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OPPORTUNITIES AND CHALLENGES ON ASSISTIVE TECHNOLOGY INNOVATION: A SYSTEMATIC LITERATURE REVIEW ON PEOPLE WITH DISABILITIES *

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ABSTRACT

Purpose: Brazil follows the global trend of an increasing number of People with Disabilities. However, there is a great lack of Assistive Technology resources, demanding their importation, which increases their cost to the end user. Innovation can be one of the contributions, once it is measured by the successful product implementation on the market. So, this paper aims to identify the development in the innovation area for People with Disabilities, pointing out barriers, opportunities and gaps.

Design/Methodology/Approach: The method used in this research was the theoretical-conceptual, based on a systematic literature review of papers from the Scopus database. It looked for Assistive Technology applications in the innovation field, using as a reference a framework for classification of Assistive Technology products.

Results: The literature review resulted in a portfolio of 75 papers. The results of its analysis established links between innovation and Assistive Technology using four groups: (i) innovation activities, (ii) object innovation, (iii) types of disabilities and (iv) AT categories.

Practical implications: This paper aims to inform various decision-makers about paths to be followed regarding research and development for People with Disabilities, highlighting the need to know how to deal with knowledge in the innovation process.

Originality/value: No specific models of innovation were identified amongst the papers, and the absence or shortage of items for some AT categories were also found. Therefore, investment in research and development in the innovation area applied to AT can contribute to the demand for Assistive Technology products.

Keywords: innovation. assistive technology. people with disabilities. systematic literature review.

OPORTUNIDADES E DESAFIOS PARA INOVAÇÃO EM TECNOLOGIA ASSISTIVA: UMA REVISÃO SISTEMÁTICA DA LITERATURA SOBRE PESSOAS COM DEFICIÊNCIAS

RESUMO

Objetivo: O Brasil segue a tendência mundial, conforme dados estatísticos, do número de pessoas com deficiência. Por outro lado, existe uma grande carência de recursos de Tecnologia Assistiva disponíveis no mercado brasileiro, tornando necessária a importação de produtos, o que encarece o custo. A inovação pode ser uma das contribuições, pois é medida pela implantação bem sucedida de um produto no mercado. Assim, neste artigo foi analisado como a inovação vem sendo tratada em trabalhos publicados para as pessoas com deficiência, apontando barreiras, oportunidades e lacunas para o inovação na área de Tecnologia Assistiva.

Design/Metodologia/Abordagem: O método usado nesta pesquisa foi a abordagem teórico-conceitual, baseada em uma revisão sistemática da literatura na base de dados Scopus. Foi pesquisado por aplicações de Tecnologia Assistiva na área de inovação, usando como referência um framework para classificação de produtos de Tecnologia Assistiva.

Resultados: A revisão da literature resultou em um portfólio de 75 artigos. A análise do resultado estabeleceu ligações entre inovação e Tecnologia Assistiva, classificando o resultado em quatro grupos: (i) atividades de inovação, (ii) objetos de inovação, (iii) tipos de deficiência e (iv) categorias de Tecnologia Assistiva.

Implicações práticas: Este artigo espera prover informações para os vários gestores envolvidos sobre caminhos a serem seguidos em pesquisa e desenvolvimento para pessoas com deficiências, destacando a necessidade de conhecer meios de lidar com o conhecimento do processo de inovação.

Originalidade/valor: Não foram identificados modelos específicos de inovação e também verificou-se a ausência ou carência de artigos relacionados à maioria dos produtos de Tecnologia Assistiva. Conclui-se, portanto, a necessidade de se investir em pesquisa e desenvolvimento na área de inovação aplicada à Tecnologia Assistiva.

Palavras-Chave: inovação. tecnologia assistiva. pessoas com deficiências. revisão sistemática da literatura.

1 INTRODUCTION

Worldwide, according to the World Health Organization [WHO] (2011), more than one billion people live with some form of disability. In Brazil, according to the 2010 census, nearly 24.0%, or 46 million people have some kind of disability (Brazilian Institute of Geography and Statistics [IBGE], 2010). With the increasing life expectancy, some elderly are now also included in the quantitative PwD, as well as pregnant women, nursing mothers and others with reduced mobility, whether permanent or temporary; this scope means it is around 43.5% of the population. Finally, adding families and others needing care and monitoring, the amount involved may exceed 70.0% of Brazilians (Brasil, 2009).

In a knowledge-based economy, innovation, being by definition a product's commercial success, is the main competitive factor. Innovation is related to Assistive Technology (AT), through a new product or service launch, or by some specific strategy used by an organization to meet the PwD needs.

Given AT's importance and the contribution that innovation can bring for PwD, through various innovative activities identified in this area, it is necessary to know barriers, gaps and opportunities for innovative work in AT area. Therefore, this paper aims to examine literature papers regarding innovation activities applied to AT, identifying how the innovation area has been developing research for PwD.

Innovation can contribute for PwD through various innovative activities identified in this area. Thus, given AT's importance, it is necessary to recognize barriers, gaps and opportunities for innovative work in AT. Therefore, this paper aims to examine literature papers regarding innovation activities applied to AT, identifying how the innovation field has been developing research for PwD.

2 THEORETICAL FOUNDATION

2.1 ASSISTIVE TECHNOLOGY CONCEPTUALIZATION

A historical milestone for AT in 2001 was the change of the medical model to the social model, which states that the limiting factors are the environmental and social barriers the person encounters and not the disability itself, exposing us to the International Classification of Functioning, Disability and Health, known more commonly as ICF (Cook & Polgar, 2008). This approach makes clear that deficiencies do not necessarily indicate the presence of a disease or that the individual should be considered ill.

Another major milestone in 2008 was the implementation of the PwD Rights Convention, a United Nation treaty, symbolizing the international community determination in putting the PwD issue on the global agenda of human rights perspective, advising and demanding from national governments actions that could transform their lives through the promotion of social inclusion (Brasil, 2009).

In this new way of treating PwD, AT can be seen as a subject of professionals' domain from different knowledge fields, which interact to restore the human function. In this perception Bersch (2005) points out that there is a great lack of AT resources in the Brazilian market, necessitating its importation, which increases the cost to the final users.

2.2 ASSISTIVE TECHNOLOGY CATEGORIES

Deficiency can already be seen at the child's birth or can be acquired throughout life, and researches show that many of these incidents could have been avoided or mitigated through preventive and protective actions. According to Ribas (1999), literature considers the existence of three types of disability: (i) physical - motor origin, amputations, sequelae or abnormal fetal development of various types, (ii) sensory - visual and auditory (total or partial) and (iii) mental - varying levels and of prenatal, perinatal or postnatal origin.

Grouping AT into categories emphasizes that its importance lies in the fact of organizing its use, prescription, study and research of resources and services, besides offering to the market labor and specialization specific focus (Bersch, 2005). In this paper the classification of Bersch (2005) was used (Table 1), which, apart from a didactic purpose, takes into account other classifications like ISO 9999 and HEART.

Finally, for the purpose of this paper, AT can be categorized into low and high technology. Despite the imprecision in categorizing low or high technology, low cost products, which are easy to manufacture or obtain, are often called low-tech; and high-cost products, more difficult to manufacture or obtain are called high-tech (Cook & Polgar, 2008). According to this definition, low-tech examples are cutlery modified to facilitate eating action, while computing resources are examples of high technology.

2.3 INNOVATION TYPES

The Oslo manual (Organization for Economic Co-Operation and Development [OECD], 2005) states the innovation concept as the implementation of a product (good or service) new or

significantly improved; a process; a new marketing method; or a new organizational method in business practices, in the workplace organization or external relations.

Table 1 - AT framework

Category	**Description**
Aid for daily life	Favor autonomous and independent performance on routine tasks or facilitate the care of dependent people in activities such as eating, dressing, bathing and personal needs.
Augmentative and Alternative Communication (AAC)	For people without speech or writing or communicative gap between their needs and their ability to speak and/or write. Ex: communication boards, vocal instruments, etc.
Computer accessibility resources	Hardware/software for computer use by people with physical and sensory deprivation. Ex, adapted keyboards, voice recognition software, Braille printers, etc.
Environment control systems	Through a remote control, one turns on, off and adjusts electrical and electronic devices such as light, sound, opening and closing of doors and windows, etc.
Architectural designs for accessibility	Ensure access, functionality and mobility to all people, regardless their physical and sensory condition. Ex: ramps, elevators, bathrooms, furniture, etc.
Orthotics and prosthetics	Artificial parts replace missing parts (prosthesis) or are placed next to a body segment (braces), ensuring a better positioning, stabilization and/or function.
Postural adaptation	Resources that promote adaptations in all postures, lying, sitting and standing. Ex: pillows in bed or orthostatic stabilizers.
Mobility aids	Equipment or strategy used in improving personal mobility. Ex: canes, crutches, strollers, wheelchairs, scooters, etc.
Aids for blind or low vision people	Aid the independence of people with visual impairment. Ex: lenses, magnifiers, screen readers software, Braille printers, etc.
Aids for deaf or hearing loss	Aids including hearing aids, phones with teletype keyboard (TTY), touch-visual warning systems, etc.
Vehicles adaptations	Ability to drive a car. Ex: boarding facilitators and disembarking ramps, driving school services, etc.

Source: Adapted from Bersch (2005)

Under this definition, the Oslo Manual current edition defines four types of innovation, according to the object, which encompass various business activities manuals (OECD, 2005):

- Product innovations: is the introduction of a benefit or service, new or significantly improved, related to its characteristics or intended uses;
- Process innovations: is the implementation of a new or significantly improved production or delivery process. This includes significant techniques, equipment and/ or software changes;
- Organizational innovations: is the implementation of new organizational methods and possibly changes in business practices, the workplace organization, or in the company's external relations;
- Marketing innovations: involve implementation of new marketing methods. May include changes in the product appearance and packaging, its dissemination and distribution and methods to set services and benefits prices.

3 METHOD

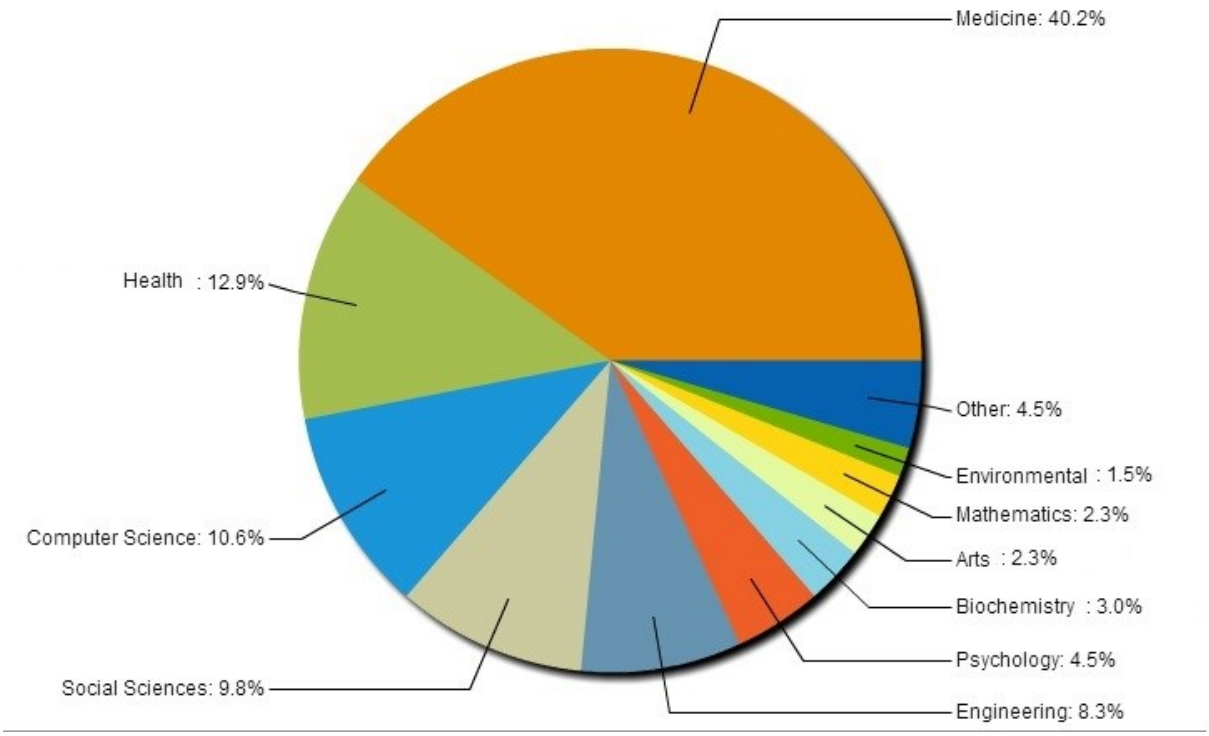
The method used in this research was the theoretical-conceptual, based on a literature review of papers from Scopus database, the most comprehensive database for research (Chadegani et al., 2013). Firstly a search for all posts with "assistive technolog*" (technology or technologies) in title, abstract and keywords was performed, which resulted in 4405 publications. After filtering it, by selecting only papers in German, English and Portuguese languages, the result was 2050 items. The last filter was searching for keywords "Innovat*" (innovation or innovations or innovative or innovativeness) in title, abstract and keywords, which resulted in 75 papers, defining the portfolio of this research.

The decision of not deleting papers by the knowledge areas criterion was due to the multidisciplinary AT area; therefore, in the portfolio were kept works related to the areas of medicine (40.3% of the results), health (12.9%), computer sciences (12.1%), social sciences (8.9%) and engineering (8.1%) (Figure 1).

After reading the portfolio papers, studies that used similar terms to AT were excluded, as for example, "assistive clinical technology", in a context of Information and Communication Technology (ICT) use to aid medical activities, related to the correct prescription drug and not directly to PwD. Another example of exclusion were studies that used the AT term, but referring to any support for activities' technology, however not applied to PwD, such as Augmented Reality applied to learning games for children or using AT as equipment to increase motorcyclists safety. Bowen (2011) does not appear in results since it only addressed ethical issues between engineering and medicine, with only indirect quotation on AT applications as a medicine subfield.

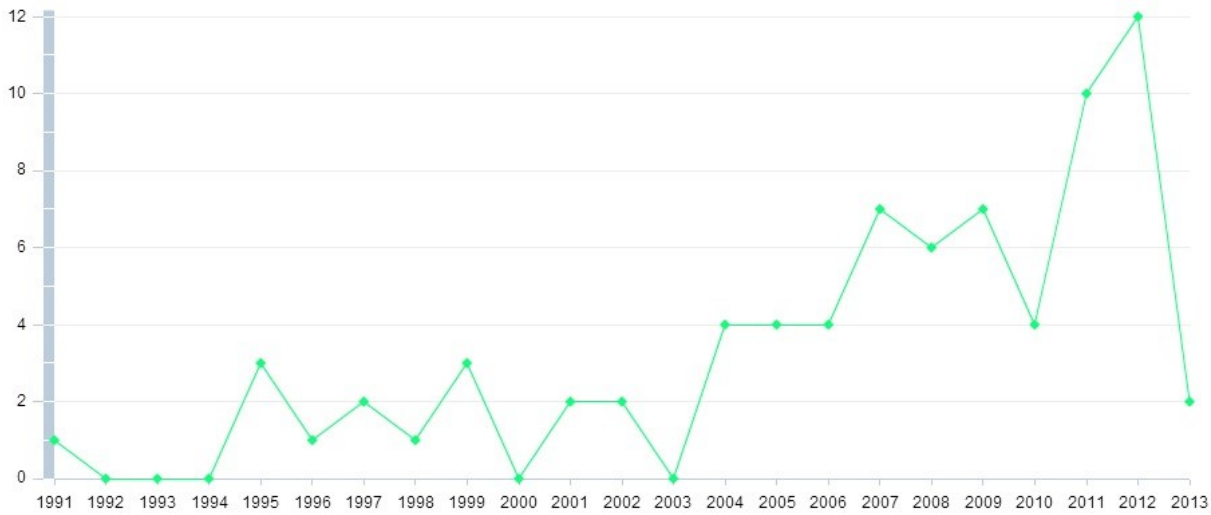
The number of publications over the years shows a growing trend of interest in the correlation among the areas of innovation and AT, as shown in Figure 2, which confirms the relevance of the literature review proposed in this paper.

Figure 1 - Knowledge areas of the portfolio



Source: The authors

Figure 2 - Publications over the years of the portfolio



Source: The authors

4 RESULTS

From the papers portfolio identified in the literature review, this section shows results of its analysis, establishing links between innovation and AT, using four groups: (i) innovation activities, (ii) object innovation, (iii) types of disabilities and (iv) AT categories.

4.1 INNOVATION ACTIVITIES ON ASSISTIVE TECHNOLOGY

Specific papers about management models in AT innovation were not found in the literature. However, were identified in these research activities that may contribute to AT innovation (Table 2), according to the Organization for Economic Co-Operation and Development's (OECD, 2005) definition of innovation activities, as scientific, technological, organizational, financial and commercial steps, which aim to lead to the implementation of innovations.

Table 2 - Innovation activities related to various stages of the product life cycle

Innovation activities	**References**
Innovation horizontal open networks	De Couvreur and Goossens (2011)
Rogers innovation diffusion theory	Fernando et al. (2010); Saladin and Hansmann (2008)
Evaluation method for AT selection	Fuhrer (2001)
Need to Knowledge (NtK)	Lane (2012)
"In loco" demonstration program	Percival (2012)
Innovation front-end	Plos et al. (2012)
Products benchmarking	Van der Woude et al. (2006)
Design	Björk (2009); Boone and Higgins (2007); Burton et al. (2011); Czarnuch and Mihailidis (2011); De Couvreur and Goossens (2011); Dewsbury et al. (2004); Green et al. (2009); Hall et al. (2012); Messinger and Marino (2010); Riley (2009); Tobias (2007); Wattenberg (2004)

Source: The authors

Innovation horizontal open networks proposed by De Couvreur and Goossens (2011) allow PwD to develop devices according to their specific needs, using local resources and appropriate technology. It is based on the Universal Design principle related to economies of scale, which involves mass production techniques and traditional design processes. This product's strategy driven by the market homogenizes the users' skills (Vanderheiden & Tobias 2000). It emphasizes

providing aid at the lowest cost possible, finding a certain consensus stage, including therefore as many users as possible.

In contrast, the innovation strength within rehabilitation engineering is characterized by a technology strategy pushed to the market. New inventions are propelled through research and development, without taking into consideration the existence or not of the user's needs (Gregor, Sloan & Newell, 2005). There is, therefore, a lack of solutions propelled according to the context, which led the authors to develop the innovation horizontal network.

The Rogers's theory of Innovation Diffusion is a widely accepted theory that describes the processes people use to adopt, reject or discontinue technologies decisions (Rogers, 2003).

Fernando, Money, Elliman and Lines (2010) demonstrate how such understanding has been employed to develop an AT, in order to improve the elderly people interaction with online forms, called Delivering Inclusive Access to Disabled and Elderly Members of the community (DIADEM).

In order to evaluate the AT services' delivery aiming to ensure its effective use by the PwD, Fuhrer (2001) presented a review of three initiatives aiming to fill the gaps in the existing measurement: (i) Psychosocial Impact of Assistive Devices Scale (PIADS), (ii) Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST), and (iii) and measurement developments executed by the interdisciplinary program called Rehabilitation Technology Effective Cost.

Fuhrer (2001) concludes that the importance of evaluating the AT services' delivery will increase in order to guide choices within the growing range of available AT innovations. These surveys will include efficacy studies conducted as part of the development process, as well as efficacy studies set in the delivery services' day-to-day context.

In order to facilitate the process of transforming ideas into inventions and innovations, Lane (2012) proposed the Need to Knowledge (NtK) model. This model reduces a very complex process of technology transfer in three basic phases with three stages each and nine stages. Each phase contains a set of steps, along with tips to complete these stages. Lane (2012), concludes that the model may be useful to help the industry meet the essential role of transforming discoveries into inventions and then in innovations to the market, the key to achieve positive social impacts with public investments.

Percival (2012) describes an AT demonstration program for seniors with vision loss. The survey results revealed that although participants had previously some knowledge of generics and devices for low vision, they valued the opportunity to learn more about technological solutions to their routines difficulties.

The AT products, responsible for meeting specific needs in a highly segmented market, are often seen as niche products. In order to improve their projects and make them strive for universality (Universal Design), Plos, Buisine, Aoussat, Mantelet and Dumas (2012) proposed the framework EMFASIS (Extended Modularity, Functional Accessibility, and Social Integration Strategy), which is based on five principles, showed on Table 3, along with the application example for the Overbed Table.

Table 3 - EMFASIS principles and application examples

Principles	**Purpose**	**Example: Overbed Table**
Market extension	Find useful need for people who do not belong to the initial target public.	The same piece of furniture can be used for work, eating, as a coffee table, an ironing board or a bedside table.
Modularity	Define a product architecture composed of interchangeable subsystems in order to increase the models number and functions.	Architecture composed of base, shelves and boards that allow users to customize style and functions.
Functional acceptability	Carefully analyze the customer's needs.	Search composed of 14 PwD, 20 caregivers and 8 potential users of the market in general.
Accessibility	Extend the functional acceptability for the majority of the population.	Involvement of a large diverse population for their needs assessment.
Social integration	Integration of the product's image, aesthetic factors and social values.	Multidisciplinary project team and emotional and semantic analysis of products requirements.

Source: Adapted from Plos et al. (2012)

EMFASIS is based on a front-end strategy to the market extent, which, according to Plos et al. (2012), seems to be essential to break barriers in AT design and achieve innovation, by removing the issue of small market size and allowing companies to improve the quality of their products (ex. suitability, reliability) and at the same time reducing their price.

According to Plos et al. (2012), the Table to Bed is the example that fully illustrates the AT junction and the Universal Design. The project's goal was to create a table that would be usable at home without stigmatizing their users, since all models have a cold look and refer to hospitals. This fact induced the user's resistance in buying them, although they needed that device for their daily life, for work or meal in their bed, sofa or wheelchair.

Wheelchairs for sports and rehabilitation technology have contributed much to innovations in support materials, technology and rehabilitation practice. Apart from systematic researches, many wheelchair innovations have happened in sport and from the analysis of vehicular mechanisms, such as stress reduction, stability and strength. Therefore, Van Der Woude, De Groot and Janssen (2006) started a discussion that can be categorized as a benchmarking of products that generate innovation, when analyzing current developments in design and technology on various wheelchairs. The authors conclude that much more work still need to be done to further improve PwD mobility in the lower limbs, both on sedentary people as well as on athletes.

Most papers related to AT innovation are specific to the design phase of the product, as a mean to pursue innovation. We identified activities regarding Universal Design (Björk, 2009; De Couvreur & Goossens, 2011; Riley, 2009), Design for context (Green, Jensen, Seepersad and Wood, 2009), Instructional Design (Filatro & Piconez, 2004), Inclusive Design (Dewsbury, Rouncefield, Clarke and Sommerville, 2004), Universal Design for Learning (Hall, Meyer and Rose, 2012; Messinger & Marino, 2010), Product Ecosystem (Tobias, 2007), Design centered on the user (Burton, Reed and Chamberlain, 2011; Czarnuch & Mihailidis, 2011; Dewsbury et al., 2004; Green et al., 2009; Messinger & Marino, 2010) and Design related to politics and education (Boone & Higgins, 2007; Messinger & Marino, 2010; Riley, 2009; Wattenberg, 2004).

As an example of the design contribution to AT innovation, it can be referred the Universal Design, which besides the previously mentioned paper from De Couvreur and Goossens (2011), was presented by Björk (2009), which highlighted the different aspects of Universal Design products development, comparing two different designs of a product development, in order to try to analyze challenges that companies face when they are involved in creating Universal Design solutions compared to AT development and solutions based on modular products.

The comparison was made between two products developed by the same company and the same teams, for the transport of PwD in vehicles. The Careva Belt was developed in a modular way and Crossit was conceived through Universal Design. This paper made a comparative analysis of the two products, identifying the factors that led Crossit (Universal Design) to take a development time four times longer than the Careva Belt (Modular product).

The main conclusions of this paper, among others, were: (i) Universal Design production should meet all people needs, which creates a product requirements' conflict; (ii) Careva focused on the Sweden domestic market solely, while Crossit was designed to cover the global market, which represented difficulties in understanding local laws and cultures; (iii) the modular thinking

could not be used in Crossit, resulting in the need to produce many conceptions, without resolving a conflict by simply adding one piece, as it is done in modular products.

4.2 INNOVATION IN ASSISTIVE TECHNOLOGY ACCORDING TO THE OBJECT

Several authors have published studies on product's innovations, as Augusto, Liu, Mccullagh, Wang and Yang (2008), Barlow and Venables (2004), Fernando et al. (2010), Halpern, Ramig, Matos, Petska-Cabl, Spielman, Pogod and Mcfarland (2012), Saladin and Hansmann (2008), Smania, Gandolfi, Marconi, Calanca, Geroin, Piazza and Picelli (2012), Van der Woude et al. (2006), Willems and Vlaskamp (2008) and Wilkowska and Ziefle (2012).

As a product innovation example, the Smart Home approach from Augusto et al. (2008) is presented, defined as a house equipped with sensors and actuators that can be coordinated by intelligent software. Their paper described the modeling of a smart home scenario, using a reasoning system called RIMER (Rule-base Inference Methodology using the Evidential Reasoning), which was extended to allow monitoring situations according to the place where activities occur, their specific order and duration.

Despite significant technology advances on sensors and networks development that allow the environment monitoring and provide alerts to users, there has been insufficient progress in the data analysis and interpretation to get the most out of these technologies. The scenario proposed by Augusto et al. (2008) was innovative in order to fully exploit this environment potential.

The organizational innovation was treated by Ahasan, Campbell, Salmoni and Lewko (2001), Björk (2009), Demiris, Parker Oliver, Fleming and Edison (2004), Lane (2012), McCarthy (2012) and Vernardakis, Stephanidis and Akoumianakis (1997). The NtK by Lane (2012), stated in the previous section, was the work found in literature that was the closest to a AT innovation model on innovation in companies, in order to facilitate the process of transforming ideas into inventions and innovations. It was therefore classified as an organizational innovation.

Ahasan et al. (2001) dealt with organizational innovation by proposing changes in the work environment organization, using ergonomics as a product success, which leads to its commercial success, with more intuitive customized products at low cost and reducing the stress factor in use. As changes in external relations, the organizations' research timing and development with gerontology were emphasized, enforcing the user's needs, highlighting the human factors and/ or ergonomic considerations in the process design and AT development.

Telemedicine, defined as the use of advanced telecommunication technologies to overcome geographic distance and improve the services' delivery, was another aspect of organizational innovation identified in the literature by Demiris et al. (2004), through its use as a form of change in the hospice business practice, evaluating the employees' perception (administrators, nurses and social workers) related to the telehospice service. The authors concluded that telehospice can be an organizational innovation potential tool, but there is a need to expand the research to be able to generalize its results.

At a discussion level and not a proposals one, organizational innovation was treated on the external aspects to organization in Europe by McCarthy (2012), on the difference between guidelines applied to AT to medical devices and different certifications' needs in order to be launched in the market; and by Vernardakis et al. (1997), who presented three restrictive factors for AT innovation: (i) the limited and inefficient interaction between the identified seven market elements (research, development, production, trade, services, acquisition and use), (ii) the structural features and the European market general economic environment for AT, and (iii) the lack of a concise set of complementary and support actions on the promotion of a favorable environment to industrial innovation and AT transfer to the European market.

In Fuhrer 's (2001), Percival's (2012) and Plos et al (2012) works, already described in the previous section of this paper, innovations in marketing were identified, respectively: (i) as a method to set benefits and services prices when evaluating the AT services delivery, as a way to guide choices in the increasingly wide range of available innovations, ensuring its effective use by PwD; (ii) as a change on how to put the product on the market, through a AT demonstration program for the elderly; and (iii) how changes in the product design may influence the market share the product will reach, coming out from a highly targeted market, as all AT products, specific to PwD for the Universality (Universal Design).

4.3 INNOVATION AND TYPES OF DISABILITIES COVERED BY ASSISTIVE TECHNOLOGY

In addition to the types of disability mentioned in the theoretical foundation of this paper (physical, sensory, mental/ cognitive), were found in literature papers related to AT innovation that can be applied to: (i) several deficiencies, being for this section results grouped as various deficiencies; and (ii) several works related to the elderly (Table 4).

As an example among the many works of AT for elderly, it is cited the paper of Wilkowska and Ziefle (2012), which used the terms AAL (Ambient Assisted Living,) and E-health when

referring to the need to assist elderly in their own homes, the proposition being however extensible to people with other types of disabilities. Although E-health is currently a widely explored subject, the authors raised here the importance of having in mind the safety aspects and data privacy, for social reasons and ethical requirements mainly.

Table 4 - References per types of disability

Deficiency	**References**
Elderly	Augusto et al. (2008); Barlow and Venables (2004); Demiris et al. (2004); Fernando et al. (2010); Halpern et al. (2012); Percival (2012); Willems and Vlaskamp (2008); Wilkowska and Ziefle (2012)
Physical	Björk (2009); Plos et al. (2012); Smania et al. (2012); Van der Woude et al. (2006)
Sensory	Percival (2012); Saladin and Hansmann (2008)
Mental	Demiris et al. (2004); Fernando et al. (2010); Halpern et al. (2012); Smania et al. (2012)
Others	Ahasan et al. (2001); Augusto et al. (2008); Barlow and Venables (2004); De Couvreur and Goossens (2011); Fuhrer (2001); Lane (2012); McCarthy (2012); Plos et al. (2012); Vernardakis et al. (1997)

Source: The authors

The results of the study of Wilkowska and Ziefle (2012) revealed that women attach more importance to protect and control access to their health data, and they insist more than men on the use of E-health anonymously and in a private way. This was predominantly the case of young and middle-aged women and less in older women, in contrast to the conclusions of ICT use in general. These results clearly indicate the need for personal accounts with password protection in E-health medical devices.

Among the papers dealing with physical disabilities, besides those already mentioned in previous sections, Smania et al. (2012) is cited as an example, showing as a product innovation a robot for steps simulation in children affected by cerebral paralysis. Unlike all the existing models on the market that are unattractive to the user due to the fact that the equipment is fixed, the NF-Walker instead allows user's movements.

Saladin and Hansmann (2008) brought up AT for people with sensory disability, for example, concerned in investigating the AT devices abandonment which occurs mainly in the first year of use. Video Relay Services (VRS) were used as an example to evaluate a new AT adoption. Results indicated that the psychosocial variables of competence, adaptability and self-esteem were significant among people who chosen VRS. Among demographic variables, only

training was highly correlated with competence and the adaptability capacity. Another interesting result is the training correlation with psychosocial variables, concluding that the training implementation may have had a positive effect on the decision process of choosing VRS (Saladin & Hansmann, 2008).

Cognitive impairment, among others, was discussed by Halpern et al. (2012) with a technological innovation development to support speech for people with Parkinson's Disease (PD), aiming to evaluate the feasibility and effectiveness of a system of AT like LSVT (Lee Silverman Voice Treatment). LSVT is an intensive therapy program that trains individuals with PD to speak aloud, with good quality and allowing them to recalibrate the sensory-motor system through self-monitoring increasing the vocal effort (Fox, Ramig, Ciucci, Sapir, Mcfarland and Farley, 2006).

Personal Digital Assistants, PDAs Compaq iPAQ3650 and 3800 were selected by Halpern et al. (2012), based on their multimedia capabilities, processing power and development tools. The results of Halpern et al. (2012)'s case study demonstrated that participants showed significant gains compared to those obtained by LSVT traditional treatments and also indicated that participants were able to use the software at home independently, with the vast majority rating the device as very useful.

Among the papers with proposals that can be applied to various disabilities types, Barlow and Venables (2004) is cited, whose literature review stated three forms of innovation in constructions supporting PwD in their own homes: (1) innovation in the design and construction of new homes, called lifetime homes and open construction systems (open building), (2) the AT introduction, both in new buildings and existing buildings, and (3) tele-assistance (telecare). Each one of these forms was analyzed in terms of potential benefits to meet the PwD housing needs and its limitations. The paper describes that policy and market influences can stimulate their adoption, concluding that technological innovation must be accompanied by new models of service delivery.

4.4 INNOVATION AND CATEGORIES OF ASSISTIVE TECHNOLOGY

In addition to AT products' categories displayed on the theoretical foundation section of this paper, papers related to AT innovation that can be applied to different product categories were found in the literature and therefore, for the results in this section, they are grouped as miscellaneous category (Table 5). All items of Table 5 have already been described in previous sections of this study and will be discussed in the results section.

Table 5 - References per AT categories

Category	**Reference**
Aids for daily life	Augusto et al. (2008); Demiris et al. (2004); Percival (2012); Plos et al. (2012); Smania et al. (2012); Wilkowska and Ziefle (2012); Willems and Vlaskamp (2008)
Augmentative and Alternative Communication	Halpern et al. (2012)
Resources computer accessibility	Fernando et al. (2010)
Environment control systems	Augusto et al. (2008)
Architectural designs for accessibility	Barlow and Venables (2004)
Orthotics and prosthetics	Plos et al. (2012)
Postural adaptation	Smania et al. (2012)
Mobility aids	Björk (2009); Halpern et al. (2012); Plos et al. (2012); Van der Woude et al. (2006)
Aid for the blind or people with low vision	Percival (2012)
Aid for the deaf or people with hearing impairment	Saladin and Hansmann (2008)
Others	Ahasan et al. (2001); De Couvreur e Goossens (2011); Fuhrer (2001); Lane (2012); McCarthy (2012); Plos et al. (2012); Vernardakis et al. (1997)

Source: The authors

5 DISCUSSION OF RESULTS

Among the total number of papers in which AT innovation activities were identified, only two, or 10.0% of the total, were closer to what might be called innovation models: (i) the NtK by Lane (2012) and (ii) the EMFASIS model by Plos et al. (2012), based on a front-end strategy for the market extent. All other items had innovation activities; most of them, around 62.0%, related to product design, against 38.0% related to other phases of the product life cycle.

The large number of papers related to innovations in products reflected in the object innovation classification results; 50.0% of the papers dealt with product innovation, 33.0% of organizational innovation and 17.0% of innovation in marketing (Fig 3). This also reflects the absence of innovation models, which could be more related to organizational or marketing innovations.

Figure 3 - Innovation in Assistive Technology according to the object.

Source: The authors

Process innovations, although cited by Barlow and Venables (2004), revealed to be inconsistent with the theoretical foundation definition. The authors referred to telecare as an innovation process, as the mechanism for the care reorganization to a more person-centered model in their own home. However, as defined in the Oslo Manual (OECD, 2005), this is an innovation of service. This paper was therefore classified as product innovation.

Therefore, papers related to innovation in processes were not found. Most works dealing with AT innovation focused on the description of some new product development, to meet some kind of specific disability. No studies that treated innovation were found to be strategic to AT. Although not classified in a theoretical foundation as a disability type, the elderly were the most cited target audience among the works of innovation applied to AT, representing 38.1% of the papers. The following deficiency types cited were cognitive/ mental (23.8%), physical (19.0%) and finally, sensory (9.5%).

Some works have been classified into more than one group, as Augusto et al. (2008), Björk (2009), Fernando et al. (2010) and Halpern et al. (2012), describing AT for elderly people, however being possibly applied to other types of disabilities. Another example would be Percival's (2012), who described an AT demonstration program for seniors with vision loss, being both rated in the elderly group, as well as the group of sensory impairment (visual).

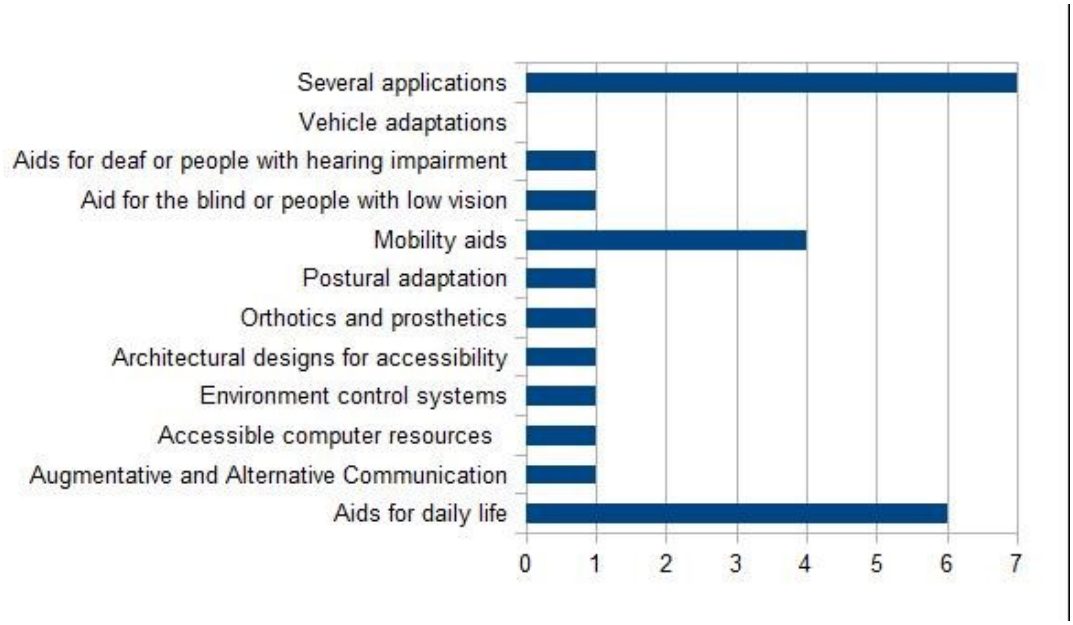
Another example was Smania et al. (2012), classified in the group of physical and mental/ cognitive disabilities, as they discussed children affected by cerebral paralysis, mental illness, with consequences on physical disability.

Many papers did not focus on a specific type of disability, being applied to diverse audiences, as for example Augusto et al. (2008), which introduced the Smart Home concept, in the aid context of people at risk, e.g., the elderly, people with dementia or Alzheimer's disease or other types of reduced mobility. Therefore, these papers have been classified as various deficiencies, representing 42.9% of the total.

Figure 4 shows the papers distribution according to AT categories. There is a higher concentration of works focused on daily living aids (28.6%), followed by mobility aid (19.0%). With the exception of vehicle adaptations, all the other categories had published papers focused on AT innovation, however only one paper for each category. This shows the absence or shortage of research groups focused on the AT innovation subject for most AT categories.

Another result observed refers to the technology degree discussed in AT. It shows a predominance of studies involving high technology, with 73.0% of cases compared with 27.0% regarding low-tech. This may represent a lack of appreciation of work on low-tech, whether by publication types or by the researchers themselves. An analysis of the commercial application of low-technology products could indicate their more precise applicability in solving real problems of PwD, which could contribute to a higher value appreciation of these works by the academic world.

Figure 4 - Papers distribution per AT categories



Source: Authors (2015)

6 CONCLUSIONS

The ability to develop technologies that result in new products and the improvement of processes is of fundamental importance for the companies' competitiveness. Investments in research and development and the scientific knowledge application in the industry are the pillars of innovation. Despite the importance of investment, a company will only become innovative if it has significant efficacy in the innovation process.

The lack of specific innovation works, addressing innovation models applied to AT, points out the lack of works focusing on AT industry. While many studies focus on the description of innovative product developments and others focus on the correct acquirement of customer needs for product design efforts, there were none found in literature works that deal with innovation processes. This could be a contribution of AT innovation, once they are niche market products, requiring customization and innovative manufacturing processes to meet the entire demand of fragmented AT.

The lack of application of innovation models in AT industry may reflect the lack of scientific studies related to many AT product categories. It was found in literature review only one paper for most AT product categories, and none in the vehicle's adaptations category.

Market factors and AT specific factors may be the major threats to reaffirm the need for AT businesses to think about innovation management. Market factors could increase competitiveness and technological advances, while AT specific factors are constant changes in AT customer needs and desires, intrinsic characteristics of this area, due to new skills acquired through training or rehabilitation, or furthermore loss of skills resulting from degenerative diseases.

It is recommended, for future research, to study factors that may hinder AT innovation activities, such as uncertainty demand, identification errors of customer needs, incorrect selection or lack of dissemination of available AT.

This paper expects to provide information for various decision-makers about paths to be followed for research and development for PwD, highlighting the need to know how to deal with knowledge in the innovation process, pointing out to the need for changes in society in general, so that organizations can in fact promote equal opportunities.

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