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Needs Identification Methodology for Inclusive Design.

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Identification of user needs is an essential phase in the early stages of every design project. Many needs identification methodologies are described in the literature. When targeting users with special needs, the task becomes more challenging for different reasons (difficulty of retrieving information, performing prototype testing, etc.). This article presents a novel methodology, NIMID (Needs Identification Methodology for Inclusive Design), that guides the process of needs' identification in the inclusive design scenario considering users' physical, sensorial and cognitive capabilities. NIMID is grounded in Abowd and Beale's HCI framework and uses WHO's International Classification of Functionalities as the taxonomy that provides a common language. We exemplify the application of the methodology in the design of a smart oven for elderly people. We also compare NIMID with other methodologies evidencing its strong points: universality (common ICF language), systematicity (clearly defined phases and outcomes) and rationality (grounded in well-established interaction theory).
Keywords: Needs identification; inclusive design; International Classification of Functionalities; interaction

1. Introduction

Elderly and disabled people suffer from different physical, sensorial and/or cognitive impairments which deteriorate over time. Age can affect the functionality of sensing organs and information processing capability as well as reducing the speed and accuracy of movements, prolonging the "thinking time" necessary for understanding some situations, increasing the difficulty of doing two things at once and reducing the attention span over long periods of time. People affected by these conditions comprise a heterogeneous group whose needs vary significantly. Many such people lose the ability to use appliances, communication devices, assistive technology, etc. and consequently suffer major loss of independence. Thus, understanding their needs is crucial for the success of Independent Living Services (Comyn, Olsson et al. 2006).
Users typically need sensory (such as vision and hearing), motor (such as dexterity, locomotion, reach and stretch) and cognitive (such as memory, learning, comprehension) capabilities when interacting with a device. Inclusive Design is a

design philosophy that considers the needs and capabilities of the whole population, with the aim of making products functionally accessible to and usable by as many people as reasonably possible (Johnson, Clarkson et al. 2010, Tenneti, Johnson et al. 2012). Identifying and understanding user capacities, as well as studying the interaction between user and product, is fundamental to successful Inclusive Design (Keates, Clarkson 2003). When considering the needs of groups of users such as aging adults or people with disabilities, this becomes more complex as capabilities decrease with age and other pathologies associated with ageing appear creating many different cases, some even unique. This situation results in a complex scenario with a fragmented map of needs where consideration must be given not only to people with special needs but also to other stakeholders such as facility managers, relatives and caregivers (Ashford, Osman et al. 2007).

This paper introduces a methodology, NIMID, to identify the needs of a specific population as a necessary first step in the design phase of a product. NIMID examines how the target population currently performs the functionalities to be supported by the new device or system. It is grounded in two well established principles: the International Classification of Functioning (ICF) (World Health Organization 2001), a taxonomy that provides a common language, and Abowd and Beale's Interaction Framework (Abowd 1991).

NIMID has been applied to the study of the needs of a smart kitchen, focusing on the study of the interaction between elderly people and household appliances present in the kitchen environment (hob, oven, fridge, etc.). As an example of the application of the NIMID framework, we have selected the oven to be a challenging appliance in terms of user interaction. Note that although an oven might not necessarily be considered as an ICT device, all kitchen appliances can be described as IT devices in this context because they include user interfaces, sensors, and communication and processing capabilities, and they integrate into a smart system making them accessible via IP through smart phones, tablets, etc.

The paper has been structured as follows. Section 2 summarises the state of the art of related research. In Section 3 NIMID is introduced and in Section 4 it is applied to the design of a smart kitchen for elderly people. Section 5 gives a reasoned discussion of the application of the methodology. Finally, the conclusions are set out in Section 6.

2. Related work

In the early 1990s, the increasing relevance of computers provided the opportunity to consider the capabilities of people with disabilities in new contexts, and this represented one of the principal challenges of human factors research (Elkind, Nickerson et al. 1995). Furthermore, the relevance of matching user needs not only with task demands but also with situational contexts became apparent (Caldwell, Uang et al. 1995, Hasdoğan 1996).

Currently, deep needs analysis is a key element in Inclusive Design. In addition to its importance for product or service design purposes, it is useful for creating knowledge that might help designers to meet the needs of those who are often excluded from product use (Coleman 2001), for building risk management frameworks to assist in selecting devices that match the needs and wishes of particular individuals (Monk, Hone et al. 2006), and for setting benchmarks against which the outcomes of device procurement can be gauged (Fuhrer, Jutai et al. 2003).

As is the case with medical devices, there is little published work on the human factors available for assessing the requirements of users with special needs in the design of new products. One important reason for this is that such devices are usually technology driven rather than driven by the identification of unmet needs (Martin, Norris et al. 2008). The study of ergonomics is thus challenging for different reasons:

- Context and sampling: devices are used by users with different capacities, within different scenarios and stakeholders (relatives, socio-medical professionals, therapists, etc.) and with a high heterogeneity that hinders quantitative methodologies and group studies. (Johnson, Clarkson et al. 2010) specifically identify the lack of data on multiple capabilities, the absence of surveys with an appropriate level of specificity in the questions (existing health and disability surveys usually ask general and disease-specific questions) and the lack of data derived from a non-representative sample of the population.
- Field research: this may be inappropriate or impracticable because access to real users is complicated due to ethical, legal, governance and privacy issues. The intrusiveness of some methods might make them unsuitable for end users, thus making proxies (carers, relatives, etc.) key players in the process.
- Multidisciplinary approach: Rapport and communication between multidisciplinary teams must be quite high. In addition to social professionals and therapists, design and development professionals should also be involved in the design of the needs assessment.
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2.1. Methodologies for user needs' analysis

User models are commonly used to facilitate needs analysis. A model is any representation of the potential user, created by or available to the designer to assist him/her in making predictions about the actual user (Hasdoğan 1996). These models are built on end user data which could be provided from different sources (statistical, capability databases, inquiry, surveys, etc.) (Van Isacker, Goranova-Valkova et al. 2008).

It is relevant that the work done in the generation of capability databases is encouraging the development of inclusive design tools (Johnson, Clarkson et al. 2010, Gyi, Sims et al. 2004). For example, HADRIAN is a computer aided design tool which enables automatic evaluation of the use of a product or service (Porter, Case et al. 2004). The Exclusion calculator estimates the number of people who would be excluded from using a particular product (Clarkson, Coleman et al. 2007).

USERfit provides a methodology and toolkit for collating design materials. It was created in order to improve the design of assistive products and is applicable to inclusive design (Poulson, Richardson 1998, EDeAN 1999).

Other common design methodologies aimed at understanding the capacities of specific users groups include contextual inquiry (Beyer, Holtzblatt 1997), surveys (Mikkonen, Väyrynen et al. 2002, Beecher, Paquet 2005), tasks analysis (Sangelkar, Cowen et al. 2012), focus groups (Morgan 1997) and the Delphi technique (Martin, Norris et al. 2008).

2.2.Human Device Interaction Models

User needs are inherently rooted in how human-device interaction occurs. Ergonomics (or human factors) is defined by the International Ergonomic Association as the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance (International Ergonomics Association 2011).

This discipline is closely related to Human Computer Interaction (HCI). Interaction models used in HCI can be applied in a general way to the study of the interaction between humans and devices, the latter being a product, system or service.

Several authors have modelled the interaction between person and device. Norman's action-circle (Norman 1988) is one of the most influential (Dix, Finlay et al. 2004, Dumas, Lalanne et al. 2009). The action-circle defines the interaction in two steps: the execution and the evaluation. The execution involves doing something and the evaluation is the comparison between what really happened and what we wanted to happen by performing the action (our goal). Norman defines seven stages in the interaction: i. Establishing the goal, ii. Forming the intention, iii. Specifying the action, iv. Executing the action, v. Perceiving the world state, vi. Interpreting the state of the world, vii. Evaluating the outcome (i.e. the system state with respect to the goals and intentions).

The Interaction Framework proposed by Abowd and Beale (Abowd, Beale et al. 1991) goes one step further in this direction by applying this perspective to HCI. They define four main components in an interactive system: the user, the system, the inputs and the outputs, each one with its own language (see figure 2). For Abowd and Beale, input and output taken together compose the system interface. They also define four transactions from one component to another: articulation, performance, presentation and observation. For example, once the user has established the goal, formed the intention and specified the action, this action must be articulated within the input language or be translated into the core language to be performed by the system (Dix, Finlay et al. 2004).

The Norman and Abowd models model the interaction with a high level of abstraction. Therefore, when these models talk, e.g., about "the user perceiving the world state", they are not explicitly considering factors such as the environment or the user capabilities which, obviously, can affect the interaction.

2.3. Models considering users with special needs

The field of assistive technology has considered human-device interaction from similar perspectives. Human Activity Assistive Technology (HAAT)(Cook, Hussey 2001) or Matching Person and Technology (MPT)(Scherer, Craddock 2002) are models specifically designed for people with special needs interacting with technology.

The Matching Person and Technology model posits that the interaction of milieu (environmental factors), individual characteristics and technology influences the use of devices. The HAAT model is close to Abowd and Beale's Interaction Framework but it explicitly introduces the context in the interaction process of a user with a device to accomplish an activity. The user has a set of motor, sensory and perceptual-cognitive abilities; the device has a human-machine interface, a processor and an output; and the context includes people (family, peers, etc.), setting (home, work, etc.) and environment (light, sound, etc.).

This perspective, taking into consideration the context and the user capabilities, is also covered by the ICF. According to the WHO, ICF is a framework for measuring health and disability at both individual and population levels that allows the assessment of functioning at the level of the whole human being in day-to-day life (World Health Organization 2001). The ICF is promoted and officially endorsed by all 191 WHO member states as the international standard to describe and measure health and disability.

This multipurpose tool provides a universal model and taxonomy to describe different levels of functioning and disability, improving the communication across disciplines as diverse as education, health, social policy and general legislation development, statistics or economics. By using a universal language, ICF enables comparisons of results between, for example, people from different countries or different health systems, or studies between population samples. It is a fact that two people with the same level of health (for example, at the same Alzheimer stage) may have different capacities and disabilities in a specific situation (for example, operating the television). It is thus impossible to determine the degree of disability of a person only from the knowledge of the condition being treated.

The ICF provides a classification of function and disability itemized into three lists called “Body Functions”, “Body Structures” and “Activity and Participation”(Figure 1). Furthermore, to classify contextual factors, it offers another two lists called “Environmental Factors” and “Personal Factors”. Each domain is structured into chapters where each item can have up to four levels of depth. Thus, the ICF offers about 1500 descriptors in its taxonomy.

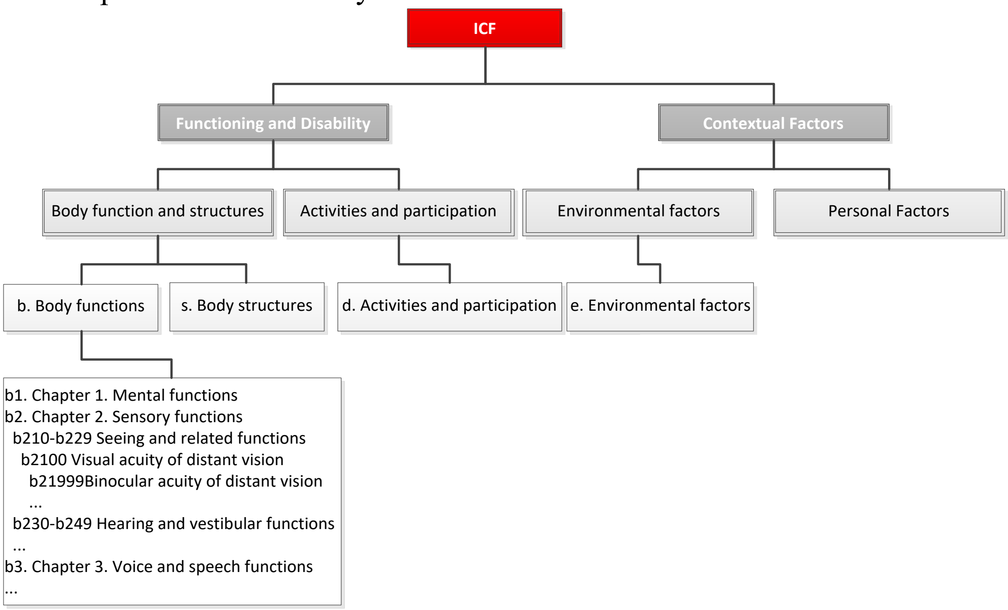

Figure 1 ICF structure

This classification is so exhaustive that its daily use usually becomes too complex; thus, many professionals use only a subset of the ICF. Being aware of this fact, WHO has developed several tools to facilitate its use such as the ICF Checklist (World Health Organization 2003). However, it has been found that these tools are too general in some cases. This has motivated the creation of the ICF Research Branch that develops, evaluates, and disseminates tools and models of functioning and health for different groups of patients and settings (Fayed, Cieza et al. 2011). Besides its main use in the health and rehabilitation sector (Xu, Kohler et al. 2011, Kiltz, van der Heijde et al. 2011), the ICF taxonomy has been used for many different purposes within inclusive design. These include the outcome research of devices (Lenker, Paquet 2003), describing user activities related to consumer products (Sangelkar, Cowen et al. 2012), modelling the selection of technology (Scherer, Jutai et al. 2007) or as a guide in ergonomic intervention (Leyshon, Shaw 2008).

3. Users’ needs identification methodology

The proposed methodology enables identification of user needs in the design of a device or system for a specific collective such as elderly or disabled people. It is based on the study of the potential barriers these users might face when performing the tasks to be supported by the device to be designed. To achieve this objective, the human-device interaction is studied following the model proposed by Abowd and Beale (Figure 2) and using the ICF taxonomy as the language to describe human capacities and actions.

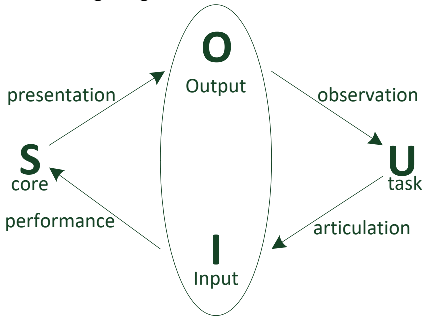

Figure 2. Interaction Framework proposed by Abowd (Abowd, Beale et al. 1991)

The user first formulates an interaction goal and decides the tasks (U in figure 2) required to achieve that goal. The only way that the user has to effectively interact with the system is using one of its inputs (I in figure 2): microphone, touch screen, gesture, etc. This step implies that the user needs to be able to articulate a response that the system can perceive by means of voice, movement, etc.

In accordance with the input, the system (S) provides an output (O) executing the command received. To finalise the interaction, the user must be able to perceive, interpret and understand the outputs and assess the results of the interaction versus the original goal. If necessary, the user needs to be able to start the process again, taking into consideration the information acquired.

In summary, the user needs to understand the stimuli that he / she perceives, to process the related information and to produce a response according to the context and the interaction objectives. NIMID defines three sequential phases with clearly differentiated objectives:

I. **User characterization**: aims to identify which capabilities of the person could be typically affected as a consequence of belonging to a specific collective. Besides generic aspects, this focuses on the critical user's capacities for the interaction: sensorial, physical, cognitive and voice.
II. **User-device interaction characterization**: aims to describe the interaction of the user performing the tasks enabled by the device or system. It describes the interaction processes, identifies the tasks involved and determines the required user capacities to successfully perform them.
III. **Identification of users' needs**: aims to extract the user needs derived from each task involved in the user-device interaction characterization, taking into consideration the users' characterization. It answers the question: what would the user characterized in (i) need to successfully interact as stated in (ii)? The relationships between users' capabilities and activities required to perform the interaction enables identification of the needs indicators. The study of these indicators by a multidisciplinary team leads to a systematic identification of needs related to the interaction between user and product.

Each one of these phases is described below in depth.

3.1. User characterization

User characterization is performed in two steps. First, researching specific capacities and limitations in specialized literature and statistics provides a general overview of the target population. Many sources are available such as the Survey of Health, Ageing and Retirement in Europe (SHARE), EUROSTAT, Centres for Disease Control and Prevention in the USA, etc. (Van Isacker, Goranova-Valkova et al. 2008, Tenneti, Johnson et al. 2012). This research needs to be focused on the skills required to perform a proper user-device interaction, according to the framework interaction model: how the person can receive information from the system through its output (senses), how the person can command it through the system input (hands, voice, gaze, etc.) and how the person can understand the information perceived and reason accordingly (cognitive capacities needed to propose a goal and to evaluate the results of the actions performed). In the second phase, this research is then embodied using the ICF taxonomy descriptors from the epigraph *b. Body functions classification*. The body functions that influence human-machine interaction according to Abowd's interaction framework and which could be affected as a consequence of the age, disease or disability of the person are described by the following ICF chapters:

- *b1. Mental functions*, concerning the functions of the brain, both global mental functions such as consciousness, energy and drive, and specific mental functions such as memory, language and calculations.
- *b2. Sensory functions and pain*, describing the functions of the senses, seeing, hearing, tasting and so on, as well as the sensation of pain.
- *b3. Voice and speech functions*, about the functions of producing sounds and speech.
- *b7. Neuromusculoskeletal and movement-related functions*, relating to the functions of movement and mobility including functions of joints, bones, reflexes and muscles.

A set of four tables (one per ICF chapter) indicating cognitive, sensorial, speech and movement-related functions is the outcome of the User characterization. Each table has two columns, one per phase. The first contains a description of the problems, limitations and capacities of the target population according to the literature or statistics. The second shows the related ICF descriptors of the population. These descriptors form a set (named C, derived from characterization) which characterizes the body functions which could be typically affected in a person included in the target population; i.e. $C = \{b_1, \dots, b_n\}$ being b_i with $i = 1..n$ a descriptor from the *Body functions classification*. User characterization should be performed by a multidisciplinary group involving social workers, health professionals and other related personnel (caregivers, etc.) who could provide additional information about the characterization in question.

3.2. User-Device Interaction characterization

The interplay between user and product is modelled following on from the user characterization. This is done by studying how a person currently performs the tasks which will be supported by the new device or system. In this context a task is understood as a set of actions to reach a goal. Task identification can be done through direct observation or by a study of the process using flow diagrams or any other systematic technique. However, note that the more rigorous this process is, the better the needs identification will be.

Each of these tasks is then analysed considering the human capacities needed to perform them using the ICF epigraph *d. Activity and participation*. In this step we follow a similar approach to Shangelkar et al. consisting of extracting knowledge from existing examples of universal design, using the ICF as a formal lexicon and an action-function diagram (Kostovich, McAdams et al. 2009) as a formal representation of the interaction between user and product (Sangelkar, Cowen et al. 2012). However, while Sangelkar et al. only consider descriptors related to physical ergonomics, we also include sensorial and cognitive activities to complete interaction model.

The ICF chapters relevant to the specific objectives of the methodology and the interaction model are the following:

- *d1. Learning and Applying Knowledge*, about the cognitive processes required for learning, applying the knowledge that is learned, thinking, solving problems, and making decisions.
- *d2. General tasks and demands*, concerning general aspects relating to carrying out coordinated actions related to a task; i.e. initiating a task; organizing time, space and materials for a task; pacing task performance, etc.
- *d3. Communication* and *d4.Mobility*, about how the person implements interaction with the device: receiving and producing messages; changing body position; carrying, moving or manipulating objects, etc.

Resulting from this phase we obtain a set (named T, derived from tasks): $T = \{t_1, \dots, t_m\}$ being t_i with $i = 1..m$ the independent tasks which describe the interaction between user and device. Additionally, each one of these tasks is described in ICF language as a set of activities from the *d. Activity and participation* list i.e. $t_1 = \{d_1, \dots, d_p\}$ being d_i with $i = 1..p$ an activity descriptor. Occasionally, it could be useful to break down the task into simple subtasks in order to ease the descriptor identification.

If the study is focused just on the interaction, the environmental factors could be omitted considering an "ideal" environment which has no influence on the interaction. However, when the new product or system works in known and different environments which may condition the interaction, the study should be carried out in each scenario. In order to ensure consistency with the rest of the methodology, these environmental situations should be described using the descriptors provided by the ICF *e. Environmental factors* list:

- *e1. Products and technology*: natural or human-made products or systems of products, equipment and technology in an individual's immediate environment.
- *e2. Natural environment and human-made changes to environment*: animate and inanimate elements of the natural or physical environment.
- *e3. Support and relationships*: people or animals that provide practical physical or emotional support, nurturing, protection, assistance and relationships to other persons.
- *e4. Attitudes, individual behaviour and social life* at all levels, from interpersonal relationships and community associations to political, economic and legal structures.
- *e5. Services, systems and policies* to organize, control and monitor instruments designed to meet the needs of individuals.

Thus, each situation is described by a set of environmental descriptors ($Es_1 = \{e_1, \dots, e_o\}$ being e_i with $i = 1..o$ a descriptor from the previously mentioned lists).

The User-Device interaction characterization phase should be performed by a multidisciplinary group involving technicians (product designers, ergonomists, developers, etc.), social workers and other relevant personnel (caregivers, etc.) who could provide additional information.

3.3.Identification of Users' needs

The Identification of Users' needs phase merges the previous phases to thoroughly extract the user needs derived from each task involved in the user-device interaction characterization (3.2.) and taking into consideration the user characterization (3.1.).

The needs identification is an iterative process which takes as a starting point the set of tasks obtained in the previous step. For each of these tasks, the process is as follows:

- The task is described as $t_i = \{d_1, \dots, d_p\}$, being t_i the task and $\{d_1, \dots, d_p\}$ the set of activity descriptors.

- Our target population is described by a characterization set ($C = \{b_1, \dots, b_n\}$).
- When there is a relationship between an activity descriptor and one or more components of the characterization set, the fact that a need could exist is indicated (i.e. if $d_1 = f(b_k, \dots, b_l)$). This relationship is called the indicator (i_n). It signifies that the user could have problems to perform a specific action, and the need or needs detected will be conditioned by the task. When an indicator is included in several tasks, the needs detected could be different for each task because, although the indicator is the same, the relation is independent of the task ($d_i = f(b_k, \dots, b_l)$). If environmental factors are considered, they must be also related with the task descriptors for each situation (i.e. if $d_1 = f(b_k, \dots, b_l, e_k, \dots, e_l)$)).
- Finally, each indicator must be studied in order to detect the need (see Figure 3).

As a result, we have a set of indicators (I_{ti}) and needs (N_{ti}) associated to each task (t_i) which has been represented in a tabular format. Each table, one per task, has three columns indicating a) a list of descriptors of the activities (according to ICF); b) indicators (I_{ti}, relation between activities and body functions according to ICF); c) a list of needs detected (N_{ti}). These tables provide an extensive and reasoned perspective about the needs to be tackled in the design of the product for the target population under study. They also provide valuable information about the indicators to be used in the subsequent product evaluation.

This methodology formalizes and systematizes the process of looking for needs' identifiers and must be performed by an expert team in order to establish the need. Ideally this team should be composed of professionals in the first and second phases of the process.

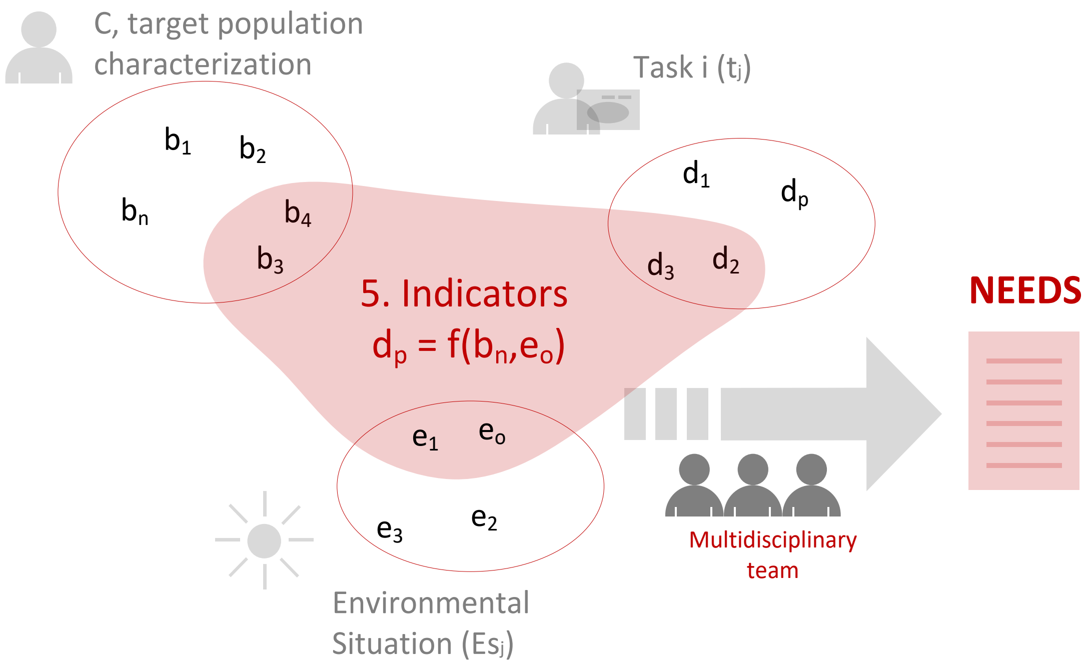

Figure 3. Example of needs identification for one task (ti) in a specific situation scenario (ESi)

4. Applying the NIMID methodology to the design of a smart kitchen for the elderly (the oven case)

NIMID was born as a result of the evolution and systematization of the design process followed in the European Project Easy Line + which aimed to design and develop a

smart environment that supports elderly people in their kitchen-related daily activities (Blasco, Marco et al. 2014). Figure 4 shows a block diagram of the target system.
This paper shows how NIMID is applied to the case of a kitchen oven. This is the most challenging household appliance in terms of human interaction; it needs programming of different parameters (time, temperature, type of heating), process monitoring and interacting, habitual maintenance, etc.

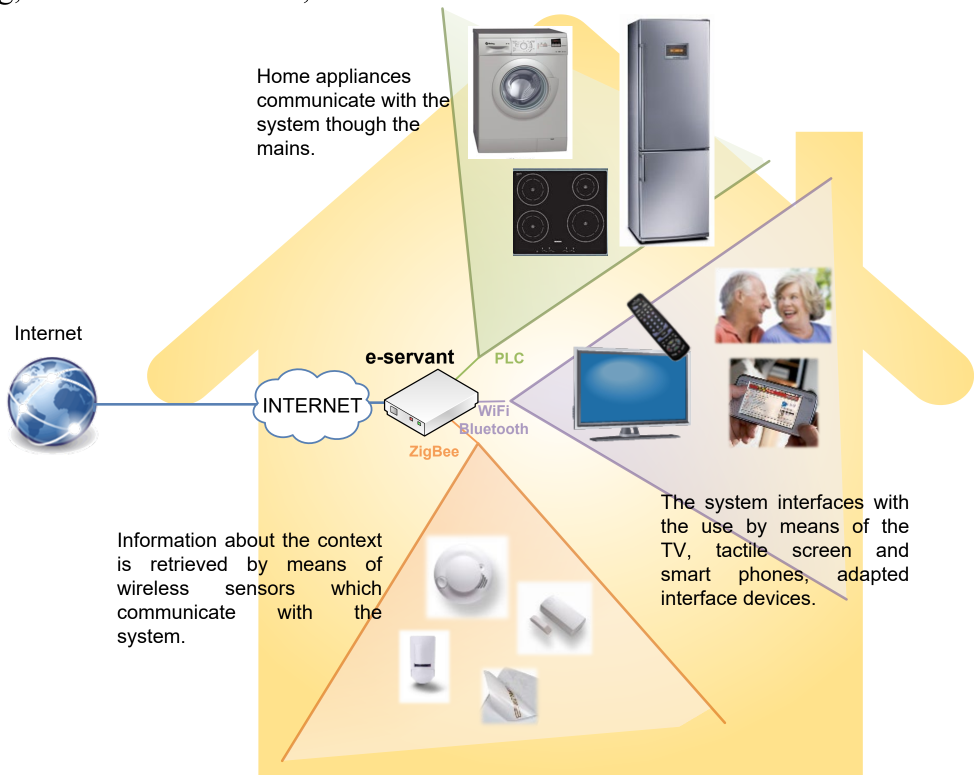

Figure 4. Smart kitchen system

4.1. User characterization: elderly people

The main source of information used for the characterization of elderly people, the target of the current study, is a report published by IMSERSO (Spanish governmental agency for the management of programs and services for elderly and handicapped people) containing a thorough analysis of the situation of elderly people in Spain (IMSERSO 2009). It also includes detailed information about the health status of elderly people, their main illnesses and the percentages of people affected. Additionally, several sources have been used to provide descriptions of these illnesses in an understandable language for all the professionals involved in the design process (these are cited in each table).
As stated in section 3.1, this characterization is represented in four tables following the corresponding mental, sensory, voice and speech, and neuromusculoskeletal and movement-related epigraphs of the ICF. The first column in each table specifies the main illnesses which can affect elderly people together with the incidence rate over the total population. The second column identifies the ICF descriptors (body functions) that could be affected by the illness.

	Diseases and conditions common in elderly people	Related ICF descriptors (b_i)
b1.Mental functions	Around 20% of the population over 65 in Spain has some **cognitive disorder** (IMSERSO 2009) : The aging brain is characterized by some degree of natural decline of cognitive functions like memory, visual-spatial skills and speed of information processing. Senile dementia is the progressive loss of cognitive functions, because of damage or brain disorders. Typically, this cognitive impairment causes inability to perform activities of daily living. Cognitive deficits can affect any of brain functions, particularly the areas of memory, language (aphasia), attention, visual-constructive skills, the praxis and executive functions as troubleshooting or response inhibition (Bartrés-Faz, Clemente et al. 1999, IMSERSO 2009). Alzheimer is the most common form of dementia. In the early stages, the most common symptom is difficulty in remembering recent events. As the disease advances, symptoms can include confusion, irritability and aggression, mood swings, trouble with language, and long-term memory loss. As the sufferers decline they often withdraw from family and society. Gradually, bodily functions are lost, ultimately leading to death. Parkinson's disease is a chronic neurodegenerative disorder that leads eventually to a progressive disability, produced as a result of destruction of the pigmented neurons of the substantia nigra. Parkinson's disease, as well as movement disorder also triggers alterations in cognitive function in the expression of emotions, speech and autonomic function.[1] [1] Parkinson and Alzheimer entries has been consulted in the Wikipedia.	**b114 Orientation functions:** General mental functions of knowing and ascertaining one's relation to self, to others, to time and to one's surroundings. **b117 Intellectual functions:** General mental functions, required to understand and constructively integrate the various mental functions, including all cognitive functions and their development over the life span. **b140 Attention functions:** Specific mental functions of focusing on an external stimulus or internal experience for the required period of time. **b144 Memory functions:** Specific mental functions of registering and storing information and retrieving it as needed. **b147 Psychomotor functions:** Specific mental functions of control over both motor and psychological events at the body level. **b156 Perceptual functions:** Specific mental functions of recognizing and interpreting sensory stimuli: b1560 (Auditory perception), b1561 (Visual perception), b1562 (Olfactory perception), b1563 (Gustatory perception), b1564 (Tactile perception), b1565 (Visuospatial perception) **b160 Thought functions:** Specific mental functions related to the ideational component of the mind. **b164 Higher-level cognitive functions:** Specific mental functions especially dependent on the frontal lobes of the brain, including complex goal-directed behaviours such as decision-making, abstract thinking, planning and carrying out plans, mental flexibility, and deciding which behaviours are appropriate under what circumstances; often called executive functions. **b167 Mental functions of language:** Specific mental functions of recognizing and using signs, symbols and other components of a language **b176 Mental function of sequencing complex movements:** Specific mental functions of sequencing and coordinating complex, purposeful movements.

Table 1. Cognitive diseases and conditions common in elderly people

	Diseases and conditions common in elderly people	related ICF descriptors (b_i)
b2.Sensory functions and pain	**Sensory functions** deteriorate with age, manifesting in impaired vision, hearing, loss of smell, taste, etc. Visual and additive capabilities are the most evident; around the 30% of the elderly people in Spain have some kind of visual disability; increasing to 34% for aural disability (IMSERSO 2009). However, though there are evidences that taste, smell, balance or touch capabilities decrease with the ageing there isn't statistics about its impact in the elderly people, due to, usually it is considered a minor problem compared with vision or hearing. From age 40 onwards, the frequency of presbyopia increases (loss of focusing capability on nearby objects) Ageing leads to deterioration of the optical properties of the eyeball (loss of transparency and yellowing), which in turn reduces the sharpness of images on the retina (they become more blurry) and alters them chromatically (the colour green becomes harder to distinguish, while the colour red does not). Ageing also leads to deterioration of the nerve mechanisms which respond to variations in light levels (adaptation to changes in the latter becomes slower and it is easier to be temporarily blinded by sharp variations). Added to this, ageing also reduces the joint capability of both eyes to combine information, and therefore, to differentiate between short distances, thus reducing hand to eye coordination. Certain ophthalmologic illnesses become more frequent: cataracts (opacity of the cornea), glaucoma (increase of intraocular eye pressure) and macular degeneration. Presbyacusia is the hearing loss brought on by ageing. From age 40 onwards, people loss hearing capabilities symmetric and progressively that affect to the ability to discriminate sounds and usually involve problems related with the speech discrimination. With age decreases the secretion of earwax and moisture from the skin, increased dryness, causing the impaction of earwax which may result the plugged up of ear by the earwax and, therefore, affect the person's hearing ability. Also, the appearance of tinnitus (perception of sound within the human ear in the absence of corresponding external sound) increases with the ageing. It usually manifests with the perception of a ringing in the ear. The capacity of perceive odours and tastes decreases with the ageing. This situation could produce dangerous situations as not perceive the burn smell, the gas smell or the state of the food. (Paulo, Gac 2000, Casas, Blasco et al. 2009)	**b210 Seeing functions:** Sensory functions relating to sensing the presence of light and sensing the form, size, shape and colour of the visual stimuli: b2100 (Visual acuity functions), b2102 (Quality of vision) **b230 Hearing functions:** Sensory functions relating to sensing the presence of sounds and discriminating the location, pitch, loudness and quality of sounds: b2300 (Sound detection), b2301 (Sound discrimination), b2302 (Localisation of sound source), b2304 (Speech discrimination) **b235 Vestibular functions:** Sensory functions of the inner ear related to position, balance and movement. **b250 Taste function:** Sensory functions of sensing qualities of bitterness, sweetness, sourness and saltiness. **b255 Smell function:** Sensory functions of sensing odours and smells. **b265 Touch function:** Sensory functions of sensing surfaces and their texture or quality

Table 2. Sensorial diseases and conditions common in elderly people

	Diseases and conditions common in elderly people	related ICF descriptors (b_i)
b3.Voice and speech functions	Around the 20% of the elderly people in Spain have some kind of disability related with the **communication** (IMSERSO 2009): Ageing will affect the ability of the individual phonation. When people get older, pulmonary system decreases and expiratory force used in the phonation is coming limited. It also decreases the ability to maintain intraoral pressure during phonation and hence the ability to produce vowel sounds. The tone of voice changes, in man the tone increases, the voice becomes more acute by a senile atrophy of the vocal cords. For the woman the tone decreases, the voice becomes deeper due to severe edema of the vocal cords. Laryngeal structures also changing to a distinct tissue appearing in the vocal cords, a decrease in mucus production and physiological atrophy of the laryngeal muscles that lead people to what is called "senile voice". Parkinson: Diction: At least 50% of patients have slurred speech, whisper, hesitate before speaking, repeating words or speak too fast.	**b310 Voice functions:** Functions of the production of various sounds by the passage of air through the larynx **b320 Articulation functions:** Functions of the production of speech sounds. **b330 Fluency and rhythm of speech functions:** Functions of the production of flow and tempo of speech.

Table 3. Speech diseases and conditions common in elderly people

	Diseases and conditions common in elderly people	related ICF descriptors (b_i)
b7.Neuromusculoskeletal and movement-related functions	Around 71% of the elderly people in Spain have some kind of disability related to the **mobility** (IMSERSO 2009): Osteoporosis is a common problem, especially for elderly women. Bones break more easily, and compression fractures of the vertebrae can cause pain and reduce mobility. Muscle weakness contributes to fatigue, faintness, and reduced tolerance to activity. Joint problems are quite common, which can range from mild stiffness to debilitating arthritis. The risk of injury increases because gait changes, the instability and loss of balance may lead to falls. Some elderly people have reduced reflexes, caused more frequency changes in the muscles and tendons. There may be decreased knee jerk or ankle jerk. Involuntary movements (muscle tremors and fine movements called fasciculations) are more common in the elderly(MedicinePlus 2013, Casas et al. 2009).	**b710 Mobility of joint functions:** Functions of the range and ease of movement of a joint. **b720 Mobility of bone functions:** Functions of the range and ease of movement of the scapula, pelvis, carpal and tarsal bones **b730 Muscle power functions:** Functions related to the force generated by the contraction of a muscle or muscle groups **b755 Involuntary movement reaction functions:** Functions of involuntary contractions of large muscles or the whole body induced by body position, balance and threatening stimuli. **b760 Control of voluntary movement functions:** Functions associated with control over and coordination of voluntary movements. **b765 Involuntary movement functions:** Functions of unintentional, non- or semi-purposive involuntary contractions of a muscle or group of muscles. **b770 Gait pattern functions:** Functions of movement patterns associated with walking, running or other whole body movements.

Table 4. Mobility diseases and conditions common in elderly people

4.2. User-device Interaction characterization: human-oven interaction

As already mentioned, this characterization is done by studying how a person currently performs the tasks that will be supported by the new device or system. After studying the most common characteristics of ovens, the oven shown in figure 5 was chosen for the study.

Figure 5: Oven selected

The oven has three rotary control knobs for selecting the timing, type of heating (top/bottom heating, grilling, etc.) and temperature (50-270°C). The door has a large handle placed at the top (see Figure 5). It also has a glass front that together with the interior light allows the state of the food to be monitored. The oven has several racks so that the tray can be placed at different heights.

We have assumed a neutral interaction environment; in other words, environmental factors neither hinder nor facilitate the interaction between the user and the appliance.

(Focusing on the study of the interaction, it is evident that the preparation of a specific dish can be very complex and that some dishes are more difficult than others. However, leaving aside the use of kitchen tools (knives, bowls, dishes, etc.) and the preparation of food for cooking (removing packaging, slicing, cutting, etc.) and focusing simply on the interaction between the user and the oven, the number of actions performed by the user are limited and clearly defined: .

- Placing/removing the recipient in/from the oven
- Opening/closing the door
- Configuring/programming and monitoring
- Maintenance and cleaning

Interaction between the user and the oven has been studied by observation, identifying processes and tasks involved in each area. Each one of these tasks has been described in ICF language as a set of activities from *d. Activity and participation:*

t_1: Placing/removing the recipient into/out of the oven	
This task includes the tasks related with accessing the appliance and putting in / taking out the recipient. Door opening and closing is studied separately.	
Subtask involved	**Capabilities required according to ICF(d_j)**
Accessing the appliance Deciding where/how to put in/take out the recipient Placing/removing the recipient in/from the oven	d110 Watching d177 Making decisions d4101 Squatting d4105 Bending d4300 Lifting d4301 Carrying in the hands d445 Hand and arm use

Table 5. Placing/removing the recipient in/from the oven characterization

t_2: Opening/Closing door	
This task studies the user capabilities required for opening and closing the oven (similar for all appliances which have a door: refrigerator, microwave, washing machine and dishwasher).	
Subtask involved	**Capabilities required according to ICF (d_j)**
Accessing the door Grasping and opening the door Closing the door	d110 Watching d1750 Solving simple problems d440 Fine hand use d445 Use of hand and arm

Table 6. Opening/closing the door characterization

t_3: Configuring/Programming and monitoring	
This task studies the user capabilities required for operating the oven the oven (similar for the refrigerator, hob, microwave, washing machine and dishwasher).	
Subtask involved	**Capabilities required according to ICF (d_j)**
Selecting a programme Initiating the programme Monitoring the programme Stopping the programme	d110 Watching d160 Focusing attention d175 Solving problems d177 Making decisions d2202 Undertaking multiple tasks independently d440 Fine hand use d445 Hand and arm use d415 Maintaining a body position

Table 7. Configuring/programming and monitoring characterization

t_4: Maintenance and cleaning	
This task includes maintenance and cleaning of the oven (similar for all appliances)	
Subtask involved	**Capabilities required according to ICF (d_j)**
Detecting that maintenance or cleaning is needed Performing cleaning or maintenance	d110 Watching d115 Listening d120 Other purposeful sensing d160 Focusing attention d175 Solving problems d177 Making decisions d2202 Undertaking multiple tasks independently d415 Maintaining a body position d440 Fine hand use d445 Hand and arm use

Table 8. Maintenance and cleaning characterization

4.3. Identification of User needs: elderly interacting with an oven

The needs identification process has been iteratively applied to each task obtained in the user-device interaction characterization following the process described in section 3.3. The result is summarized in the next set of tables:

t_1: Placing/removing the recipient in / from the oven		
Capabilities required according to ICF (d_j)	Indicators (I_{t1}) $d_j = f(b_i,..,b_j)$	Needs detected (N_{t1})
d110 Watching	d110 related to b156, b210, b265	People with visual disabilities could have problems identifying how and where to position the recipient**.** This situation could also be dangerous for the user.
d177 Making decisions	d177 related to b117, b140, b144, b156, b164	People with cognitive disabilities may require help to understand that some parts of the oven can burn.
d4101 Squatting d4105 Bending d4300 Lifting d4301 Carrying in the hands d445 Hand and arm use	d4101, d4105, d4300, d4301, d445 related to b147, b176, b710, b720, b730, b755, b760, b765, b770	Minimisation of handling and moving weight as well as bending and squatting due to oven height installation.

Table 9. Needs identification in the placing/removing the recipient in/from the oven task

t_2: Opening/Closing door		
Capabilities required according to ICF (dj)	Indicators (I_{t2}) $d_j = f(b_i,..,b_j)$	Needs detected (N_{t2})
d110 Watching	d110 related to b156, b210	People with visual disabilities could have problems identifying how to open the door.
d1750 Solving simple problems	d1750 related to b114, b117, b140, b144, b156, b160	People with cognitive disabilities might need help, in some situations, to remember that the door of the oven should not be open for a long time.
d440 Fine hand use d445 Use of hand and arm	d440, d445 related to b147, b176, b710, b720, b730, b760, b765	People with mobility disabilities may need aid grasping the handle to open and close the door of the oven. Minimizing the strength and movement required to handle the door could ease this task.

Table 10. Needs identification in the opening/closing the door task

t_3: Configuring/Programming and monitoring		
Capabilities required according to ICF (dj)	Indicators (I_{t3}) $d_j = f(b_i,..,b_j)$	Needs detected (N_{t3})
d160 Focusing attention d175 Solving problems d177 Making decisions d2202 Undertaking multiple tasks independently	d160, d175, d177, d2202 related to b114, b117, b140, b144, b156, b160, b164, b167	People with cognitive disabilities may require help to take decisions about temperature, time, etc. They could also have problems following several steps and taking decisions. Monitoring the cooking process, detecting mistakes and taking dynamic decisions could also be challenging. Knowing the current state of the process can be complicated.
d110 Watching d415 Maintaining a body position d440 Fine hand use d445 Hand and arm use	d110 related to b156 d415, d440, d445 related to b147, b176, b710, b720, b730, b755, b760, b765, b770	People with visual disabilities could have problems with the interface if the controls are not easy to differentiate. This could be worse when maintaining the body position is challenging. People with mobility disabilities may need help to access the controls. Also, if fine hand use or strength is required, manipulation can be compromised.

Table 11. Needs identification in the configuring/programming and monitoring task

t4: Maintenance and cleaning		
Capabilities required according to ICF (dj)	**Indicators (I_{t4}) $d_j = f(b_i,..,b_j)$**	**Needs detected (N_{t4})**
d110 Watching d115 Listening d120 Other purposeful sensing	d110, d115, d120 related to b210, b230, b250, b255, b265	People with sensorial disabilities may require help to detect breakdowns. This could generate a dangerous situation.
d160 Focusing attention d175 Solving problems d177 Making decisions d2202 Undertaking multiple tasks independently	d160, d175, d177, d2202 related to b114, b117, b140, b144, b156, b160, b164, b167	People with cognitive or visual disabilities may require help to know when the appliance should be cleaned or maintained. In case of a breakdown, the person may require help to solve the emergency. This could generate a dangerous situation. Furthermore, the user may need help with some maintenance and cleaning operations which require following several steps. Procedures that include contact and interaction with the technical service centre could be challenging.
d415 Maintaining a body position d440 Fine hand use d445 Hand and arm use	d415, d440, d445 related to b147, b176, b710, b720, b730, b755, b760, b765, b770	People with mobility disabilities may require help to do cleaning or simple maintenance due to the difficulty of accessing the inside of the oven, if strength is required, etc.

Table 12. Needs identification in the maintenance and cleaning task

5. Discussion

As already mentioned, the methodology is included in the framework of a European project in which we analysed how elderly people interact with different white goods (hob, washing machine, fridge, microwave and dishwasher). Besides NIMID, two traditional methodologies have been used to detect user needs: experts analysing the results of surveys conducted in Germany, UK and Spain (Mikkonen, Väyrynen et al. 2002; Beecher and Paquet 2005) and multidisciplinary teams (geriatrists and technologists) working in co-design workshops and applying the USERfit methodology (Poulson, Richardson 1998, EDeAN 1999). To quote the authors of the methodology: *"USERfit methodology comprises a set of nine summary tools designed to assist assistive technology developers in addressing the issue of usability in design. The tools combine to assist in the process of collating design information obtained using a variety of data gathering techniques. The essence of the methodology is that it provides a structure to assist the developer in assuring that relevant design issues have been considered"*. The design workshops consisted of 14 teams of engineers, designers, social workers and health professionals which, using the USERfit methodology, analysed how elderly users deal with kitchen activities in the home scenario. Opinion questionnaires and methodology outcomes were compared by experts with the following results.

As expected, each methodology had different strengths and weaknesses providing different types of outcomes that served as complementary sources of information for the designers when considering the special needs of the collective under study. Table 13 shows an objective comparison of both methodologies.

	USERfit	NIMID
Product phases considered	User needs Product specification Usability evaluation	User needs

Areas of study	User Activity Environment	User Activity Environment
Language	Open	Defined and standard (ICF)
Instruments and techniques	Open to designer's choice	Defined
Complexity	High (many tables interrelated)	Low (clear and sequential steps)

Table 13. Userfit and NIMID comparison

NIMID and USERfit have some similarities. Both study the user, the activity and the environment. While USERfit covers the entire design process from the characterization of the user/environment to the product specification or even evaluation of the product, NIMID focuses on the identification of needs only. Moreover, USERfit does not consider a specific phase for needs identification. It merges the process with functional specification favouring not considering needs properly. This integration and the broader range of application mean that USERfit is more complex as it can be approached from many different perspectives and it encourages iteration. On the other hand, NIMID is easier to put into place as it defines which tables, how and by whom, and a linear sequence to complete them. Also, USERfit provides a broad set of alternative tools and techniques for carrying out its phases while NIMID defines not only the steps but also the standard language to be used (ICF). We found that different teams studying the same case with USERfit ended up with different results which, moreover, were hardly comparable among themselves because the language is not unified. Furthermore, it was common to jump from user/activity/product analysis to requirements without considering the user needs with the necessary degree of detail.

When comparing the surveys analysed by experts, we found that NIMID provides far more exhaustive and reasoned information in terms of quantity and quality. Thanks to the systematization, every need is supported by a rational explanation of why it emerged instead of being supported by a mere statistical figure. Rather than being mutually exclusive, we consider NIMID to be a previous phase that serves as a valuable source of information. As the methodology is based on the definition of indicators in a common language, these indicators can be used to establish surveys for gaining more knowledge about specific issues, to build statistical information to complement the theory in order to prioritise needs, or to set up focus groups.

The main advantage of NIMID over the rest of the methodologies is the systematic way in which it finds indicators which are described in a common and internationally agreed language. Also, using ICF descriptors allows the identification of assessment indicators that can guide the design of product evaluation methodology. This is a necessary phase for assessing the extent to which a newly-developed product fulfils identified user needs.

The use of the ICF language also makes possible a comparison of the outputs at all levels of the methodology. As NIMID is grounded in well-established theories, once a device or a specific user group is analysed, it can be reused for different projects. Thus, the development of an information database may be feasible and desirable depending on each specific case.

Finally, NIMID encourages collaboration between technical and social profiles. The methodology requires that different profiles of professionals work together in order to generate common and negotiated output. In contrast with other methodologies where technical profiles do not participate in the process but merely receive a report with the results, we find that this methodology enables the creation of a shared understanding about a project's ecosystem. In our experience, this is very desirable as it avoids the formation of two possibly confrontational teams: the technical (provider side) and the user-oriented (client side).

6. Conclusions

This work presents a methodology for identifying needs in the inclusive design scenario considering users' physical, sensorial and cognitive capabilities. It is constructed in three phases: (i) a user characterization that determines which capacities of the person could be affected as a consequence of being included in a specific population; (ii) an interaction characterization that determines which actions the person needs to perform in order to have a successful interaction; and (iii) matching both characterizations, resulting in the identification of the user's needs. The taxonomy and lexicon proposed by the ICF is used in all these phases, easing the standardization of the process and the comparison of results.

We have put the methodology into practice in various projects (such as the case of the oven as previously described) and compared its results with other methodologies. NIMID's strongest points are its universality (common ICF language), systematicity (clearly defined phases and outcomes) and rationality (grounded in well-established interaction theory).

Compared to other methodologies, NIMID offers a more systematic way of identifying indicators that hinder the interaction between the person and the system. Given that the indicators are grounded by a thorough process, they also facilitate the understanding of the capabilities of the target population and their difficulties in performing the functions that are to be supported by the new product. This is very valuable information for developers.

The identification of users' needs is subject to analysis by a multidisciplinary group of experts. This is both one of the strengths and one of the weaknesses of the methodology because the results can vary greatly depending on the experts' background. In the end, it is a tool that catalyses the multidisciplinary work of the various stakeholders involved in the design process, typically social workers, care givers and technical experts.

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