPR, Av. Cel. Francisco H. dos Santos, 100, Centro Politécnico, Jardim das Américas, Curitiba/PR - Brazil[1], Master's degree Researcher, caelenteger@gmail.com
Isabella de Souza Sierra
LABERG (Ergonomy and Usability Lab), UFPR, Av. Cel. Francisco H. dos Santos, 100, Centro Politécnico, Jardim das Américas, Curitiba/PR - Brazil, PhD Researcher, isa.dss@gmail.com
Dominique Leite Adam
LABERG (Ergonomy and Usability Lab), UFPR, Av. Cel. Francisco H. dos Santos, 100, Centro Politécnico, Jardim das Américas, Curitiba/PR - Brazil, PhD Researcher, domiadam@gmail.com
Maria Lúcia Leite Ribeiro Okimoto
LABERG (Ergonomy and Usability Lab), UFPR, Av. Cel. Francisco H. dos Santos, 100, Centro Politécnico, Jardim das Américas, Curitiba/PR - Brazil, Professor, lucia.demec@ufpr.br
José Aguiomar Foggiatto
NUFER (Additive Manufacturing and Tooling Center), UTFPR, R. Deputado Heitor Alencar Furtado, 5000, Ecoville, Curitiba/PR - Brazil, Professor, jafoggi@gmail.com

ABSTRACT

The use of low-cost 3D printers, and other such technologies, has contributed to the development of sustainable products since they only use the material needed for production and are specifically

customized for the person, reducing the cases of abandonment and increasing the product's life cycle. In this context we developed a wrist orthosis using the user-centered design approach along with the fundamentals of sustainability, ergonomics and the limitations of the low-cost production process. Using this product as an example we discuss the positive impact this method can bring to the three pillars of sustainability: the product is economically viable, considering the low-cost technology, socially just, both in terms of access, production and inclusivity and ecologically correct, from the minimization of material used for manufacturing and abandonment of the product. Finally, we propose a reflection about the product development process that balances functionality, sustainability and design.
Key Words: Design, Sustainability, Orthosis, 3D print.

1. INTRODUCTION

Design practice has evolved in terms of scope and approach (Suri, 2003). Its scope increases as it fits into medical and engineering contexts as a possible problem solver in ways not previously presented to the original developers. By having a role in the user-centered design practice (Ornelas & Gragory, 2009), design stands as an alternative project mediator within related areas, considering the context and the functional, aesthetic, social and symbolic needs of the product's users.

In terms of changes in approach to design projects, there is a confluence of the insertion of other areas into the design process and the natural evolution of the area itself (Suri, 2003). In this way, new possibilities for the realization of projects are inserted in a more effective and efficient manner, and concepts such as sustainability (Bhamra & Lofthouse, 2016, Vezzoli & Manzini, 2008), social design (Ornelas & Gragory, 2009; Margolin & Margolin 2004) and experiential design (Suri, 2003) that affect how a project is developed are included.

At the intersection of these new possibilities there are Assistive Technology (AT) resources, that refer to products, systems and services, developed to increase the autonomy and functional capacity of people with disabilities and reduced mobility for quality of life improvement and greater social inclusion (Brazil, 2015; Ornelas & Gragory, 2009; Margolin & Margolin 2004). These products are traditionally developed by skilled professionals (Moraes et al., 2018; Basso, 2012), generally with medical training (Marins, 2011), they normally only consider the functional aspects of the product, lacking solutions that meet all the users' needs, whether they are functional, symbolic and/or aesthetic. By using a user-centered design approach, it is possible, for example, to use specific techniques and tools that provide the most appropriate solutions to the global context and the needs of users and the society in which they are embedded (Basso, 2012, Ornelas & Gragory, 2009).

The main problems encountered in the development of AT products are: waste caused by the development process by "trial and error" (Beretta, 2011), the delay in the manufacture of equipements that quickly become obsolete (Moraes et al, 2018; Basso, 2012), and the inadequacy of products to users in aesthetic terms, which imply abandoning and early discarding (Basso, 2012). These problems are also related to sustainability issues as they stand in opposition to the pillars of economic viability, socially justice and ecologically correctness (UNGA, 2005).

AT products, as well as all others, should take into account not only the functional aspects but also the aesthetic and symbolic ones (Paschoarelli, Campos & Santos, 2015; Löbach, 2001) to improve the living conditions of people, both by reducing stigma, which prevents abandonment, and by increasing the identification of people with the product. In complement Pullin (2007) states that with design it is possible to change the perspective of social issues and the stigma of disability. Also, AT products that are inadequate in these aspects can affect user's safety, social opportunity, stress level, sense of belonging, self-esteem and physical health (Margolin & Margolin, 2004).

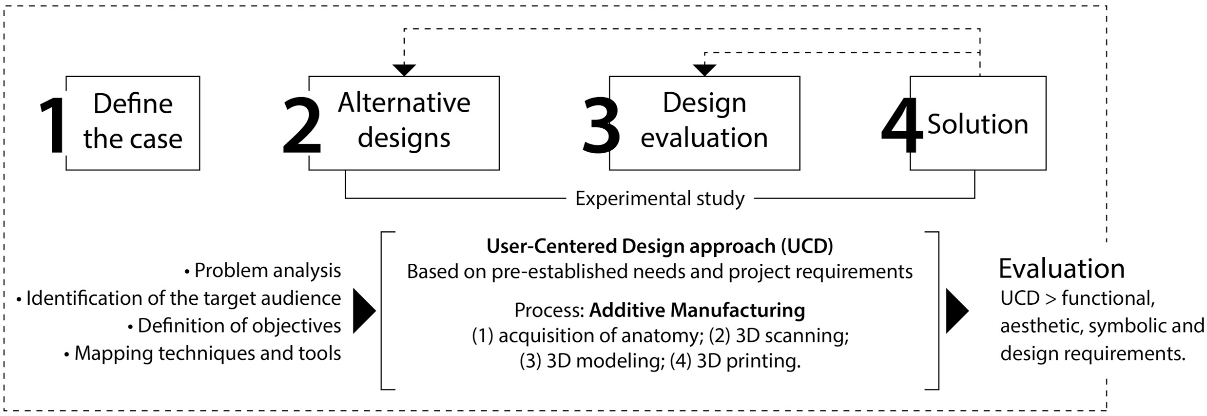
New technologies, when combined with project planning, contribute to the creation of more sustainable products. For example, the additive manufacturing (Volpato & Carvalho, 2017) facilitate the production process, spending less material needed for product development. In addition, it is possible to use materials such as PLA (polylactic acid), which is a biodegradable polymer constituted by the fermentation of starch-rich plants (Canessa, Fonda & Zennaro, 2013) which when converted into filaments can be used in 3D printing projects or reuse the materials into filaments for the generation of even more sustainable products. Nonetheless, there are also some setbacks and limitations of 3D printing such as the possible exclusion of people without the access to the technology, the energy use and the importation of materials and machines that may not come from local suppliers, these can be mitigated by innovative solutions, but are still points to be considered (Daly, 2016). In relation to 3D scanning technology, it contributes to the development of products in a fast and customized way, attending to the specific needs of the users (Beretta, 2011).

This paper presents the development of a assistive product (wrist-hand orthosis), which encompasses the principles of product development from a user-centered design approach and taking into account the principles of sustainability and new technologies available (mainly low-cost). It discusses the possibilities of the use of new technologies as allied to the development of sustainable and ergonomically adequate projects and the aesthetic influence of the product for its acceptance.

2. MATERIALS AND METHODS

The wrist-hand orthosis was developed based on the method proposed by Löbach (2001), and illustrated in Figure 1. From a user-centered approach, the process prioritizes the functional, aesthetic and symbolic requirements of the product, as well as design requirements that aim at sustainability, low cost and customization (Basso, 2012; Ornelas & Gragory, 2009). At first, the problem, the context and the target audience were identified.

Following, an experimental phase of the study was started, composed by the generation of alternatives, selection and prototyping. At this stage, from the pre-established needs, five design alternatives were developed for the design of the orthosis. Among them, one was selected as a final alternative to be prototyped. To do this, it was necessary to acquire the anatomy of the wrist, followed by 3D scanning, modeling, 3D printing and finishing. It is important to emphasize that the experimental study is not linear and that the link between methods, methodological approaches and productive processes depends on calibration and adequacy of theoretical and technological languages. In this way, it is possible to go back to the previous steps in order to verify the best design solution according to the problem encountered and the production limitations.



[Figure 1] *Applied method (Font: the authors, 2019)*

2.1. Materials

We used plaster bandages to acquire the wrist-hand morphology (Rosenmann, 2017) and the Recap software (Autodesk, 2019b) for 3D digitalizing. The mesh treatment and preparation (defect repair) was performed with Meshmixer software (Autodesk, 2019a). With the mesh repaired, the design changes were made using Rhinoceros (McNeel et al., 2019) and Solidworks (SKA, 2019). Finally, the file was finalized with Repetier (Hot-World GmbH & Co., 2019). For the production of the prototype, additive manufacturing process was used (Volpato & Carvalho, 2017; Canessa, Fonda & Zennaro, 2013). For this project we used 0.3 mm thick layers with PLA filaments with the low-cost 3D printer Stella (Good 3D Printing, 2019 - Figure 4).

3. RESULTS

The results of this work consist in the elaboration of the project and its consolidation in a final alternative as planned in figure 1 and shown below.

3.1. Characterization of the target audience - *persona*

A *persona* of a 43-year-old woman with chronic tendinitis in the wrist was conceived due to the excessive and constant use of the computer. Wrist immobilization with the use of a wrist-hand orthosis is a medical recommendation and should be uninterrupted. The user demands a wrist-hand orthosis that can be used during a social event. Her report shows difficulty in acquiring a product that offers, besides functionality, a pleasant look (according to her subjective judgment). In this sense, the briefing makes clear that this user wants to feel included in their social group, and that the use of a traditional orthosis in the market does not make this desire possible.

These characteristics translate to the following requirements:

- Functional: safety, comfort, stability, respect to the anatomy and offer of an ergonomic product.
- Aesthetics: pleasantness of form, sensitization, identifying characteristics of artistic movements sympathetic to the user; generation of desire to use.
- Symbolic: inclusive in the context, disruptive of "medicalized" aesthetics and status through exclusivity.
- Design: low cost, sustainable, customizable.

Next is the experimental study of the development of the wrist-hand orthosis for this *persona*.

3.2. Anatomy acquisition

The user had the anatomy of the wrist acquired by means of cast bandage and the 3D scanning was done with ReCap software. The plastered model can be visualized in Figure 2.

[Figure 2] *Anatomy acquisition (Font: the authors, 2019)*

3.2. Alternative designs

The alternatives developed and the final solution can be verified in Figure 3. The choice was made by ranking the options considering the context of use and by the requirements and mainly by the choice of the user, who participated actively in the process.

1. 2. 3. 4. 5.

[Figure 3] *Alternative designs (1-4) and selected model (5) (Font: the authors, 2019)*

3.4. Prototyping

Based on the chosen alternative, the three-dimensional model was developed (Figure 4), from the morphology collected in step 2 (Figure 2). Then the adaptation was done for 3D printing (Figure 5). Some printing problems were encountered at this stage given the complexity of the modelled form (Figure 6).

[Figure 4] *Digital version of the orthosis (Font: the authors, 2019)*

[Figure 5] *3D printing of the orthosis (Font: the authors, 2019)*

[Figure 6] *Problems with 3D printing (Font: the authors, 2019)*

(Figure 4). A space is planned in the design so that an EVA layer can be introduced into the final product in order to increase user comfort.

4. DISCUSSION

The user-centered design method applied to the development of the wrist-hand orthosis was essential to identify the limitations and benefits found in the integration between design, new technologies and their contributions to project and product sustainability. We could address the main problems mentioned regarding the development AT: *waste* (Beretta, 2011) -with the reduced use of material and it being biodegradable-; *obsolescence* (Moraes et al., 2018; Sierra, 2017) -by rapid production and functional, aesthetic and symbolic adequation-; *high cost* (Marins, 2011) -through the use of low-cost equipment and materials- and *the inadequacy of products* that cause abandonment and early disposal (Basso, 2012) -by using a user-centered development methodology-.

The acquisition of the anatomy through the plaster bandage proved to be an economically viable process, providing a good physical three-dimensional model to be digitized. 3D scanning did not present measurable technical problems. The 3D modeling stage presented some technical limitations. Among the most important are the inadequacy of the software used to model organic lines, the need to transition between non-compatible software -surface modeling and solid modeling- and the inexperience of the developers on these software. The obstacles and failures during the 3D modeling of the product, made the 3D printing process difficult, resulting in unnecessary material expenses. With the improvement of skills in the area of 3D modeling and printing it is possible to obtain a product using less material raising its level of sustainability and making it ecologically correct.

The final issue to be discussed is the importance of the aesthetic and symbolic suitability of the product (Paschoarelli, Campos & Santos, 2015; Löbach, 2001). As it is a user need this factor that can reduce abandonment, early discarding (Basso, 2012) and the stigmatization brought about by the product (Pullin, 2007; Margolin & Margolin, 2004). However, adapting to the aesthetic and symbolic requirements tends to raise the complexity of the orthosis development process. Still, we recommend to consider these aspects from the use of appropriate methodologies and with the help of qualified professionals to ensure the development of a product that satisfies the user in all aspects.

5. CONCLUSION

In this work a wrist-hand orthosis was developed using a user-centered development method considering the sustainability issues, limitations of the productive process, and functional, aesthetic and symbolic needs of assistive technology products. We believe that, by allying such components one can achieve a product that is *economically viable*, considering the low-cost technology, that uses cheaper material than traditional methods; *socially just*, both in terms of access to the product that is easily produced, and inclusive of people with disabilities; and *ecologically correct*, from the minimization of material needed for manufacturing and the unnecessary disposal caused by the abandonment of the product.

Although this work is an experimental study, designed to discuss the articulations between design/sustainability/assistive technology themes, the fundamental problems of process adequacy suffered by the industry and product manufacturing are present. It means that the solution to these issues needs to be articulated at several levels and later expanded.

We acknowledge that this is a complex project because it requires the designers to seek and articulate concepts and technologies. Nevertheless, such solutions contribute to the popularization of 3D technology, which is currently expanding, to converge to customizable, sustainable projects and yet considering the subjective requirements of users.

AKNOWLEGEMENTS

Special acknowledgments to LABERG UFPR, NUFER UTFPR and PPGDesign UFPR.

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001.

BIBLIOGRAPHY

Autodesk (2019a). MeshMixer. Retrieved from http://www.meshmixer.com/

Autodesk (2019b). ReCap. Retrieved from https://www.autodesk.com/products/recap/overview

Beretta, E. M. (2011). *Tecnologia assistiva: personalização em massa através do design e fabricação de assentos customizados para cadeiras de rodas.* (Master's thesis Universidade Federal do Rio Grande do Sul) Retrieved from https://lume.ufrgs.br/handle/10183/36349

Bhamra, T., & Lofthouse, V. (2016). *Design for sustainability: a practical approach.* Routledge.

Brasil (2015). Lei Brasileira de Inclusão da Pessoa com Deficiência (Estatuto da Pessoa com Deficiência).

Basso, L. (2012). *A contribuição do designer no projeto de recursos de tecnologia assistiva: proposta de intervenção colaborativa*. (Master's thesis, Universidade Federal do Rio Grande do Sul). Retrieved from https://www.lume.ufrgs.br/handle/10183/62048

Boa Impressão 3D (2019). Stella. Retrieved from: https://boaimpressao3d.com.br/shop/impressora3d/impressora-3d-stella/

Canessa, E., Fonda, C., & Zennaro, M. (2013). *Low-cost 3D printing for science, education and sustainable development.* ICTP—The Abdus Salam International Centre for Theoretical Physics.

Daly, A. (2016). *Socio-legal aspects of the 3D printing revolution.* Springer.

Hot-World GmbH & Co. (2019). Repetier. Retrieved from https://www.repetier.com/

Löbach, B. (2001). *Design industrial: bases para a configuração dos produtos industriais.* Edgard Blücher.

Madhavan, K.N; Nair, N.R, John, R.P. (2010) An overview of the recent developments in polylactide (PLA) research. *Bioresour Technol* 101:8493–8501. doi: 10.1016/j.biortech.2010.05.092

Marins, S. C. F. (2011). *Design universal, acessibilidade e tecnologia assistiva: a formação profissional do terapeuta ocupacional na perspectiva da equidade.* (Doctoral dissertation, Universidade Federal de São Carlos). Retrieved from https://repositorio.ufscar.br/handle/ufscar/2875

Margolin, V., & Margolin, S. (2004). Um modelo social de design: questões de prática e pesquisa. *Revista Design em Foco*, 1(1). Retrieved from https://designparasustentabilidade.files.wordpress.com/2010/06/um-modelo-social-de-design.pdf

McNeel, et al. (2019). Rhinoceros. Retrieved from https://www.rhino3d.com/

Moraes, G. G., Catecati, T., Merino, G. S. A. D., Merino, E. A. D., & Ferreira, M. G. G. (2018) *Processos Produtivos de AFO nas Oficinas Ortopédicas do SUS: Implantação da indústria 4.0 – uma revisão*. in: Paschoarelli, L. C., & Medola, F. O. (2018) Tecnologia Assistiva: estudos teóricos. Canal 6 Editora.

Ornelas, Y., & Gragory, J. (2009) *Design for Social Inclusion.* In Proceedings of IASDR 2009, Seoul. Retrieved from http://www.iasdr2009.or.kr/Papers/Special%20Session/Design%20for%20Social%20Inclusion%20and%20Social%20Sustainability/Design%20for%20Social%20Inclusion.pdf

Paschoarelli, L. C., Campos, L. F. A., & Santos, A. D. P. (2015). *A influência da estética na usabilidade aparente: aspectos para a criatividade e inovação no design de sistemas e produtos.* In: Fiorin, E., Landim, P. C. & LEOTE, R. S., orgs. Arte-ciência: processos criativos [online]. Editora UNESP.

Pullin, G. (2007). *When fashion meets discretion*. In Online Proceedings of Include 2007, London. Retrieved from https://www.researchgate.net/publication/264883620_When_fashion_meets_discretion

Rosenmann, G. C. (2017). *Avaliação de sistemas de digitalização 3D de baixo custo aplicados ao desenvolvimento de órteses por manufatura aditiva* (Master's thesis, Universidade Tecnológica Federal do Paraná). Retrieved from http://repositorio.utfpr.edu.br:8080/jspui/handle/1/2630

Sierra, I. S. (2017). *Sistematização da prescrição de assentos para adequação postural de pessoas com tônus muscular anormal.* (Master's thesis, Universidade do Estado de Santa Catarina). Retrieved from https://www.udesc.br/arquivos/ceart/id_cpmenu/1229/Isabella_Souza_Sierra_15087711026413_1229.pdf

SKA (2019). Solidworks. Retrieved from http://www.ska.com.br/ska/produtos/solidworks

Suri, J. F. (2003). The experience of evolution: developments in design practice. *The Design Journal*, 6(2), 39-48. Retrieved from https://doi.org/10.2752/146069203789355471

UNGA - United Nations General Assembly (2005). 2005 World Summit Outcome, Resolution A/60/1, adopted by the General Assembly on 15 September 2005.

Vezzoli, C., & Manzini, E. (2008). *Design for environmental sustainability*. London: Springer.

Volpato, N., & Carvalho, J. D. (2017) *Manufatura Aditiva–Tecnologias e aplicações da impressão 3D.* Edgard Blücher.