Ergonomics for the inclusion of older workers in the knowledge workforce and a guidance tool for designers

Highlights

- Approach of Elder workforce inclusion through ergonomics of work environment User Sensitive Design.
- Review of existing source of assistance tools for inclusive design of knowledge work environment.
- Proposal of a theoretical framework to assist designers in the first stage of the inclusive design process.
- Study of relevant information for designers at the first stage of the design process.

Abstract

The ageing of the population and the inverted population pyramid is bringing important changes to society as a whole. These changes are associated with the inclusion of an older workforce in knowledge work and the challenge they represent in adapting the work environment accordingly. In order to approach a more universal design of the work environment, industrial designers need support from user-sensitive inclusive design studies. While there are plenty of guidelines and tools containing relevant information, there is a need to develop more appropriate tools for Industrial Designers that cover the initial phase of the design process. This study provides a review of the available tools and guidelines and proposes a theoretical framework intended for developing a design guidance tool for inclusive workstation design.

Keywords

Inclusivity

Older workers

Knowledge work

1. Introduction

An inverted population pyramid is predicted for 2050 (Jackson, Initiative, and Plan, Jackson, 2011, Serrano et al., 2014). The proportion varies from one country to another: more than

23% of the population will be over 65 in Japan and in the US, and 17.9% of the population will be over 65 in Europe (CIA, 2010). Moreover, in the Basque Country (northern Spain) the percent of the population over 65 has reached 18.5% percent (17% in the rest of Spain) in the last 16 years, and that percentage is predicted to keep growing (Fig. 1). This requires a deep transformation of our model of society.

Fig. 1. "Population pyramid inversion in the Basque country for 2015 (left) and 2026 (right)".

This current study is framed within the strategy promoted by the Basque Government of enjoying the advantages that will come with the potential increase in an older population and what their expertise, know-how and relationships represent, where "knowledge" is the raw material. The idea is to prevent the loss of all the knowledge that has been acquired by these people throughout their professional career, knowledge that implies change, growth and internal enrichment that is beneficial to the organization they work for, which results in "knowledge capital".

A great part of national income is derived from knowledge-based industries, were the knowledge workforce plays a significant role. Knowledge-based industries are classified by the Organization for Economic Co-operation and Development (OECD) as manufacturing, financial services, business services, telecommunications, education, and health services. As knowledge work grows in significance, the door to further opportunities is opened to society, wherein we can take advantage of valuable elements that senior knowledge workers can provide us with, namely motivation, experience, knowledge, know-how and the relationships that have been cultivated over their personal experience and professional career. The trends point to an increased number of older knowledge workers, reaching numbers that have never been seen before (Myerson et al., 2010, Shiokawa and Hagino, 2002). Older knowledge workers also benefit from being active in knowledge work as well by having social contact and by feeling valuable. The changes in activity that older people experience have been studied from the perspective of the Activity Theory of ageing (Neugarten et al., 1961) and the Disengagement Theory (Havighurst et al., 1964). The Activity Theory explains the progressive drop in the activities that were previously part of an individual's daily normal life pattern and the process of progressive disconnecting between the individual and society. The Disengagement Theory supports the idea that the ability to stay active is one of the fundamental conditions for living successfully after retirement and while ageing.

'Universal design' is defined as "the design of products and environments usable by all people to the greatest extent possible, without the need for adaptation or specialized design" by North Carolina State University (Mace, 2004). 'Universal design' originated in construction and web site design (Waller et al., 2015, Design for All Foundation, 2015; Klironomos et al., 2006, Preiser and Ostroff, 2001), and thus public spaces and housing have received most attention (Shiokawa and Hagino, 2002). Shiokawa and Hagino also point out the necessity, advantages and disadvantages of focussing on the workplace, and of offices in particular, in order to face the challenge of the ageing population, that 'Universal design' can sometimes be used as a synonym for 'Inclusive design', and that 'Universal design' benefits those with similar disabilities at the same time (Shiokawa and Hagino, 2002). 'Inclusive design', in contrast, originated with product design, and although it follows the same principles, there are some differences that make 'Inclusive design' more appropriate for product design, as the 'Inclusive Design research centre' webpage (OCAD University, 2015) explains.

Age changes do not occur to the same degree or in the same amount in every person. Instead, there is great diversity among older people. Though most people today often reach old age with better health and fewer age-related issues than their predecessors, intra-individual changes are significant for design (Kothiyal and Tettey, 2001). Age is also related to the decline in physical and motor skills (Smith, 2008b), such as reaching, bending, dexterity, sight (Maguire et al., 2014), perception, memory and understanding, among other changes (Chavalkul et al., 2011). Emotional changes as the so-called positive effect (Carstensen and Mikels, 2005), or the influence of past experiences, or values change in favour of personal and social relations.

As a consequence, the contemporary marketplace should evolve to satisfy the needs of more mature users too, extending beyond those of physical size, movements and force applications. Variations also expand expectation, interpretation, perception and physical characteristics (Hitchcock et al., 2001). More attention is being paid to workplace stress, which is often related to musculoskeletal issues and which needs to be addressed in a holistic manner (Osmond, 2013). True inclusive design must engage the wider population as actual users, not just potential users (Reed and Monk, 2011). Current work environment (tools, workstation, and workspace) requires a more inclusive design in order to cope with these age-related changes, treating age-related requirements as mainstream. Moreover, new generations bring along new working styles, new technologies and new ways of interacting. This problem has been addressed by relying on the user's ability to adapt. Users become concerned about consequences; they go through training sessions, follow ups, and manuals. The problem is that these solutions too often require a lot of effort and carry an associated human cost (Tsai et al., 2012, Porter Mark et al., 2004); in addition, the solutions are costly and do not always address the problem, or at least not efficiently enough. Relying on design and ergonomics instead can provide a more suitable option. As Kawahara and Narikawa note in their study, it all boils down to the question of how we focus on the users and on humanitarian considerations when thinking about the interface between the user and artificial objects (Kawahara and Narikawa, 2015). Designers play a critical role in promoting inclusive design practice (Dong et al., 2015).

The main idea is to address the needs of the knowledge workers who use workstations. The problem is that the components of these workstations have been designed for a context that has evolved and is expected to evolve through changes in the workforce, organizational factors and activity, while the product, the workstation has not evolved enough. In the introduction this problem and design can play an important role in addressing population ageing. In Section 1.1. State of the art shows how this problem has been addressed, and the fact that there is a gap between designers' needs and ergonomics and human factors research. In Section 1.2 it is explained that ultimately it is the users' needs that will benefit as a result, it is however, necessary to intervene through designers; designers' needs are also to be addressed in the current study. Then what content is required to develop such tool framework is presented in Section 2, discussed in Section 3 and finally It is concluded that being coherent with an ergonomics system perspective, the product design, the workstation, has to evolve accordingly and the presented points are especially relevant to build upon them the future tool that serves as a bridge from ergonomics and human factors research, to designers' understanding and application in practice.

1.1. State of the art

After conducting a literature search, numerous works have been found regarding ergonomics in the workplace. However, these mainly focus on functional ergonometric characteristics, the physical or sensory aspects of ergonomics. These studies contain posture measurement tools, assessment and recommendations (UNISON, 2003; Osmond Group Limited (Osmond), 2015, Office Ergo,), anthropometric data (Kaklanis et al., 2012), methodologies, ISO Standards (Bevan, 2006), etc., all of which are relevant for workstation design and development.
There are multiple standards in CEN-CENELEC and ETSI for office environments, but they are based on current standard users and do not address inclusive purposes regarding older users. On the other hand, ISO/TR, 20081:2008 does address older people and people with disabilities. ISO/TR, 20081:2008 is intended to help standards developers understand the accessible design principles of ISO/IEC Guide 71 and implement them in individual standards by providing design considerations and ergonomic data related to human abilities. It provides relevant and useful data on ergonomics and human abilities regarding older users for inclusive design purposes. Furthermore, as Guide 71 notes, additional sector-related guides need to be developed for specific product and service sectors.

Methodologies for acquiring these measurements have also been reviewed, including active measurement. Active measurement is the recognition of posture and anthropometrics while the user is at the workstation. Automatic active recognition systems have been studied (Martins et al., 2014, Wongpatikaseree et al., 2014, Haveman and Kant, 2008), which allow some of the potential MSD (muskuloesqueletal) risks to be detected. One system uses two matrices of sensors arranged in cushions (Mota and Picard, 2003), and the CAPRIO system is a compromise between the other most used systems (Haveman and Kant, 2008). As Haveman and Kant explain in the 'Smart monitoring of worker posture in an office environment' the reason is that Video Monitoring, even with double camera used, one of the most used systems has problems when desks or other obstacles intercept the reception. Pressure mapped sensors accuracy is low compared to the other available methods, and EMG (Electromyography) is often too intrusive (Haveman and Kant, 2008). When users know how to self-adjust their posture and they are provided with continuous feedback when attention is required they react positively by sitting in the right posture (Epstein et al., 2012). Many items can be found in the market that are intended to be ergonomic in the best case, or are tagged as "ergonomic" by marketing (Osmond, 2013), from tools such as keyboards and mice to chairs and other workstation items. However, even when a product is designed "perfectly fit-for-purpose", the user might not use it as it was intended to be used. As a result, this may cause a lack in ergonomics. For example, even though a chair is "ergonomic",

fully adjustable, easy to use and comfortable in every way, the user might place the monitor too low and slide down in the chair with an unhealthy posture, especially regarding lumbar support, which results in guaranteed back and neck pain. The problem is that knowing how to use the products appropriately is not very intuitive for users, and even when designers provide information or users can access it some other way, the information too often does not reach them or they simply do not bother until they are aware they are suffering pain.
There are audit tools based on functional capability scales and anthropometric capability such as The Exclusion Analysis Tool (Cardoso et al., 2006) and HADRIAN. HADRIAN provides a multivariate of anthropometric and capability measures in virtual user trials (Kaklanis et al., 2012; Porter Mark et al., 2004; Marshall et al., 2010). But as it is based on 3D CAD, it requires having reached a design phase in which the design is clear and defined enough that it can be modelled in 3D. Other tools are more intended for field research and can provide designers with a better idea about older users' impairment through impairment simulators such as the ones found in the Inclusive Design Toolkit (Waller et al., 2015). Requirements and analytical frameworks have been proposed (Langdon et al., 2010) and have become the basis for the development of a cognitive capabilities analysis tool (Mieczakowski et al., 2013).
However, as Reed and Monk (2011) state in their study, while the tools themselves are centred on a capabilities framework, no emotional, situational, social or political components are contemplated. Actual use depends on other factors, the most important of which are preference and whether the potential user chooses to use the product over an alternative. Preference and access must be considered for true inclusive design (Reed and Monk, 2011). Customers tend to make decisions based on emotion rather than logic and reason (Khalid, 2006).
The majority of inclusive design information and ergonomics is presented as written guidelines and handbooks (Persad et al., 2007). Design guidelines are simplifications that must be general enough to be applicable to a wide range of products and technology. And where these are more precise by applying particular dimensions, they become difficult to apply to other technical areas or are too restrictive for innovative designers (Nicolle and Abascal, 2001); they also lack usability, usefulness and desirability (Nickpour and Dong, 2011), nor do they provide a specific focus on inclusive design in an office environment.

1.2. Objectives of this study

The idea is to ultimately address the necessary design requirements for adjusting the work environment (tools, workstation, and workspace) for the use of both older and younger users from a perspective of ergonomics.

The aim of this study is to propose a theoretical framework for the development of a guidance tool for assisting designers in the phase between conceptual and final formal detailing. The importance of the ergonomic systems' perspective and the coherence of the different elements of that system (formed by the workstation, tools to support the activity and workspace as interrelated parts that the user interacts with) are highlighted. The coherence between the user's body and the workstation elements, (components, user, context and the activity), are critical for both providing postural and activity support both for the user's body and other tools and items used during the working activity.

The most popular as well as challenging workspace trends are the Open Space and Activity Based Workspace (a.k.a. Hot Desking) (Myerson et al., 2010), where workstations are used by multiple users, often for a short time. The lack of ergonomics and particularly the lack of coherence between the user's body and the workstation elements is a problem especially in Activity Based Workspaces, or for users who have greater physical needs, such as many older knowledge workers. For this reason, though workspace and tools are considered as well, workstation design is the main focus of this study.

The tool that will be based on the outcomes of the study should assist designers by providing the information related to the specific design item from the workstation items studied, without overwhelming the designer with too much information. This way, the risk of pitting creativity against functionality, which is critical in this phase (Reed and Monk, 2011), is minimised while leaving space for creativity to develop. Consequently, it is necessary to provide guidance without providing constricting values. As a result of using this guidance tool the designer should be able to identify the potential problems regarding physical and cognitive abilities, as well as emotional issues. Moreover, the guidance tool should provide information on the coping strategies found in the interaction with the studied cases, and some guidance for choosing methods for assessing product accessibility (Cardoso et al., 2006), further development methods information sources suggestions. Information needs to be presented in easy and accessible formats, perhaps by educating designers in useful data sources (Goodman et al., 2006).

2. Inclusive workstation design guidance tool development

The theoretical framework for the development of our guidance tool will be referred to as the Inclusive Workstation Design Guidance tool (InWoDG). This section describes the context in which InWoDG is intended to be used, two field studies which address users' and designers' needs, and a range of topics, that is, the essential physical, cognitive and emotional requirements to adapt each workstation to each person, where the users of the workstation include older persons.

2.1. Design process contextualization

As defined by the Design Council-Double Diamond model, the design process usually involves the following four main phases: 1) Discover, observe and analyse the context and the field research; 2) Define and evaluate the identified requirements; 3) Develop, propose solutions; 4) Deliver and test the final decisions (Design Council, 2007). Fig. 2 illustrates this process. It is precisely in the first two areas, Discover and Define, which are shaded in darker grey circles and are illustrated as the first diamond, where action is required. These areas are the most conceptual and abstract part of the project. This part starts from the client brief and ends just before technical details are specified and the development phase starts. During the Development phase, formal definition takes place (often involving detailed sketching, materials definition, 3D modelling, etc.). The phase in the first diamond includes the familiarization and research process of the designer and the abstract and conceptual idea. For that purpose it is common for designers to do field research, whether it means observing or directly interacting by asking or otherwise trying to involve the users and self-experience, as proposed in the IDEO user-centred design methodology or other research methods (Kumar, 2012). Apart from the research, in this phase storyboarding and sketching, as well as other common ways of exploring an abstract idea, are also common. As a result of this phase, the designer has an idea of what the product has to be, what the final use is, who is going to use it and in what context, and more or less what the final product will look like.

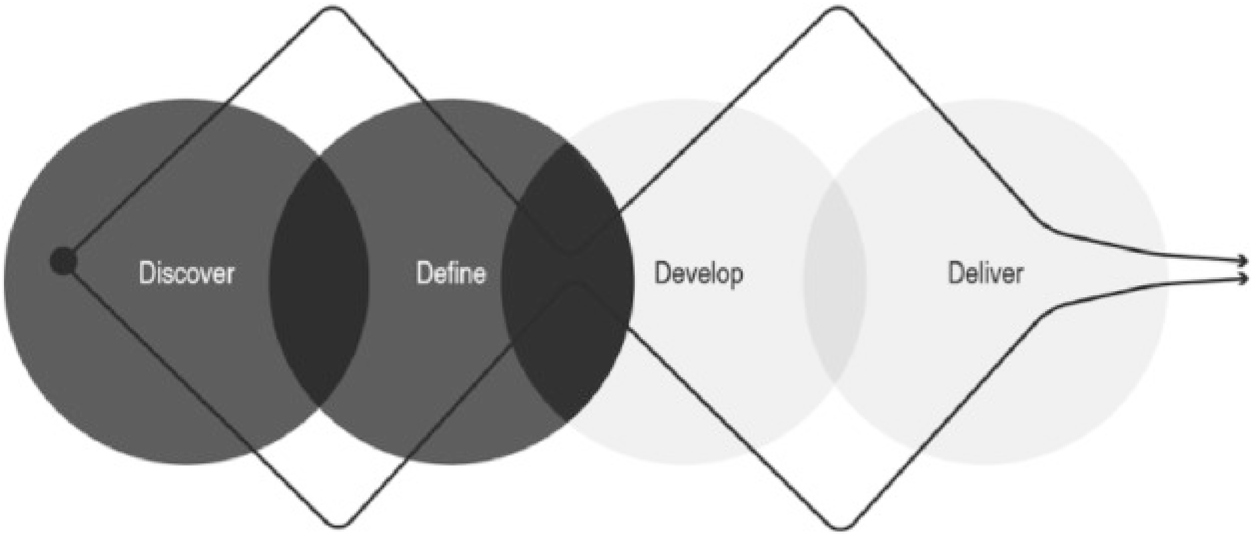

Fig. 2. “Design process four main stages Design council-Double diamond model (Design Council, 2007)”.

The Discover and Develop stages defined by the Design Council-Double diamond model correspond to Explore and Development, according to Dong et al.'s terminology, which are the phases of the project when data is most used (Dong et al., 2015). Product Designers want to have as much human factor inspiration as possible in the conceptual design phase (Fulton Suri and Marsh, 2000).

InWoDG does not propose specific solutions, but instead provides the basic direction for the designer who uses it to interpret the data. More particularly, the guidelines provided are intended to give assistance during the initial phase of design, prior to dimensioning. The costs in this phase are only marginal since making changes to plans is minor compared to making changes in the physical manifestation of the plans (Edwards and Jensen, 2014).

Although there is a wide range of tools which address the first and third phases of the design process illustrated in the diamond model, there are no tools designed to address the needs for the second phase. A consequence the designers are left with little more than intuition to overcome such gap. This gap from projecting to correcting can result in an iterative process in which it is easy to get lost.

Physical, sensorial and even cognitive science has been widely explored and considered in such tools at the first stage and third stage. But too often emotional ergonomics are ignored even from the first stage in the design process. The presented framework highlights the relevance of emotional ergonomics as well as another significant issue to cover together with usability and recommends the tools from the first and third phase in case the designer wants to expand the base or continue the development beyond the second phase.

2.2. Field studies

We carried out two field studies. One addressed the needs and preferences of the users who are going to work at the workstations and the other addressed the needs and preferences of the designers of those workstations.

2.2.1. Field study with users

2.2.1.1. Objective

The first field study aimed to obtain information regarding the contents of InWoDG in order to see how inclusivity and ergonomics are applied in practice and how this varies with age and new trends in the workforce and the workplace. It also studied the elements (environment, workstation components and tools) that were used and preferred by knowledge workers in practice.

2.2.1.2. Participants

Participants were classified into three age groups: 24–35, 36–59 and 60–70. The main focus of the study was the oldest and youngest groups. The reason for this is that the 60–70 group is closest to the current official retirement age, and in 2050 the 24–35 year olds will be the ones who will be near retirement and who have experienced the newest office trends, such as shareability and openness.

2.2.1.3. Methodology

The methodology is based on design thinking. For this purpose a combination of IDEO method card tools were used (i.e. Extreme User Interviews, Card Sort, Surveys & Questionnaires, Behavioural Archaeology and Fly on the Wall).

Each respondent performed two tasks: the card sorting exercise and an online survey. While these tasks were being performed by the respondent, the surveyors observed the physical ergonomics of the workstation based on an OSHA evaluation checklist.

2.2.1.4. Results

One of the outcomes from this field study was that even the most ergonomic designs were used improperly due to a lack of coherence in adjustment between the tools. As a result, not only were the older knowledge workers not enjoying an ergonomic workstation, but neither were users from all ages and workspaces. This highlights the importance of an inclusive approach for the workstation adjustment process, as the whole workforce would benefit.

2.2.2. Field study with designers

2.2.2.1. Objective

To aim of this study was to address designers' specific needs, content and format. This field study was based on a survey in order to get qualitative information. Our second aim was to see whether the designer needs and preferences described in the literature would match the participants'. The literature reviewed describes designers' needs and preferences as follows:

Designers use visual thinking and have a visual memory (Shah et al., 2011). They prefer information that is quick to find and easy to use, is visual and stimulating, is flexible and open-ended, and relates clearly and concretely to design issues (Goodman et al., 2007, Dong et al., 2015).

Designers have to deal with tight deadlines, and they do not always have the technical background or time to research. Especially when users like older people are involved (Persad et al., 2007, Cardoso and John Clarkson, 2012), it is hard for them to deal with the whole array of information that needs to be read in order to understand the main ergonomic requirements (Mieczakowski et al., 2013, Hitchcock et al., 2001).

2.2.2.2. Participants

Only product designers were selected for this field study. They have different levels of expertise, from junior to master.

2.2.2.3. Methodology

Designers were asked about what information they would look for, what information they would be missing from the content (draft version of content to be included in InWoDG) they were asked to look at, what methods they apply before and after the conceptual phase and how the content should be arranged in order to fit with design practice.

2.2.2.4. Results

They all had in mind a system in terms of where and in which context the designed product would be used as well as what type of user would be interacting with the product. They all agreed about the issue of tight deadlines regarding time resources and research. However, they placed great value on field research and rich information. Anything that could facilitate the information process, suggest related information and provide guidance and rich information would be a great idea. Some of them appreciated the case study from some chosen specific products. And as previous studies have shown, experienced designers were more selective regarding tools and information than novices (Dong et al., 2015), and for that reason a filter that personalized information according to the brief and preference was rated as a very valuable tool. But as the previous field studies showed, designers are not aware of the need for there to be coherence in how the different elements of the workstation's components are adjusted in order to provide the appropriate fit to the user's body and activity.

2.2.3. Outcomes

As a result of the two field studies and considering the data provided by users and the information provided by designers in terms of the required content and format preferences, the InWoDG content was shaped and integrated as described in Section 2.3.

2.3. Required information

In order to provide an overall view of the problem that needs to be solved when trying to design an inclusive workstation, a coherent system view is needed. In what follows, we describe the information that was required for and included in InWoDG, the four elements from the system view (products, user, context and activity) and examples from the case studies.

2.3.1. Work environment system view

Human Factor Ergonomic theory points out four correlated factors that are crucial when considering technology–human interaction: 1) the tools and workstation components that constitute the workstation (product); 2) who are they are designing for, from master and senior to younger knowledge workers (user); 3) what organizational factors and workspace they are designing for (environment or context); 4) the activities and tasks over time that constitute interaction (activity) (Persad et al., 2007, Bridger, 2003, Karwowski, 2002). This system view is illustrated in Fig. 3.

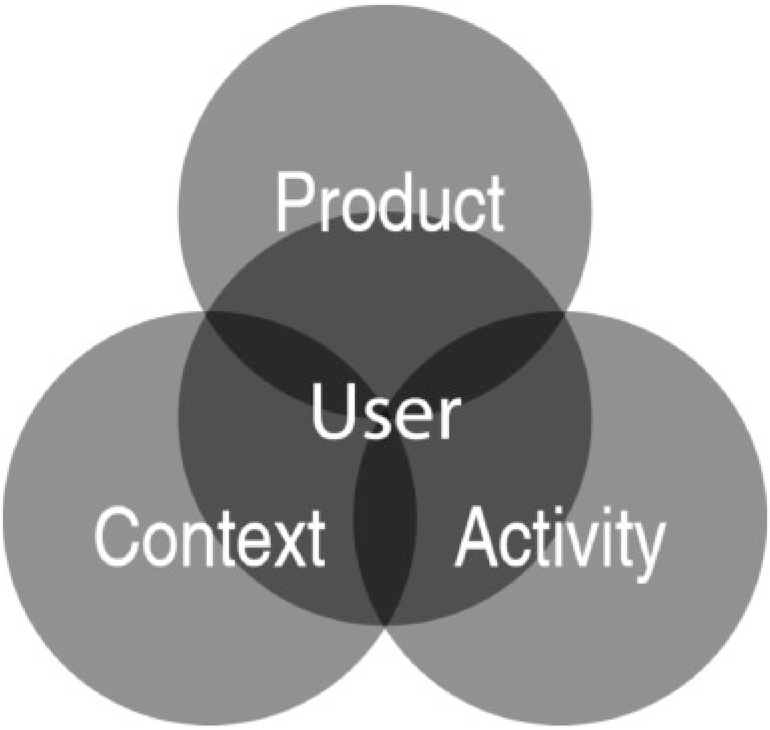

Fig. 3. “System view”.

When approaching workstation design and determining the limits and scope of the system to be designed (Edwards and Jensen, 2014), there is the possibility that the designer only intends to design one of the workstation components and would think that it is not necessary to know about the rest. As a consequence, in order to develop an ergonomic design where there is coherence between the products, users, contexts and activities that make up the workstation, it is necessary to see the designed workstation component from a wider scope, as a component of a system (Wilson, 2014, Chandrasegaran et al., 2013).

2.3.2. The product: workstation components

It is the product, in this case the workstation components, that designers are responsible for. The term 'workstation components' can cover a very wide range of items and tools and combinations of them (i.e. chair, desk, monitor, keyboard, task lamp, footrest, etc.). Under this system view, the workstation should provide support for and be coherent with the four system view elements. In other words: 1) the designed product should be compatible with the other workstation components which are present and used in the workstation (product compatibility); 2) the designed product should provide physical-sensory, cognitive and emotional support for each user (user compatibility); 3) the designed product should fit its context and environment (context compatibility); 4) the designed product should provide support for that activities and tasks that over time constitute the interaction activity.

There are various postures apart from the sitting position (Bettany-Saltikov et al., 2008). In fact, research on the benefits of a system which allows postures to change has proven to be positive (Cranz, 2000, Cramer, 1998, Kraemer et al., 1985, Veiersted et al., 1993). As an example of these many possibilities, InWoDG illustrates the most currently common example of a workstation, which is composed of a chair, table, and computer elements with the footrest when necessary and their potential configurations and the adjustment possibilities. Case studies considering other workstation component possibilities such as a standing desk, a height adjustable electric or manually adjustable desk, etc., or chairs with different adjustment possibilities (i.e. reclining backrest and seat, fixed or adjustable armrests, etc.) should be included as well. The InWoDG tool should provide the designer with the idea of various possibilities and examples for workstation components, workspaces and users.
And what is more important, InWoDG should provide the designer with the idea of the relation between the system items, why each item can be more suitable for one environment/workstation/tool or another from an ergonomics perspective. This allows a designer to see, for each item, how well it provides a service for the user from the physical, cognitive and emotional points of view, when evaluated against the factors related to the other items. That way, as suggested by the designers interviewed (Section 2.2 Field review),

the designer should be able to filter information according to the input constrictions while being open to inspiration from the possibilities of the given constrictions.

2.3.3. The user: user-sensitive perspective and workstation users

From a user-sensitive inclusive design point of view, the three branches of ergonomics should be considered. Moreover, sensitive inclusive design considers the whole person, not only physical ergonometric characteristics (Newell et al., 2011, Reed and Monk, 2011, Edwards and Jensen, 2014). This is the three branches of ergonomics are related to the Physical, Cognitive and Emotional aspects.

As noted in the State of the art section (1.1), the measurable physical and cognitive aspects of ergonomics have been widely and deeply covered by the research literature. However, user emotion and the areas in design aesthetics that have an impact on user behaviour have been comparatively neglected. Nevertheless, research in marketing, design, consumer behaviour and business strategy, and in the field of human factors is presented as evidence of the importance of these topics (Parker, 2014, Jordan, 2002a).

As Lindström and Bholin suggest in their study, it is evident that the role that emotion plays in influencing human behaviour is not yet fully understood, although it clearly impacts user satisfaction and it may play a larger role within information processing (Lindström and Bohlin, 2011, Parker, 2014). Emotional factors are very important for product acceptance and are necessarily considered in user-sensitive inclusive design. Actual use depends on more factors than usability (Reed and Monk, 2011, Khalid, 2006).

Aesthetics should be considered as well. Some studies show aesthetics play a significant role and can influence the users more than the actual usability of the interface (Tractinsky et al., 2000). As Newer and Alan point out in their studies, many products specifically designed for older people show evidence that the design teams do not engage emotionally with the user groups, assuming that older and disabled people lack aesthetic sense and unlike other users groups are motivated entirely by the functionality of the products. They hold the view, supported by other authors as well, that assistive technology can be attractive rather than discrete, understated rather than invisible, or indeed be deliberately visible, even provocative (Newell et al., 2011, Gregor et al., 2005, Pullin, 2007, Tractinsky et al., 2000).

Too often existing products and services make age-related changes more evident for users. As a result, users are forced to invent coping strategies or accept or reject products and services that are unavoidably linked to the emotions related to accepting those natural age changes. Presenting products as any other consumer good, designed for mainstream users instead of presenting them as for a very specific target audience, such as people with disabilities or older people, can prevent labelling and stigmatization (Correia de Barros et al., 2011).

2.3.4. The environment or context: the workspace and organizational factors

Four main organizational factors have been identified in determining the workspace: 1) openness, which refers to the lack of partitions or walls; 2) shareability, which refers to how many people share the space and/or the workstation; 3) protocol, which refers to whether the users are allowed or expected to collaborate or concentrate; 4) personalization, which refers to the allowed or expected availability of personal items and preferences.

The large increase in the number of knowledge workers has brought two main changes to work environment design, resulting in a decrease in personalization in the office. These changes, as described in the studies by Gustafsson and Felstead et al., translate into two different ways of using space to accommodate the increasing number of workers. One change that affects openness is the simultaneous sharing of workspace among workers, a.k.a. Open-Space (OS) plans. Another change is shareability, in which workers share available workstations with other workers at different times, a.k.a. Activity-Based-Workplace (ABW) (a.k.a. Hot Desking) in order to maximize the diversity of activities and different usage times (Gustafsson, 2014, Felstead et al., 2003). In ABWs users do not have assigned workstations but instead they share the workstation depending on what time they need it. Thus, different users use the same workstation at different times. Many older workers, especially when near retirement or under flexible retirement, work part time and many organizations support ABW. In both types of environment, the lack of ergonomics and human factors (physical, cognitive and emotional) and inclusivity are even more evident.

As a consequence of increased openness, protocols and personalization are changing as well. A lack of protocol is often a problem for those who need to concentrate in open spaces. And a lack of personalization is a consequence of shareability (Myerson et al., 2010).

Numerous studies have investigated the effects of environmental factors on work performance and satisfaction; such factors include temperature, sound (Haake, 2011) and light (Salvendy, 2001, Clausen and Wyon, 2008). When the space is shared, other environmental factors are acoustic exposure (i.e. lack of privacy when holding a conversation, hearing noise form co-workers or tools in the environment, etc.) and visual exposure (i.e. feeling 'on-call', confidentiality issues, etc.) (Myerson et al., 2010). Though sound issues are an issue for all workers regardless of their age, especially in shared open-plans, some studies

show that workers over 45 are more sensitive to these sound-related environmental factors (Mak and Lui, 2012, Evans and Johnson, 2000).
Environmental factors should be considered for the layout and products selected (i.e. 90° window-monitor; luminance levels and task lamps) and product design (i.e. reflectivity of the desk surface, task lamps with lower luminance levels, etc.) (Salvendy, 2001, Myerson et al., 2010; ISO/TR, 20081:2008).
When the workstation follows a lean space policy, personal items or other items that are not strictly necessary are expected to be absent from the workspace. Enriched spaces, in contrast, encourage the presence of plants and personal items and allow other workstation components to be arranged and placed in the workspace. A study comparing three levels of personalization (Knight and Haslam, 2010) has shown lean spaces to be counterproductive, while a certain degree of personalization and creating an enriched environment can contribute to improving worker satisfaction and performance.

2.3.5. The activities and tasks: during, before and after work activity

2.3.5.1. During work activity

Office work nowadays involves more complex interactions in which there is more ambiguity, analysing, creating, learning and acting on information. For this reason it is called knowledge work (Erlich and Bichard, 2008, Smith, 2008b). Some examples of knowledge workers are manufacturers, service providers, researchers and students (Dong et al., 2015).
Knowledge work tends to be driven by objectives, allowing more autonomy in the way tasks are performed, for example in terms of time and presence. Additionally, in many cases, knowledge workers tend to be more mobile (Greene and Myerson, 2011). Knowledge work demands more personal involvement, self initiative, flexibility and autonomy.
The other activities in which the workstation adjustment and work are contextualised should be considered when designing the layout and workstation components, these include human–human interaction, whether an activity is going to involve collaboration and networking, or rest or concentration.

2.3.5.2. After work activity

After work activity, the user gets tired. One of the factors that lead workers to experience flow during a work activity is achieving a feeling of serenity, which is often hard to find in a stressful workspace. A short period of recuperation can help to improve concentration and performance. When this restoration and serenity can be found in a workspace, not only does it make the work environment more comfortable and stimulating, it also gives the knowledge workers a signal of trust. Contemplation and rest are often associated with relaxation. However, active rest, as changing activity, not necessarily implying a higher degree of mobility, but basically distracting form the main activity, can also be beneficial. Google's gaming rooms are a good example. It is still hard for managers to assume that an idling mind can also add value to work (Myerson et al., 2010).

2.3.5.3. Before work activity

The first and crucial activity before any user can start working is to adjust the workstation to the user's body and preferences. This adjustment is so important because it directly affects the performance of the worker during work activity. There are some layout adjustments (i.e. screen at 90° to the windows, luminance levels, product selection) that are carried out by different employees than the ones using the workstation; each workstation user has some other adjustment parameters that are usually adjusted by the user.

In ABW spaces, like other types of non-assigned workstation systems (i.e. Hoteling, touchdown areas, etc.), the way the last user left the workstation affects how the next user will have to readjust it. After the user has left the workstation, factors like confidentiality, security and maintenance also become relevant.

3. Case study: physical parameters and adjustment parameters for adjustment before knowledge work activity

In order to illustrate how the above-described theoretical framework can be applied to InWoDG in practice, in this section a case study is presented.

This case study's objective is to design a height adjustable chair, following an inclusive design point of view. The requirements specified by the client are used as a filter. Based on this filter, specific guidelines can be provided by InWoDG. These inputs, determined by the client and specified to the designer, are considered in InWoDG to be a trigger and a filter of the suggestions. In this case study, the defined system view is: Product—chair with adjustable seat height; User—any worker that finds the workstation available, from junior to master; Context—ABW, with a lean space policy; Activity—Knowledge work, in a seated position and chair adjustment is made by the workstation's smart system or manually by the user.

InWoDG then suggests a series of variables based on the specified Product, User, Context and Activity for the designer to choose from as the designer navigates, so only the relevant information is displayed. In this case, InWoDG would suggest the following age-related potential changes illustrated in Fig. 4 as design challenges to consider in the filtered navigation (Fig. 4: A) Motor, B) Sensory, C) Cognitive, D) Emotional).

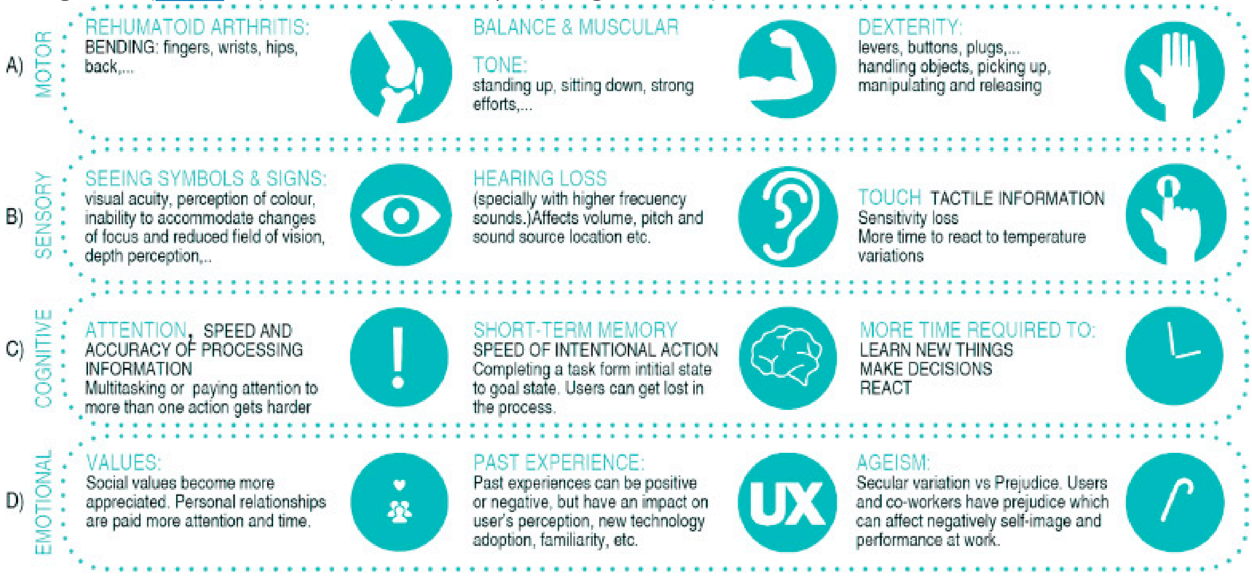

Fig. 4. “Potential age-related changes to cater for as design challenges”.

By the end of the system view definition process and navigation, the designer has acquired the ‘abstract idea of the product’. The designer is aware of what inclusivity points are covered and dismissed in the design, what other products are compatible with the designed product, what type of users can find the designed products easy to use, in what context they can fit and what activity are they suited for.

InWoDG at this point provides the designer with orientational rather than prescriptive information about the existing and possible solutions by providing examples of case studies, information sources and suggestions for further exploring design thinking tools. At this point, the designer will get the last input from InWoDG before starting to define a more conceptual idea of the product, about what the interaction is to be like, and what the shape and results can be, or whether similar solutions already exist.

3.1. Information flow

In order to obtain the information for a suitable adjustment of the workstation (whether this adjustment is done manually or by a smart system) the following information is required: 1) **physical parameters**, 2) **different capabilities** and 3) **personal preferences**. This information is used as input for the adjustment process and flows through the steps described in the following paragraph and illustrated in InWoDG.

Firstly, the information needs to be retrieved from some reliable source. Usually, this information is a product of the user's impression and how well this is interpreted and executed in the system's adjustment. For the physical parameters, active information reading (Martins et al., 2014, Wongpatikaseree et al., 2014, Haveman and Kant, 2008) is also possible. Fig. 5 illustrates different information source possibilities. These are based on user perception and impression, active measuring or stored information. Stored information would add one more step to the process: measure, which in the case of 1) **physical parameters** and 2) **different capabilities** could be done by a professional ergonomist, and in the case of 3) personal preferences they could be defined by the user at a different time. The physical parameters that are affected by adjustable seat height are illustrated in Fig. 6. After the information has been stored the second step would be to retrieve it from storage.

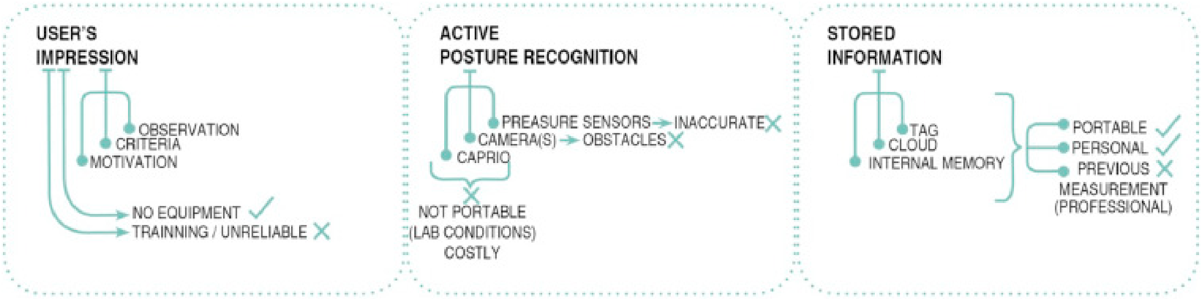

Fig. 5. "Potential information sources".

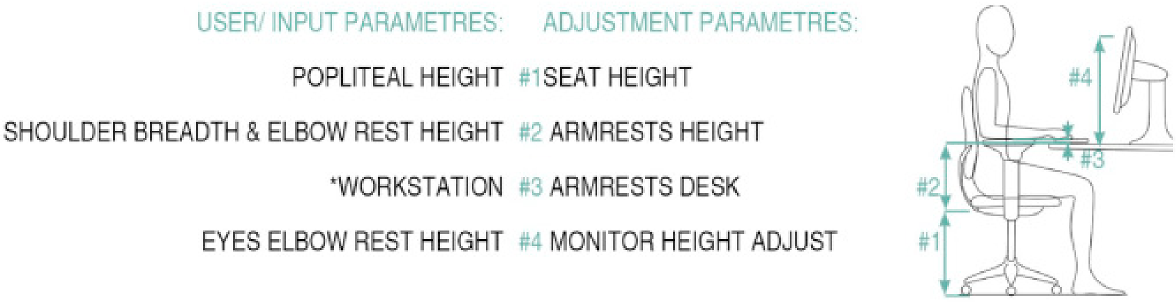

Fig. 6. Seat height dependent adjustment parameters.

The information retrieved then needs to be communicated through any one of the different mechanisms to the information processing agent. This information processing agent is the person or processor from the smart system that executes the adjustment action and movement. The agent could be the user, as is expected with traditional office furniture, or in the case where the workstation were sufficiently smart, the agent could be the workstation's smart system (through an automated or semi-automated process), such as the one described in Herman Miller's patent (Beck et al., 2011).

Manual adjustment and user interaction, however, should be considered. One major reason is the importance of pleasurable interaction and how it may be derived by integrating adaptability into designs and providing features that enhance control (Khalid, 2006).

3.2. Adjustment steps

For each step there are three main sections—1) Goals, 2) Current solutions, and 3) Guidelines—which are illustrated in Fig. 7, Fig. 8, Fig. 9, respectively.

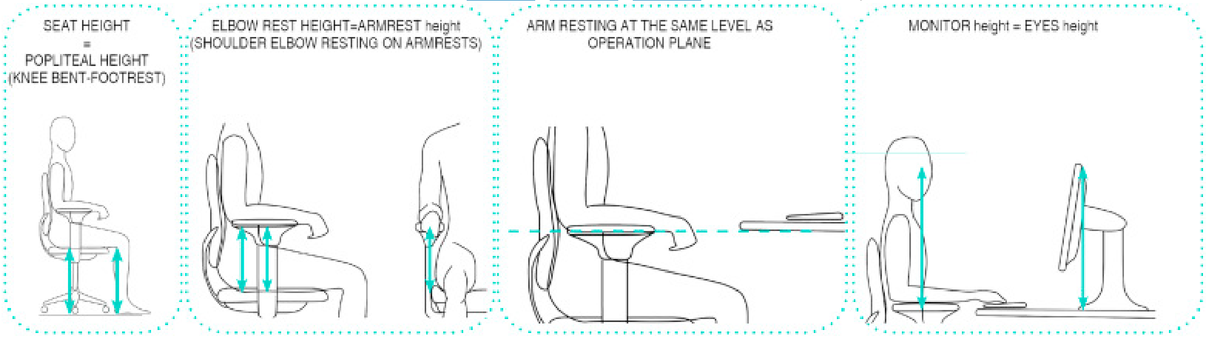

Fig. 7. "Goals for seat height".

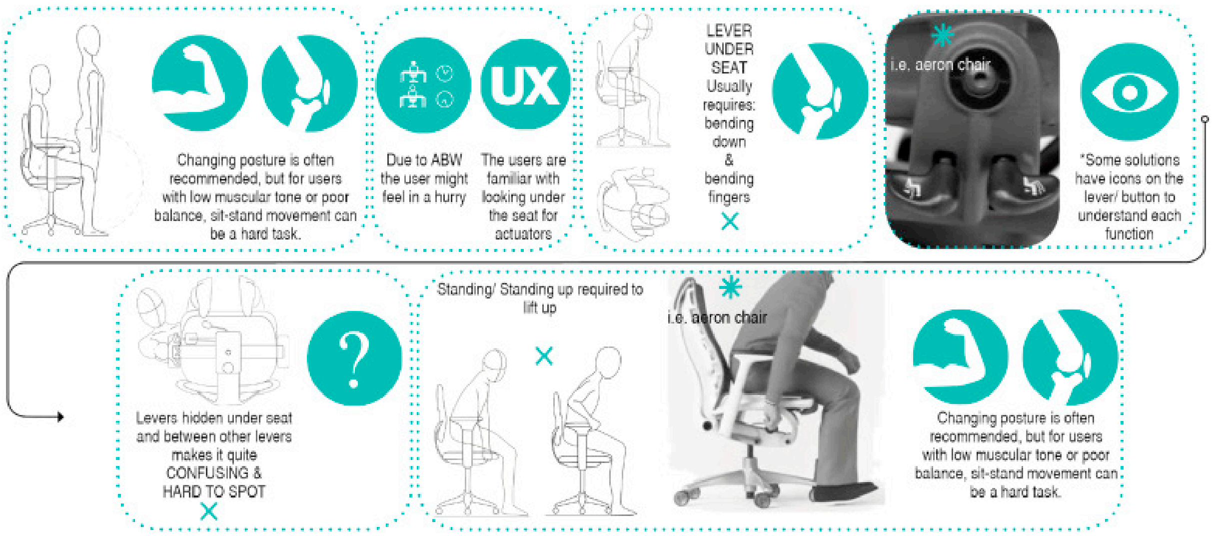

Fig. 8. "Current solutions for seat adjustment: case study".

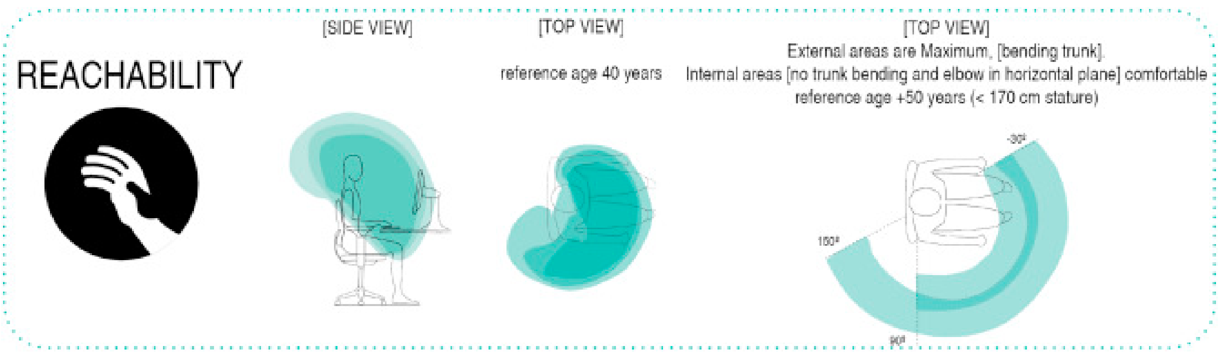

Fig. 9. “Guidelines for reachability mapping from a sitting posture (NASA-STD-3001,, ISO/TR, 2008)”.

The Goals section refers to the ideal adjustment scenario. In the Goals section, user parameters and workstation parameters are related. This alone would help the designer to see the relation between the different components of the workstation defined in the system view.

The Current solutions section (Fig. 8) refers to the evaluation of existing solutions, where common issues, good solutions and some examples appear. In this section some of the most adjustable and popular items available on the market are evaluated.

The Guidelines section gives advice on the most accessible posture for that adjustment process in particular and some other design ideas to interpret and develop into tangible solutions. In case the adjustment was to be manually executed visualizing the mapping accessibility by posture as for example the one illustrated in Fig. 9. (which shows reachability from a sitting posture). Another example is illustrated in the third vignette from Fig. 8 (reachability from sitting posture to solve the Lever under the seat problem). And a third example is illustrated in fourth and fifth vignettes from Fig. 8 (visibility to solve the ‘Levers hidden under the seat’ lever searching problem). These illustrated examples are especially relevant, together with other sensory and cognitive factors. Other design thinking tools, such as activity analysis, like the result illustrated in the timeline from Fig. 10, can be helpful for better understanding the design for the activity and the other workstation components. The manual adjustment process timeline illustrates how the adjustment process is usually executed to avoid interfering with previous adjustments and a logical order for the minimal amount of steps. If the adjustment process is being done automatically, the order would depend on the system's engineering.

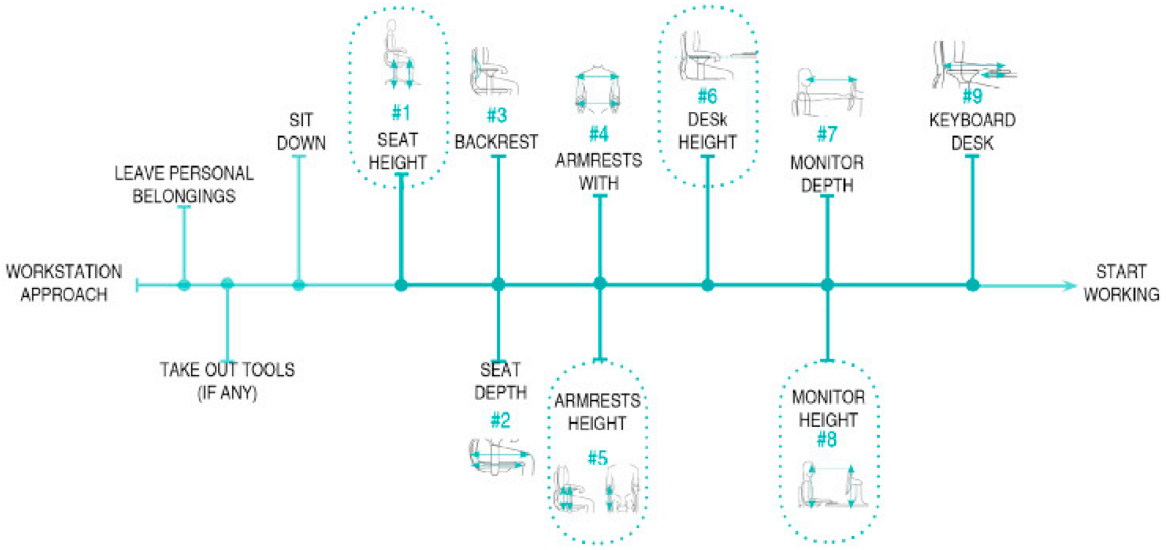

Fig. 10. "Guidelines for timeline illustrating the activity, before, during and after seat height adjustment".

4. Discussion

There are some unclear issues regarding how the final implementation of InWoDG will translate into practice relative to other aspects such as 1) other workstation components, 2) emotional ergonomics content, 3) guidance for other design steps, 4) context setting, 5) all the content that should be covered by and the limitations of InWoDG, and 6) the format it should be presented in.

While it is relatively simple to review the physical layout of the workstation, it is harder to review all the tools the user may operate. For this reason, although currently standard tools have been classified and included in InWoDG, the rapid and rich diversification of these makes it hard to review all the tools a user may operate in practice. As a consequence, it would be interesting to keep updating the InWoDG content regularly from field research and information provided and requested by the users themselves.

Another concern is how to address emotional assessment. User emotion and preferences can be more significant than other factors in user behaviour, as we saw in Section 2.3.2. The main problem with emotional ergonomics is that emotions are personal and can be experienced simultaneously, and how to measure them is still a great unknown (Desmet, 2003). Individual differences may encompass culture, gender, anthropomorphic tendencies and interaction and these may be predictive for 'product emotional expression' as coined by Smith or in other words, how emotions are perceived, associated and expressed in relation with the product (Smith, 2008a). There is a range of methodologies for approaching the challenge of considering emotional ergonomics in design, by identifying emotions related with the product or product features (i.e. SeQuaM, PAD, SAM, PrEmo, Kansei engineering, QFD, etc.). For more information about these methodologies see (Nagamachi, 1995, Nagamachi, 2002, Schütte et al., 2008, Lokman, 2010, Jordan, 2002a, Jordan, 2002b, Spillers, 2004, Smith, 2008a, Di Bucchianico and Vallicelli, 2011, Levy, 2013). Although some works exist regarding the application of these methods to the design of office-related workstation components (Mohanty and Mahapatra, 2014, Smith, 2008b, Vilnai-Yavetz et al., 2005, Helander, 2003) and mainly in environment (Donald, 2001), further research should rely on psychology and potential age-related emotional changes in order to better use the identified emotions and relate those emotions with products or product features. This will enable designers to expand to other workstation components in order to cover applicable content for InWoDG's purpose. InWoDG is intended for the initial phase of design, for more detailed information required by a specialist or further phases of the design project development other existing documents and tools are explained in the reference links, which can be found in the InWoDG.

Once all the required information is fulfilled a tool should be developed based on that content and the final tool users, industrial designers' feedback. A systematic analysis of the system is presented. This system analysis can be based on the systematic application of ISO/TR, 20081:2008, paying attention to the considerations related to the context of the inclusive design of a workstation in order to obtain more particular guidelines. However, the information obtained would be so extensive that only the most relevant information that applies to the design purpose in the first stage would be forwarded to the InWoDG content; to make this more manageable, creating such a format can be an open source development project. More designers' feedback and evaluation should be taken as reference. In other words, in order to build an effective and valuable tool further field research and feedback from industrial designers would be of great value.

And finally, based on this framework a tool that encourages empathy should be developed in easily accessible formats, such as the example suggested by Goodman et al. of presenting a card or magazine format (Goodman et al., 2006) or a digital application that follows designers' preferences (Goodman et al., 2007, Dong et al., 2015), from which interviewed designers considered most appropriate an interactive application or web page and which is currently under development.

5. Conclusions

In order to face the challenges that the inverted population pyramid will bring and to make use of the great potential and benefits of having an older workforce in knowledge work, the necessity and relevance of relying on design and ergonomics has been shown. An extensive literature review has pointed out the lack of tools in effectively assisting industrial designers in the first phase of the design process, which focuses both on inclusive design for older persons and design for the knowledge work environment. For this reason, the current objectives of our study were to 1) help adapt the design requirements to the work environment for the use of older and younger knowledge workers by considering ergonomics and focussing on the coherence of the designed product as part of a coherent system formed by the product, user, context and activity, and 2) provide a theoretical framework for developing a digital guidance tool to help industrial designers in the initial phase of the design process, in a way that connects research with application in a more usable, useful and desirable way.

First, the process and needs of industrial designers were described. Then the required information content covered 4 main ideas: 1) workstation component design is inherently linked to the system it belongs to; 2) a user-sensitive coherent perspective, which covers ergonometric and psycho-social considerations, is demanded; 3) the context has changed with new generational trends and the emergence of ABW highlights importance of the adjustment activity; 4) the adjustment activity determines how the work activity will develop. Physical and adjustment parameters are strongly linked to each other and are critical in the adjustment process. Finally, a case study was presented.

This theoretical framework provides relevant information regarding the three ergonomics aspects (physical, cognitive, emotional) contemplated in user-sensitive inclusive design. This, when used from the beginning of the design process, helps to reduce the following iterative process of correcting the measurable aspects of the product (physical and cognitive) and helps to acquire a broader understanding of the user. As a result the theoretical framework proposed in the current document provides a base in order to create a tool that can help the designer to make a mental model of the user that more closely matches reality, to create a solution that is coherent with the user's environment, and to find a starting point for the next step in the design process.

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