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Ergonomic Evaluation of Assistive Technologies: a Case Study with a Manual Vegetable Peeler for People with Rheumatoid Arthritis

Giselle Merino[1], Felipe Goulart[2], Danielle Carneiro[3], Ana Karina Cabral[4], Daniela Amaral[5] and Eugenio Merino[6]

[1]Giselle Schmidt Alves Diaz Merino, Federal University of Santa Catarina (UFSC)

[2]Felipe Indalêncio Goulart, Federal University of Santa Catarina (UFSC)

[3]Danielle Carneiro de Menezes Sanguinetti, Federal University of Pernambuco (UFPE)

[4]Ana Karina Pessoa da Silva Cabral, Federal University of Pernambuco (UFPE)

[5]Daniela Salgado Amaral, Federal University of Pernambuco (UFPE)

[6]Eugenio Andrés Díaz Merino, Federal University of Santa Catarina (UFSC)

Gisellemerino@gmail.com

Author Note: This article is the result of several studies conducted in collaboration by researchers from the Laboratory of Design and Usability & Design Management Center (NGD-LDU) at the Federal University of Santa Catarina (UFSC) and the Laboratory of Assistive Technology and Occupational Therapy & Assistive Technology Center (LabTATO-NTA) at the Federal University of Pernambuco (UFPE) in Brazil. Through an interprofessional approach, products are developed based on human needs and evaluated to identify opportunities for improvement. In this case, a manual vegetable peeler was the result of a collaborative project between the fields of Design, Engineering, and Healthcare, with Occupational Therapy providing the main support and contact with patients. Focusing on patients with rheumatoid arthritis, the product was developed based on real needs, materialized, distributed, and analyzed over time through different studies - eight in this case - allowing continuous evaluation of both the product's performance and the patients' progress, with safety being one of its important aspects.

Abstract: Human beings are very diverse, with specific characteristics and different levels of abilities, especially when considering People with Disabilities (PWDs), who have very particular and individual limitations. Within this plural spectrum, the ability to safely perform Activities of Daily Living (ADLs) is an important indicator for the field of Ergonomics, as it can be used to assess an individual's degree of autonomy, which is essential to their independence and self-esteem. Furthermore, in the case of progressive and chronic diseases, such as Rheumatoid Arthritis, continuous monitoring is needed to ensure the patient remains autonomous for as long as possible. This responsibility often falls on the objects that make up the person's daily life, as these are the mediums through which interactions with their environment occur. For this study, a series of investigations were conducted by an interprofessional team (Design, Engineering, and Healthcare) concerning a manual vegetable peeler distributed to women with Rheumatoid Arthritis at the Clinical Hospital of the Federal University of Pernambuco (HC-UFPE; Pernambuco, Brazil). The goal was to verify if the object was safe and comfortable for the users. The methods used included: Semi-structured Interviews; Hand Discomfort Map; Infrared Thermography Records; Audiovisual Records; Semantic Differential Technique (SD); User Experience; Electromyography; Usability Principles. This article aims to evaluate the Assistive Technology Device (ATD) concerning daily living activities, prioritizing the user's health and safety, through a compilation of the results from eight studies conducted on a manual vegetable peeler for people with Rheumatoid Arthritis. The findings identified the contributions of each study regarding the product for patients with Rheumatoid Arthritis, providing positive and relevant data for the fields of Ergonomics and Usability. Currently, the product continues to be produced and distributed at HC-UFPE, with direct monitoring by Occupational Therapists. The research anticipates future studies to continue evaluating user safety and related aspects.

Keywords: Rheumatoid Arthritis, Assistive Technologies, Safety.

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1. Introduction

The human hand is an essential limb for performing Activities of Daily Living (ADLs), whether these are domestic tasks or carried out in external environments. From simple tasks like combing hair or brushing teeth to more complex activities such as changing a light bulb or peeling a vegetable, the hand plays a central role in nearly all interactions in the world. Given this context, the reality of a patient with Rheumatoid Arthritis (RA) deserves the consideration of designers, as their autonomy is compromised by this disease, characterized by inflammation of the joints in the human body, particularly affecting the joints of the hands and wrists in a symmetrical and additive manner (Goeldner et al., 2011).

Rheumatoid Arthritis (RA) is an autoimmune, chronic, and systemic condition, primarily identified by inflammation in the synovial membrane, a structure that lubricates and nourishes the joint capsule and tendons (Buckner, 2005; Falzon, 2006). Affecting approximately 1% of the global population, RA is more frequently observed in females (Paula, 2017), particularly within the age range of 30 to 50 years (Cavalcanti et al., 2006). This condition is a significant concern regarding human independence, being one of the major causes of mobility loss and pain worldwide, leading to functional limitations and reduced quality of life (NC-C-CC, 2008; Bertolo, 2008).

The prevalence of this condition is increasing in Brazil, partly due to a significant rise in life expectancy, which reached 75 years and two months in 2014 (IBGE, 2015). This makes Brazilians more susceptible to diseases like RA, as clinical manifestations can be observed more frequently in the fourth and fifth decades of life (Goeldner et al., 2011, p.3). In this context, the need for Assistive Technologies (AT) arises, which work alongside medicinal treatments to enhance the functional capacity and independence of patients (Paula, 2017).

In view of this, the development of a vegetable peeler was made possible through a partnership between Designers and Engineers from the Federal University of Santa Catarina (UFSC; Florianópolis, Brazil) and Occupational Therapists from the Federal University of Pernambuco (UFPE; Recife, Brazil), to serve people with RA being treated at the Clinical Hospital (UFPE). Considering this, this article aims to evaluate the Assistive Technology Device (ATD) concerning activities of daily living, prioritizing the user's health and safety, through a compilation of the results from eight studies conducted on a manual vegetable peeler for people with Rheumatoid Arthritis.

2. Method

This applied research involved both qualitative and quantitative studies and is characterized as a case study. Additionally, it included a document analysis resulting from a research project conducted in partnership with the Brazilian Unified Health System (SUS), called PPSUS.

The Guide for Project Development (GODP), developed by Merino (2016), was used to systematize the case study, being employed from the opportunity identification process to the trials conducted with the manual vegetable peeler. This approach is based on User-Centered Design, focusing on the user throughout the product or service development process. Thus, the GODP methodology is structured into three major phases, subdivided into eight stages, encompassing everything from the foundation to the execution of the project (Merino, 2016). For this article, considering the real context of studies with the tool, the Implementation phase (stages 5 and 6) is highlighted, omitting stage 4 due to the scope of the article.

3. Results

3.1 Product presentation

Initially, as the basis for using the GODP, Reference Blocks (PUC) were established. According to Merino (2016, p.8), in the development of a project, "we deal with the challenge of a large volume of information, considering that we design something (product) for someone (user), somewhere (context). Everything we design generates an experience; similarly, the experience can be designed and is also part of User-Centered Design." From this perspective, the study focuses on a manual vegetable peeler (Product), used by a person (user) in a home kitchen (Context). This information is synthesized in Figure 1.

Figure 1. Reference Blocks (MERINO, 2016).

Initially, The product was developed based on the needs identified by Occupational Therapists at the Clinical Hospital, which is a part of the Federal University of Pernambuco (UFPE; Recife, Brazil). The team collaborated to design a peeler that better accommodates the user's hand anthropometry, enhancing comfort for patients with rheumatologic diseases. Post-development, the device was distributed at the hospital, monitored by Occupational Therapists. With an organic shape, the object is produced via additive manufacturing, offering a larger contact area for the user's hand, requiring less effort and dexterity.

From an ergonomic perspective, the task prescribed was to peel and/or slice fruits, vegetables, and cold cuts. A palmar grip was considered, providing greater stability, and reducing joint impacts, allowing individuals with Rheumatoid Arthritis or other upper limb limitations to perform the task with less pain.

3.2 Stage 5 - Feasibility

With functional prototypes produced and distributed to patients at the Clinical Hospital, the initial studies were conducted to gather real and empathetic feedback from four female users with RA. The tools employed included: semi-structured interviews, thermographic records, hand discomfort maps, and audiovisual recordings.

In summary, the **semi-structured interviews** helped map the users' profiles, verifying their capabilities and dexterities concerning the use of the new manual vegetable peeler. **Thermographic records** were then conducted, comparing the color spectrum before and after using a common vegetable peeler and the subject of this study, demonstrating a significant reduction in the temperature of hands and wrists. Similarly, the **hand discomfort map** was used to allow individuals to report—simply and directly—their discomfort and pain when using both objects. Additionally, **audiovisual recordings** were employed to capture the user's perception while performing the activity, using the thinking-aloud method to minimize interference from the people collecting the information. This activity provided positive contributions to the study, supporting the progress of the research.

Overall, relating the developed trials to the previously structured Reference Blocks, it is understood that information was provided about the **Product** (through infrared thermography and the hand discomfort map), the **User** (through semi-structured interviews), and the **Context** (through audiovisual recordings), thus covering all Blocks.

Subsequently, the **Semantic Differential** (SD) technique was applied to three female users with RA, presenting them with two opposing adjectives (e.g., comfortable, and uncomfortable), allowing each individual to express their opinion on each item. Regarding functionality perceptions, the highlighted words were "ease of use," "safety," and "reliability." Regarding appearance, the tool resulted in a satisfactory perception concerning the notion of durability and quality of finish. Similarly, the **User Experience** yielded very positive results with the same participants, who described the product-user interaction as resulting in a good experience, using words such as "Love," "Kindness," "Achievements," and "Gratitude" at the end of each activity, demonstrating the importance users feel in participating in the design process. Both studies brought a greater focus to the User block.

Next, **Surface Electromyography** (EMG) was used to evaluate the myoelectric activity of hand function during the peeling of a tuber in two conditions: (a) using a common knife and (b) using the manual peeler developed for RA. For this, the New Miottol Wireless Miotec electromyograph, with 8 channels and 16-bit resolution and 3M electrodes, was used. The collection points on the right hand were: Superficial Digital Flexor (FSD - channel 1), Radial Flexor of the Carpus (FRC -

channel 2), Ulnar Flexor of the Carpus (FUC - channel 3), Short Abductor of the Thumb (ACP - channel 4), along with the reference electrode (ground) on the clavicle. Evaluations were performed with three users from the Occupational Therapy outpatient clinic of the Clinical Hospital at UFPE, using the following variables: peak contractions, mean contractions, integral contractions, minimum contractions, standard deviation of contractions, and mean and median frequency, combined with maximum voluntary contraction. The results indicated a decrease in muscle activity for most participants when comparing the use of the device developed for RA and the common device, with this difference reaching 60% in the case of ACP regarding peak contractions. This study provided information about the Product block.

Finally, **usability principles** were assessed based on Jordan's (1998) 10 principles, which, in summary, found that the product met 7 principles and partially met 3. The study provided a more global view, fitting into the Context block, with the product meeting the following principles: consistency (1), compatibility (2), capability (3), user control (6), visual clarity (7), prioritization of functionality and information (8), and appropriate transfer of technology (9). On the other hand, the principles of feedback (4), error prevention (5), and evidence (10) yielded partial results.

Figure 2. Studies conducted with the users.

In summary, the studies conducted have brought contributions that demonstrate the advancements of this new format for the manual vegetable peeler, providing specific information regarding each of the Reference Blocks (PUC). However, it was observed that there was a prevalence of a micro approach (Product and User blocks), with six trials, and a minority (only two) of studies on a macro scale (Context block). This can be quite significant as, according to Hendrick (1995), the micro approach yields improvements of 10 to 25%, while macro studies can bring improvements of 60 to 90%.

Therefore, concerning users with reduced dexterity (patients with rheumatologic diseases), analyzing the context of user safety in interaction with a product is highly relevant but has not been specifically studied yet. Furthermore, the issue becomes more prominent when considering the peeler as a sharp object, which according to the National Health Surveillance Agency (ANVISA; Brazil, 2018), belongs to the Group E classification, comprising any device or object with sharp and rigid edges, points, or protrusions capable of cutting or puncturing.

In this context, it is necessary to explore and understand the potential risks involved in dealing with such utensils designed for Activities of Daily Living, while raising questions such as activity visualization and blade cleaning. It is believed that such aspects become more apparent in the domain of Organizational Ergonomics, also understood as Macroergonomics, by comprehending issues related to the system (product-user interaction), which can be compared to the Context block view of the GODP, as it provides a systemic perspective of where the product is incorporated.

Thus, it is evident that studies need to be conducted regarding user safety through a Macroergonomics perspective, to understand if the product's usage context poses any risks to a patient with Rheumatoid Arthritis, with an emphasis on activity visualization and post-use (blade cleaning).

4. Discussion

As a product resulting from an interdisciplinary and interinstitutional partnership, with constant user involvement in the process, it is understood that this plurality of fields and specializations has brought significant contributions and true enrichment to the project. Furthermore, the studies conducted were able to demonstrate, in a qualitative and quantitative manner, how a user-centered and collaborative process can result in an object that allows greater autonomy for patients with RA in the task of peeling vegetables, particularly within the scope of the analyzed studies.

On the other hand, as the conducted trials focused on a micro approach, there is a clear need to develop macro studies in the future, which could provide insights to further adapt the product to the context of people with Rheumatoid Arthritis.

5. Conclusion

The evaluation of the manual vegetable peeler for individuals with RA was carried out through the compilation of the results of eight studies with the user, highlighting the positive findings that these different tools were able to bring to the field of Assistive Technology. Therefore, it is understood that the article achieved its objective by assessing the Assistive Technology Device (ATD) in relation to Activities of Daily Living, prioritizing the health and safety of the user, through a compilation of the results of eight studies applied on a manual vegetable peeler for individuals with Rheumatoid Arthritis.

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Currently, the tool is being distributed at the Clinical Hospital of the Federal University of Pernambuco, under the supervision of Occupational Therapists and with recurring feedback from patients with rheumatologic diseases. For future studies, the need to further understand user safety has been identified, employing Macroergonomics to have a broader view of the context of use, as well as post-activity considerations (blade cleaning).

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